Bulletin No. 260 Series A, Economic Geology, 53

DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY

CHARLES D. WALCOTT, DIRECTOR

CONTRIBUTIONS

TO

ECONOMIC GEOLOGY

1904

S. F. EMMONS
C. W. HAYES
Geologists in Charge

WASHINGTON
GOVERNMENT PRINTING OFFICE
1905

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LETTER OF TRANSMITTAL.

Department of the Interior,
United States Geological Survey,
Washington, D. C., February 9, 1905.

Sir: I have the honor to transmit, for publication as a bulletin of the Survey, a manuscript entitled "Contributions to Economic Geology, 1904."

The report contains 63 contributions from 37 members of the Survey who have been engaged more or less continuously throughout the year in economic work, together with brief statements by the geologists in charge of the section of metalliferous ores and the section of nonmetalliferous economic minerals, of the extent and character of the economic work being carried on in the Survey.

Very respectfully,

C. W. Hayes,
Geologist in Charge of Geology.

Hon. Charles D. Walcott,
Director United States Geological Survey.

CONTRIBUTIONS TO ECONOMIC GEOLOGY, 1904.

S. F. EMMONS,
C. W. HAYES,
Geologists in Charge.

INTRODUCTION.

By C. W. HAYES, *Geologist in Charge of Geology.*

This bulletin is the third of a series, the first being Bulletin No. 213 and the second Bulletin No. 225, Contributions to Economic Geology for 1902 and for 1903, respectively. These bulletins are prepared primarily with a view to securing prompt publication of the economic results of investigations made by the United States Geological Survey. They are designed to meet the wants of the busy man, and are so condensed that he will be able to obtain results and conclusions with a minimum expenditure of time and energy. They also afford a better idea of the work which the Survey as an organization is carrying on for the direct advancement of mining interests throughout the country than can readily be obtained from the more voluminous reports. The bulletins for 1902 and 1903 have been so favorably received by those interested in the development of the mineral industries of the United States that it is proposed to issue early in each calendar year a similar publication containing the results of the last year's field work in economic geology.

In the two preceding bulletins of this series were included numerous papers relating to the economic geology of Alaska. In view of the rapid increase during the past year of economic work both in Alaska and in the States and the organization of a division of Alaskan mineral resources, distinct from the division of geology, it has been considered advisable to exclude from the present volume all papers relating to Alaska. These have been brought together into a separate volume entitled " Report of Progress of Investigations of Mineral Resources of Alaska in 1904," Bulletin No. 259. It is believed that the information will be most economically and effectively disseminated by this segregation.

In the preparation of the present volume promptness of publication has been made secondary only to the economic utility of the material presented. The papers included are such only as have a direct economic bearing, all questions of purely scientific interest being excluded.

The papers are of two classes: (1) Preliminary discussions of the results of extended economic investigations, which will later be published by the Survey in more detailed form; (2) comparatively detailed descriptions of occurrences of economic interest, noted by geologists of the Survey in the course of their field work, but not of sufficient importance to necessitate a later and more extended description. A third class of papers was included in the bulletin for 1902, namely, abstracts of certain economic papers which had appeared in Survey publications during the year, chiefly such as gave a general account of the distribution and mode of occurrence of particular mineral deposits throughout the United States. Most of the publications on economic geology which have appeared during the past year were abstracted for advance publication in Bulletin 225, and it has therefore been unnecessary to abstract them in this volume.

The papers have been grouped according to the subjects treated. At the end of each section is given a list of previous publications on that subject by this Survey. These lists will be serviceable to those who wish to ascertain what has been accomplished by the Survey in the investigation of any particular group of mineral products. They are generally confined to Survey publications, though a few titles of important papers published elsewhere by members of the Survey are included.

The preparation of this bulletin, as well as of the corresponding bulletins, already referred to, has been chiefly the work of Mr. E. C. Eckel, to whom is due in large measure the credit for planning the work and carrying it to a successful issue.

The results of the Survey work in economic geology have been published in a number of different forms, which are here briefly described:

1. *Papers and reports accompanying the Annual Report of the Director, United States Geological Survey.*—Prior to 1902 many economic reports were published in the royal octavo cloth-bound volumes which accompanied the Annual Report of the Director. This form of publication for scientific papers has been discontinued and a new series, termed Professional Papers, has been substituted.

2. *Bulletins of the United States Geological Survey.*—The bulletins of the Survey comprise a series of paper-covered octavo volumes, each containing usually a single report or paper. These bulletins, formerly sold at nominal prices, are now distributed free of charge to those interested in the special subject discussed in any particular

bulletin. This form of publication facilitates promptness of issue for economic results, and most economic reports are therefore published as bulletins. Their small size, however, precludes the use of large maps or plates, and reports containing large illustrations are therefore issued in the series of Professional Papers.

3. *Professional Papers of the United States Geological Survey.*—This series, paper covered, but quarto in size, is intended to include such papers as contain maps or other illustrations requiring the use of a large page. The publication of the series was commenced in 1902, and the papers are distributed in the same manner as are the bulletins.

4. *Monographs of the United States Geological Survey.*—This series consists of cloth-bound quarto volumes, and is designed to include exhaustive treatises on economic or other geologic subjects. Volumes of this series are sold at cost of publication.

5. *Geologic folios of the United States Geological Survey.*—Under the plan adopted for the preparation of a geologic map of the United States the entire area is divided into small quadrangles, bounded by certain meridians and parallels, and these quadrangles, which number several thousand, are separately surveyed and mapped. The unit of survey is also the unit of publication, and the maps and descriptions of each quadrangle are issued in the form of a folio. When all the folios are completed they will constitute a Geologic Atlas of the United States.

A folio is designated by the name of the principal town or of a prominent natural feature within the quadrangle. It contains topographic, geologic, economic, and structural maps of the quadrangle, and occasionally other illustrations, together with a general description.

Under the law, copies of each folio are sent to certain public libraries and educational institutions. The remainder are sold at 25 cents each, except such as contain an unusual amount of matter, which are priced accordingly.

Circulars containing lists of these folios, showing the locations of the quadrangular areas they describe, their prices, etc., are issued from time to time, and may be obtained on application to the Director of the United States Geological Survey. The following list shows the folios issued to date and the economic products discussed in the text of each, the products of greatest importance being printed in italic.

List of geologic folios, showing mineral resources described.

No.	Name of folio.	State.	Area in sq. m.	Author.	Mineral products described as occurring in area of folio.
1	Livingston	Mont	3,354	Iddings, J. P.; Weed, W. H.	Gold, copper, clays, lime, stone, *coal*.
2	Ringgold	Ga.-Tenn	980	Hayes, C. W	*Coal*, *iron*, manganese, lime, clays, stone, road metal.
3	Placerville	Cal	932	Lindgren, W.; Turner, H. W.	*Gold*, copper, quicksilver, chromite, stone.
4	Kingston	Tenn	969	Hayes, C. W	*Coal*, *iron*, lime, stone, road metal, clay.
5	Sacramento	Cal	932	Lindgren, W	*Gold*, copper, chromite, iron, coal, stone, lime, clay.
6	Chattanooga	Tenn	975	Hayes, C. W	*Coal*, *iron*, lime, stone, road metal, clay.
7	Pikes Peak	Colo	932	Cross, W	*Gold*.
8	Sewanee	Tenn	975	Hayes, C. W	*Coal*, *iron*, lime, stone, road metal, clay.
9	Anthracite-Crested Butte.	Colo	465	Eldridge, G. H	*Coal*, *silver*, stone, lime, clay.
10	Harpers Ferry	Va.-W. Va.-Md.	925	Keith, A	*Iron*, *ocher*, copper, stone, road metal, lime, cement.
11	Jackson	Cal	938	Turner, H. W	*Gold*, *copper*, chromite, iron, manganese, ocher, coal, stone, lime, clay.
12	Estillville	Va.-Ky.-Tenn.	957	Campbell, M. R	*Coal*, iron, marble, limestone.
13	Fredericksburg	Md.-Va	938	Darton, N. H	*Greensand marl*, stone, fuller's earth, clays, sand, gravel, *underground water*.
14	Staunton	Va.-W. Va	938	do	Iron, marble, lime, clay, coal.
15	Lassen Peak	Cal	3,634	Diller, J. S	Gold, infusorial earth, lime, stone, coal.
16	Knoxville	Tenn.-N. C	969	Keith, A	*Marble*, slate, stone, gold, lime, cement, clay, water power.
17	Marysville	Cal	925	Lindgren, W.; Turner, H. W.	*Gold*, coal, gas, clay, lime, stone, water.
18	Smartsville	do	925	do	*Gold*, copper, quicksilver, iron, lime, clay, stone.
19	Stevenson	Ga.-Ala.-Tenn.	980	Hayes, C. W	*Coal*, *iron*, lime, stone, road metal, clay.
20	Cleveland	Tenn	975	do	*Iron*, lead, lime, stone, clay.
21	Pikeville	do	969	do	*Coal*, iron, stone, clay.
22	McMinnville	do	969	do	*Coal*, iron, stone, clay.
23	Nomini	Md.-Va	938	Darton, N. H	*Greensand marl*, fuller's earth, clay, stone, sand, gravel, *underground water*.
24	Three Forks	Mont	3,354	Peale, A. C	*Gold*, silver, copper, iron, coal, lime, clay, pumice, *mineral springs*.
25	Loudon	Tenn	969	Keith, A	*Coal*, marble, lime, stone, clay, iron, slate, water power.
26	Pocahontas	Va.-W. Va	950	Campbell, M. R	*Coal*, lime, stone, clay, marble.
27	Morristown	Tenn	963	Keith, A	*Marble*, *stone*, lead, zinc, lime, cement, clay, water power.
28	Piedmont	Md.-W. Va	925	Darton, N. H.; Taff, J. A.	*Coal*, iron, lime, stone, road metal, clay.
29	Nevada City special.	Cal	35	Lindgren, W	*Gold*.
30	Yellowstone National Park.	Wyo	3,412	Hague, A.; Weed, W. H.; Iddings, J. P.	National Park; no mining permitted.
31	Pyramid Peak	Cal	932	Lindgren, W	*Gold*.

List of geologic folios, showing mineral resources described—Continued.

No.	Name of folio.	State.	Area in sq. m.	Author.	Mineral products described as occurring in area of folio.
32	Franklin	Va.-W. Va.	932	Darton, N. H.	*Iron*, coal, manganese, lime, stone, road metal, clay.
33	Briceville	Tenn.	963	Keith, A.	*Coal*, *iron*, lead, marble, lime, stone, clay.
34	Buckhannon	W. Va.	932	Taff, J. A.; Brooks, A. H.	*Coal*, lime, stone, clay.
35	Gadsden	Ala.	986	Hayes, C. W.	*Coal*, *iron*, lime, stone.
36	Pueblo	Colo.	938	Gilbert, G. K.	*Stone*, *gypsum*, clay, iron, *underground water*.
37	Downieville	Cal.	919	Turner, H. W.	*Gold*, iron, chromite, lime, marble.
38	Butte special	Mont.	23	Emmons, S. F.; Tower, G. W.	*Copper*, *silver*, gold.
39	Truckee	Cal.	925	Lindgren, W.	*Gold*, silver, coal, stone, mineral springs.
40	Wartburg	Tenn.	963	Keith, A.	*Coal*, *oil*, iron, lime, clay.
41	Sonora	Cal.	944	Turner, H. W.; Ransome, F. L.	*Gold*, quicksilver, copper, chromite, lime, stone.
42	Nueces	Tex.	1,035	Hill, R. T.; Vaughan, T. W.	Stone, gravel, *underground water*.
43	Bidwell Bar	Cal.	919	Turner, H. W.	*Gold*, manganese iron, chromite, stone.
44	Tazewell	Va.-W. Va.	950	Campbell, M. R.	*Coal*, iron, barite.
45	Boise	Idaho	864	Lindgren, W.	*Gold*, silver, coal, diatomaceous earth, stone, clay, springs, underground water.
46	Richmond	Ky.	944	Campbell, M. R.	Coal, fluorite, phosphate, clay, stone, road metal.
47	London	do	950	do	*Coal*, stone.
48	Tenmile district special.	Colo.	62	Emmons, S. F.	*Silver*.
49	Roseburg	Oreg.	871	Diller, J. S.	Gold, copper, quicksilver, coal, clay, stone.
50	Holyoke	Mass.-Conn.	885	Emerson, B. K.	Granite, emery, chromite, quartz, trap, sandstone, clay.
51	Big Trees	Cal.	938	Turner, H. W.; Ransome, F. L.	*Gold*, silver.
52	Absaroka	Wyo.	1,706	Hague, A.	Silver.
53	Standingstone	Tenn.	963	Campbell, M. R.	*Coal*, oil, lime, clay.
54	Tacoma	Wash.	812	Willis, B.; Smith, G. O.	*Coal*, *stone*, clay.
55	Fort Benton	Mont.	3,234	Weed, W. H.	Gold, *silver*, lead, iron, gypsum, *coal*, stone, underground water.
56	Little Belt Mountains.	do	3,295	do	*Coal*, *silver*, lead, copper, iron, *sapphires*, mineral water.
57	Telluride	Colo.	236	Purington, C. W.	*Gold*, *silver*.
58	Elmoro	do	950	Hills, R. C.	*Coal*, stone, *underground water*.
59	Bristol	Va.-Tenn.	957	Campbell, M. R.	*Coal*, iron, zinc, barite, marble, clay.
60	La Plata	Colo.	237	Purington, C. W.	*Gold*, *silver*, coal.
61	Monterey	Va.-W. Va.	938	Darton, N. H.	Iron, stone, clay, road metal.
62	Menominee special.	Mich.	125	Van Hise, C. R.; Bayley, W. S.	*Iron*.
63	Mother Lode district.	Cal.	428	Ransome, F. L.	*Gold*, silver, manganese, quicksilver, stone.
64	Uvalde	Tex.	1,040	Vaughan, T. W.	*Asphalt*, gold, silver, iron, coal, water.

List of geologic folios, showing mineral resources described—Continued.

No.	Name of folio.	State.	Area in sq. m.	Author.	Mineral products described as occurring in area of folio.
65	Tintic special	Utah	229	Tower, G. W.; Smith, G. O.; Emmons, S. F.	*Gold, silver, lead, copper.*
66	Colfax	Cal	925	Lindgren, W	*Gold*, stone, clay, water.
67	Danville	Ill.-Ind	228	Campbell, M. R	*Coal*, clay, gravel, underground water.
68	Walsenburg	Colo	944	Hills, R. C	*Coal*, stone, clay, *underground water.*
69	Huntington	W. Va.-Ohio	938	Campbell, M. R	*Coal.*
70	Washington	D. C.-Va.-Md.	465	Darton, N. H.; Keith, A.	Gold, iron, clay, stone, road materials, greensand marls, *underground water.*
71	Spanish Peaks	Colo	950	Hills, R. C	*Coal*, stone, gold, silver, *underground water.*
72	Charleston	W. Va	938	Campbell, M. R	*Coal, salt, oil, gas*, iron.
73	Coos Bay	Oreg	871	Diller, J. S	*Coal*, gold, stone.
74	Coalgate	Ind. T	980	Taff, J. A	*Coal*, stone, clay.
75	Maynardville	Tenn	963	Keith, A	*Marble*, coal, stone, lead, zinc, lime, road materials, clay, water power.
76	Austin	Tex	1,030	Hill, R. T.; Vaughan, T. W.	Oil, stone, lime, clay, cement rock, underground water.
77	Raleigh	W. Va	944	Campbell, M. R	*Coal.*
78	Rome	Ga.-Ala	986	Hayes, C. W	*Bauxite, iron, slate*, lime.
79	Atoka	Ind. T	986	Taff, J. A	*Coal*, stone, clay.
80	Norfolk	Va.-N. C	1,913	Darton, N. H	Sand, clay, *underground water.*
81	Chicago	Ill.-Ind	892	Alden, W. C	*Stone*, clay, molding sand, water power, water.
82	Masontown-Uniontown.	Pa	458	Campbell, M. R	*Coal, oil, clay*, stone, glass, sand, iron.
83	New York City	N. Y.-N. J	906	Merrill, F. J. H.; Hollick, A.; Darton, N. H.	*Trap, marble*, granite, *road material*, clay, iron, water power, water.
84	Ditney	Ind	938	Fuller, M. L.; Ashley, G. H.	*Coal*, gas, clay, stone, iron.
85	Oelrichs	S. Dak.-Nebr	871	Darton, N. H	Stone, gypsum, lime, volcanic ash, *underground water.*
86	Ellensburg	Wash	820	Smith, G. O	Building stone, road metal, *ground water, underground water.*
87	Camp Clarke	Nebr	892	Darton, N. H	Volcanic ash.
88	Scotts Bluff	do	892	do	Do.
89	Port Orford	Oreg	878	Diller, J. S	*Coal*, gold, platinum.
90	Cranberry	Tenn	963	Keith, Arthur	Mica, gold, brick clay, *iron ore.*
91	Hartville	Wyo	885	Smith, W. S. T	*Iron ore*, copper, limestone.
92	Gaines	Pa.-N. Y	223	Fuller, M. L.; Alden, W. C.	*Oil*, coal.
93	Elkland-Tioga	Pa	445	do	Flagstone, limestone, gravels.
94	Brownsville-Connellsville.	do	457	Campbell, M. R	*Coal, natural gas.*
95	Columbia	Tenn	969	Hayes, C. W.; Ulrich, E. O.	*Phosphate*, iron.
96	Olivet	S. Dak		Todd, J. E	Granite, limestone, quartzite.
97	Parker	do	871	do	Quartzite, chalk, cement rock.

List of geologic folios, showing mineral resources described—Continued.

No.	Name of folio.	State.	Area in sq. m.	Author.	Mineral products described as occurring in area of folio.
98	Tishomingo	Ind. T	986	Taff, J. A.	Granite, limestone.
99	Mitchell	S. Dak	863	Todd, J. E	Sandstone, chalkstone.
100	Alexandria	do	863	Todd, J. E.; Hall, C. M.	Quartzite, sandstone, chalkstone.
101	San Luis	Cal	975	Fairbanks, H. W	*Bituminous rock*, building stone, road metal, chrome iron, hematite, manganese, pumice, infusorial earth.
102	Indiana	Pa	237	Richardson, Geo. B.	*Coal*, *gas*, *fire clay*, brick clay, building stone.
103	Nampa	Idaho		Lindgren, Waldemar; Drake, N. F.	Gold, coal, *opals*, building stone.
104	Silver City	do	871	do	*Gold*, *silver*, coal, opals.
105	Patoka	Ind.-Ill	938	Fuller, M. L.; Clapp, F. G.	Coal, gas, oil, asphalt, fire clay, brick clay, building stone, gravel.
106	Mount Stuart	Wash	805	Smith, G. O	*Gold*, copper, silver, nickel, quicksilver, *coal*, stone, road metal.
107	Newcastle	Wyo.-S. Dak.	864	Darton, N. H	*Coal*, petroleum, *gypsum*, bentonite, salt brines, stone, water.
108	Edgemont	Nebr.-S.Dak	871	Darton, N.H.; Smith, W. S. T.	Water supply, coal, gypsum, stone, grindstones.
109	Cottonwood Falls	Kans	938	Prosser, C. S., and Beede, J. W.	Building stone, limestone, clay, road metal.
110	Latrobe	Pa	228	Campbell, M. R	*Coal*, natural gas, building stone, *glass sand*, rock for paving blocks and ballast, limestone, salt, *fire clay*.
111	Globe	Ariz	249	Ransome, F. L	*Gold*, *silver*, *copper*, lead, limestone, building stone, *underground water*.
112	Bisbee	do	170	do	*Copper*, gold, lead, clay, silica, building stone, *underground water*.
113	Huron	S. Dak	857	Todd, J. E	Building stone, clay, sand and gravel, *underground water*.
114	De Smet	do	857	do	Clay, sand, gravel, and underground water.
115	Kittanning	Pa	226	Butts, Chas	*Coal*, *oil*, *gas*, *clay*, limestone, iron, building stone, sand.
116	Asheville	N. C.-Tenn	969	Keith, Arthur	*Talc*, soapstone, *barite*, corundum, garnet, magnetite, brown hematite, marble.
117	Casselton-Fargo	N.Dak.-Minn	1,640	Hall, C. M., and Willard, D. E.	Underground water.
118	Greeneville	Tenn.-N.C.	963	Keith, Arthur	*Marble*, building stone, road metal, iron, limestone, brick clay, water power.

6. *Mineral Resources of the United States.*—From 1883 to 1894, inclusive, an octavo cloth-bound volume bearing the above title was issued annually, except that the reports for the years 1883–84 and 1889–90 were included by pairs in single volumes. The first of this series was Mineral Resources of the United States, 1882; the last, Mineral Resources of the United States, 1893. In 1894 this form of publication was discontinued, in accordance with an act of Congress, and the statistical material was included in certain parts of the sixteenth, seventeenth, eighteenth, nineteenth, twentieth, and twenty-first annual reports. The separate publication of the series on mineral resources was resumed, however, in 1901, in accordance with an act of Congress, and four volumes of the new series, Mineral Resources of the United States for 1900, for 1901, for 1902, and for 1903 have been issued.

This publication contains a systematic statement of the production and value of the mineral products of the United States, a summary of new mineral resources developed, and occasional short papers on economic geology, when these may be necessary to account for the new developments.

INVESTIGATION OF METALLIFEROUS ORES.

By S. F. Emmons.

ECONOMIC PUBLICATIONS OF THE YEAR 1904.

The list of publications on subjects connected with the investigation of metalliferous ores that have appeared during the year 1904 is longer than that for 1903. Chance has much to do with such annual variation, for the reason that in an organization like the present Survey, whose work covers an enormous area and has to do with a variety of subjects that do not ordinarily come under the charge of a geological survey, and whose publications are all handled by one set of men, those of one branch often have to wait on those of another, and the time that must elapse between the completion of the manuscript by the author and its issue by the Public Printer is necessarily variable. If it happens to be handed in when there are not many ahead of it, it may appear in a relatively short time. On the other hand, if a number of other reports have the right of way, it may be weeks, or even months, before it can be taken up.

The list embraces the following publications:

Monograph XLVII:
- Treatise on Metamorphism, C. R. Van Hise.

Professional Papers:
- No. 12. Ore Deposits of the Globe District, Arizona, F. L. Ransome.
- No. 21. Geology and Ore Deposits of the Bisbee Quadrangle, Arizona, F. L. Ransome.
- No. 24. Zinc and Lead Deposits of Northern Arkansas, George I. Adams, A. H. Purdue, E. F. Burchard.
- No. 25. Copper Deposits of the Encampment District, Wyoming, A. C. Spencer.
- No. 26. Economic Resources of the Northern Black Hills, J. D. Irving, T. A. Jaggar, jr., S. F. Emmons.
- No. 27. Geological Reconnaissance Across the Bitterroot Range and Clearwater Mountains, Montana and Idaho, by Waldemar Lindgren.

(In press:)
- No. 36. Lead, Zinc, and Fluorspar in Western Kentucky, by W. S. Tangier Smith and E. O. Ulrich.
- No. 38. Economic Geology of Bingham Mining District, by J. M. Boutwell, A. Keith, and S. F. Emmons.
- No. 42. Geology of Tonopah Mining District, Nevada, by J. E. Spurr.
- No. 43. Copper Deposits of Clifton-Morenci, Arizona, by W. Lindgren.

Bulletins:

No. 246. Zinc and Lead Deposits of Northwestern Illinois, H. F. Bain.

No. 254. Resurvey of the Cripple Creek District, by W. Lindgren and F. L. Ransome.

No. 255. Fluorspar of Southern Illinois, by H. F. Bain.

Folios:

No. 111. Globe District, Arizona.

No. 112. Bisbee District, Arizona.

The title of the first work on the list, "A Treatise on Metamorphism," does not at first suggest reading that would be of interest to the man engaged in practical mining, but if one has the desire to get at the root of his subject he may reflect that metamorphism, which is the general term used to express the changes that rocks have undergone since their formation, must necessarily have to do with ore deposits, since the most of those worked to-day are the result of changes and transfers of material within the rock masses that make up the earth's crust. If he will consult this monumental volume, which is the final result of the profound studies carried on by the author for many years, largely in the great iron-ore regions of the Northwest, he will find that the last 240 pages are devoted to an elucidation of the principles which control ore deposition, and that a careful study of these pages will greatly aid in giving him a clearer idea of the manner in which the ores he is mining have reached their present form, and by inverse reasoning he will be better fitted to trace out the probable direction in which they are liable to extend in the parts of his mine that are as yet unexplored.

Abstracts of all the other publications have already appeared in previous economic bulletins (Bulls. 213 and 225), with the exception of the preliminary report on the "Resurvey of the Cripple Creek district," an abstract of which is published in this volume. This publication has been pushed in advance of all other Survey reports for the reason that half of the cost of the work was paid by the citizens of the State of Colorado, and it was considered, therefore, that they had the right to know, at the earliest possible moment, such of its results as may have immediate commercial value. It is probable that some of these citizens will be disappointed because the report does not speak more freely with regard to the future of the district. Such persons do not fully understand the limitations of geological investigation and the caution which the careful student must necessarily observe in speaking of the results of his survey before the facts which he has gathered have been worked over with scientific thoroughness in all their multiple bearings. The members of the Survey would be pleased to satisfy everyone if it were possible—those who wish results published as rapidly as newspaper notices, as well as those who desire that they should have the greatest possible scientific accuracy. But since this is an evident impossibility, their only safe course is to state nothing in the way of prophecy that is not most amply justified in the investigations already completed, and to give their grounds in full, that any other worker may use the same facts to make a more daring prophecy if he sees fit. In the present case the promises as to the future of the Cripple Creek district, which may be gathered by those who are competent to interpret the facts presented, seems sufficiently brilliant to satisfy the most captious. During the years that immediately preceded this study a number of mining engineers of good standing, who had occasion to explore different parts of the district, had thought to find evidence of considerable secondary enrichment in the ore deposits thus far opened. This meant, if proved true of the whole district, that within a definite time its ore deposits will be found to be of increasingly lower grade as exploitation reaches deeper levels, and that it is only a question of time when the ore will probably become of too low grade to work at a profit. The present careful study, with far greater facilities than are available to any private individual, have removed this menace to the prosperity of the camp by showing that there is no evidence of secondary enrichment; whence it may be concluded that there are as rich ore bodies in depth as any that have yet been discovered.

The next question is, In what quantity are the ores likely to be found? In respect to this, science has yet discovered no method of forecasting the future similar to the secondary enrichment theory. All that can be done is to study with great care the ground already opened, and, by observing the relative quantity of ore discovered in the upper and lower parts of that ground, to reason by analogy as to what relations of quantity the still deeper and unexplored parts will bear to those already opened. Into this question there enter certain factors bearing on the probability of the development of new ore bodies that have nothing to do with their actual quantity. These are the increase in expense of working with increase of depth and the difficulty of handling water in parts not drained by some tunnel, as the deepest workings get a large part of the water from all of the surrounding regions. Taking these factors into consideration, the authors, while admitting the possibility that the stronger fissures will carry ore to far greater depths than have yet been attained, think it "unlikely that the zone between the 1,000 and 2,000 foot level will yield as much as the zone between the surface and the 1,000-foot level." Hence they conclude that in the future, while "new ore bodies will undoubtedly be discovered from time to time and individual mines may be profitable—even more profitable than in the past"—the production of the district as a whole has reached its zenith and will slowly decline.

ECONOMIC WORK IN PROGRESS DURING YEAR.

GENERAL DISCUSSION.

An important function of the Geological Survey in the examination of the geological structure, mineral resources, and products of the public domain which it is directed by law to make may, and it seems should, be to furnish from time to time, in addition to the bare statistics of production, a review of the progress of such production in its geological relations. The first material for such a review was collected by members of the Survey acting as special agents for the Tenth Census, and published in Volume XIII of that report under the heading "Geological sketches of the precious-metal deposits of the western United States."

It had been hoped by those who had carried on this work that when the collection of statistics concerning the mineral resources of the United States by the U. S. Geological Survey should be authorized by Congress such collection would include simultaneous gathering, by the agents employed in the work, of a certain amount of geological data with regard to all producing mining districts of the United States. Such data would have enabled those in charge of the mining branch of the Survey to make, from time to time, a review of the progress of mining industry which should show the geological reasons for such progress, as far as they could be ascertained, and which might permit a forecast of the directions in which the most important advances may be looked for in the future. Unfortunately the law authorizing the collection of mineral statistics by the Survey expressly excepted the precious metals.

In 1893, when the question of the probable future production of gold and silver was assuming national importance in its bearing upon the financial policy of the Government, the writer prepared a review of the progress of the precious-metal industry of the United States since 1880, in which he predicted a decrease in the silver production and a very great increase in gold production, not only in this country but also in the whole world, thus directly opposing the views of such authorities as Suess and Del Mar. This review was confessedly imperfect from the geological side, because, although certain important districts had been thoroughly studied by the economic geologists of the Survey, there were many of actual importance, and a host of smaller districts of possible future importance, over which it had not been practicable to extend this work. Nevertheless, the article evidently served a useful purpose, having been republished in the report of the Director of the Mint, and it was hoped that it might influence Congress to remove its restrictions on the collection of the statistics of the precious metals by the Survey.

In 1902 Mr. Waldemar Lindgren, of the corps of economic geologists of the Survey, published a paper on "The geological features of gold production of North America."[a] This was a far more important contribution to the subject, from the geological standpoint, than the previous one, because in the decade just elapsed the economic work of the Survey had increased far more rapidly than in the previous decade, and already it included within its scope most of the great gold-producing districts of the country. Mr. Lindgren was therefore enabled to make a somewhat detailed classification of the sources of gold, based on geological age, the inclosing rock, and the character of deposits. The information on which this classification was based, however, was in no measure furnished by the division of mining and mineral resources of the Survey, because, although Congress had, in 1900, permitted the collection by the Survey of the statistics of gold and silver, and added $20,000 to the annual appropriation for this purpose, up to 1903 the figures given in the volume on Mineral Resources were still merely a condensed copy of those published by the Director of the Mint.

In Mineral Resources for 1903 segregated statistics of the production of gold and silver are given for some of the precious-metal producing States, but they contain no geological information whatever, and are too imperfect to furnish much aid in the segregation of that product on geological grounds. In view of the importance of this subject, however, it has been judged best, even in the absence of as complete information as could be desired, to prepare such reviews of the production of the respective metals during the past year as shall furnish a more philosophical discussion of the industry than can be derived from the contemplation of a column of figures.

The discussion of the year's production of gold and silver has been intrusted to Mr. Lindgren, who has classified these products according to geological age and according to the character of the ores from which they have been derived. The latter classification, which it is believed has never before been made, divides the ores into (1) placer, or detrital deposits, and (2) ores from rock-in-place. The latter class is further subdivided, according to mineralogical composition, into three classes, based primarily upon the different processes required for the extraction of the precious metals from their matrix. These are siliceous ores, copper ores, and lead ores. The percentage of the total production derived from the four classes thus established is as follows:

	Placers.	Siliceous ores.	Copper ores.	Lead ores.
Gold	15.2	74.3	5.0	5.4
Silver	0.1	22.2	34.7	42.9

[a] Trans. Am. Inst. Min. Eng., vol. 33, p. 790.

A similar discussion of the copper product of the United States is given by Mr. W. H. Weed, in which the percentage product in round numbers is distributed, according to the form in which the copper occurs in the ores, in the following percentages:

	Per cent.
Native ores	27
Oxide ores	6
Sulphide ores	67

Mr. Bain has made a similar review of the lead and zinc deposits of the United States, based primarily upon geographical distribution.

APPALACHIAN REGION.

The reconnaissance study of the copper deposits of the Appalachian region has been continued at intervals during the last season by W. H. Weed, and a brief statement of the results of his observations is given in this volume. It is intended that special studies shall be made of some of the more important copper-producing districts of this region as soon as financial and other conditions permit.

In the States of North and South Carolina the occurrence of tin ores has been known for some time. After the close of the field season in the West a reconnaissance examination of a district along the boundary of the two States was made by Mr. Graton, under the direction of Mr. Waldemar Lindgren, which has shown that the deposits are probably of considerable economic importance, although they have not yet been so extensively and systematically developed as to afford a regular and constant production of this important metal. An account of the geological relations and extent of the Carolina occurrence, followed by a concise statement of what is known with regard to tin deposits throughout the rest of the world, will be found in this volume.

Geological work in the region to be described in the Franklin Furnace folio has been actively carried on during the past summer by Mr. A. C. Spencer. This additional work was considered advisable on account of the importance of the remarkable zinc deposits of the region from a scientific as well as an economic point of view, and also because the mines of the New Jersey Zinc Company, which for some years past have been closed to all outside visitors on account of pending litigation, have again been thrown open for inspection. This further investigation has opened up some new geological problems, which will require another season's work for their solution. The present condition of this work is not favorable to the presentation of the results in the usual abstract form.

MISSISSIPPI VALLEY REGION.

This great region stands in marked contrast geologically with the mining region of the West by the practical absence of intrusions of igneous rocks, and by the relatively undisturbed position of its sedimentary beds. Certain areas have, however, proved of great economic importance because of the abundant and cheaply worked ores of lead and zinc that are found in them. The most important of these producing areas have been studied and reported upon in previous years. During the last season examinations have been made by Mr. Bain, assisted by Mr. Ellis and others, of some outlying and hitherto undescribed districts, and information has also been collected with regard to the occurrences of copper ore, some of which seem to be of economic importance, in the same general area. Reports on these will be found in this volume.

ROCKY MOUNTAIN REGION.[a]

Work of the past summer in this region will be noted geographically, the States being mentioned in alphabetic order.

Arizona.—No systematic field work has been done in Arizona during the past season. Some topographic surveying has been done as a preparation for future geological investigations, and the territory was traversed by the writer in his official journeyings. Some information obtained by him with regard to copper deposits in the Colorado Plateau region has been used for the text of an article on copper deposits in Permo-Triassic beds, which appears in this volume.

California.—Economic surveys had been planned for the three copper districts in Shasta County, Cal., which lie either within or on the borders of the Reading quadrangle. As the geologists assigned to this work were unable to complete their surveys in other regions early enough to undertake it, the work has been postponed until another season.

Colorado.—The resurvey of the Cripple Creek district, as already noted, has been completed. Economic work has been commenced in the oldest and most continuously productive region of the State—that of Gilpin and Clear Creek counties. Two parties have been employed here during the summer, one in mapping the areal or surface geological features of the region, which are unusually complicated because of the great age and intensely metamorphosed character of the rocks, the other in studying the internal rock structure and ore deposits, as shown by the underground workings of the mines. The

[a] No mention is made here of economic work in Alaska, as the bulk of the material with regard to that region, which has hitherto been published in the Economic Geology bulletin, is this year so great that it has been thought advisable to incorporate it in a separate volume—Bulletin No. 259.

area is so great that it was not expected to complete the work in a single season.

The present volume contains a preliminary report on the ore deposits of the Georgetown or Silver Plume district by Mr. J. E. Spurr. This district, from an economic point of view, is long past its zenith, and a report upon it necessarily belongs in the category of what has been called "back numbers" by some of the critics of the Survey, who look only to the immediately applicable results of its work. The scientific student of ore deposits will find, however, upon a perusal of Mr. Spurr's report, that it fills a gap in our knowledge of an important type of ore deposits—the older fissure veins—which are by no means so simple in their structure and manner of formation as has generally been conceived. To the miner, on the other hand, it is evident that the knowledge obtained during these studies will be of great practical use, if not in this particular district, at any rate in others in which he may happen to be working where the same type of deposits are developed.

Economic work incidental to areal surveys was carried on during the summer by Mr. J. D. Irving in the San Juan district, complementary to the surveys of the Ouray and Needle Mountains quadrangles, and a small but interesting group of mines in the Durango quadrangle which carry gold in association with some amalgam were studied and reported upon by Mr. W. H. Emmons, a recent acquisition to the corps of geologists. A brief visit was also made by the writer to Leadville to keep in touch with the recent underground developments and incorporate their results in his data for the preparation of a more detailed and accurate map of this region.

Idaho.—In northwestern Idaho, Mr. Ransome, with the assistance of Mr. Calkins, completed the survey of two 15′ quadrangles, which include the mines of the Coeur d'Alene district. These mines are of great economic importance, furnishing as they do one-third of the annual lead product of the United States, together with about 6,000,000 ounces of silver and a little gold. Scientifically, the veins are of interest because of their metasomatic origin and their occurrence in a very old series of rocks of great thickness that have never before been studied in detail. A summary of the results is given in this bulletin by Mr. Ransome.

Nevada.—The development of important deposits of gold-bearing ores in south-central Nevada has been actively conducted during the year, and in the new district of Goldfield phenomenally rich bodies have been opened. These developments have been materially aided by the establishment of railroad connection with the trunk lines. Mr. Spurr made a reconnaissance examination of both Tonopah and Goldfield in the autumn months, after the snowfall in the mountains around Georgetown had rendered it necessary to close work there. The results of this examination are given later in two articles, one a report on the important geological facts determined since the completion of field work in the Tonopah district, the other a preliminary report on the geological relations of the Goldfield deposits. His completed report on the whole Tonopah district will soon appear as a professional paper.

Oregon.—As shown by exhibits at the Mining Congress at Portland in August last, mine developments are being actively prosecuted in various parts of western Oregon. The gold deposits in the south-central part of the State, around what is known as the "Grants Pass region," seem particularly promising. The writer had occasion to visit the mercury mine of Black Butte, near the headwaters of the Willamette River. The deposits consist of a faulted zone in eruptive rocks, which is extensively impregnated by cinnabar. A large amount of low-grade ore is exposed, and the problem which the owners are trying to solve is how to reduce the whole mass at a profit.

Among the other exhibits that attracted interest were specimens of iron ore found along the south bank of the Columbia River and of the metallic iron which had been smelted from it. At the request of the writer the locality was visited by Mr. J. S. Diller, in company with one of the owners of the property, and it was found, as had been expected, that the deposit is part of a flow of volcanic tuff which forms the mass of the hills bordering the river, and contains no apparent concentration of iron in what could be called an "ore deposit." The occurrence is described by Mr. Diller, and the results of analyses of the material gathered by him show that it can hardly be regarded as an ore of iron, though it is a very readily fusible material and carries at times over 10 per cent of that metal.

Washington.—Gold-bearing beach sands sufficiently rich to be worked at a profit have been known to exist at various points along the Pacific coast, notably in California and Alaska. In recent years there has been something of a "boom" in regard to such sands along the coast of the State of Washington. These were visited during the past season by Mr. Ralph Arnold, and his report in the present volume shows their extent and the source from which their gold may have been derived. It is interesting to note that a certain amount of platinum and iridosmine is found with the gold.

INVESTIGATION OF IRON AND NONMETALLIFEROUS ECONOMIC MINERALS.

By C. W. Hayes, *Geologist in Charge.*

The investigation of the nonmetalliferous minerals has been carried on during the year 1904 as heretofore, chiefly in connection with work on areal geology. The selection of areas for mapping, however, is made largely with reference to the occurrence of such mineral deposits, so that the economic aspect of the work is generally the most important one. There is scarcely an area in the United States the size of a Survey quadrangle which does not contain more than one important mineral of this class in commercial quantity. The wide distribution of some of these minerals, such as coal, clay, limestone, etc., while adding vastly to the aggregate value of the lands explored, makes their investigation slow and expensive. They can not be studied in detail with advantage in advance of topographic and areal geologic mapping.

IRON ORE.

In view of the dominant influence of the Lake Superior region in the iron industry and the active prospecting being carried on in the various districts, it is considered essential that some field work should be done there each season. This consists in the correction and amplification of maps and sections as better data become available. A summary report on the iron districts of the region is in process of preparation. This will not only summarize the economic geology of the several monographs already published, but will embody such new information as has been obtained concerning the extent and relations of the ore deposits. During the past year field work has been done by Messrs. Van Hise, Leith, and Seaman.

During the year a further examination has been made of the iron-ore deposits of the Rocky Mountain and Pacific coast States by Mr. Leith. This reconnaissance has been directed chiefly to obtaining a general view of the deposits in question for the purpose of planning detailed work on several of the districts during the coming year.

In response to urgent local demands Mr. Eckel made a hurried examination of the iron-ore deposits of several counties of northeast Texas. A preliminary report on the region appears in this volume. Detailed work must necessarily await the completion of the topographic mapping.

The monographic study of the Birmingham district, begun during the past year in cooperation with the State survey of Alabama, involves a thorough investigation of the red hematite or Clinton ore in the region of its greatest development. One important result of this work has been the extension of the ore beyond its supposed southern limit. A brief paper by Mr. Burchard describing this occurrence appears in this volume.

FUELS.

The fuel resources of the country have received a larger share of attention during the past year than at any previous time since the organization of the Survey. In the Appalachian region field work has been carried on by Messrs. Griswold, Clapp, and De Wolf in Pennsylvania, by Messrs. Ashley and Phalen in West Virginia, and by Messrs. Butts, Burchard, and Gale in Alabama. About 3,000 square miles of coal-bearing territory has been mapped in great detail, and the exact extent, position, and structure of the coal beds will be shown in the geologic folios now being prepared. The introduction of economical methods of coal mining, rendered possible by this work, while of more immediate benefit to the owners and operators, should in the end cheapen the fuel, and so directly benefit all who are dependent on this field.

Mr. Campbell has remained in charge of the Appalachian coal work, though most of his time has been taken up by his duties as a member of the committee in charge of the Survey coal-testing plant at St. Louis. This work, however, has enabled him to come into close touch with the coal industry of the entire country and to gain information of great value in planning for future work, particularly in connection with the low-grade coals of the West.

The mapping of the Indian Territory coal fields has been continued during the past year by Mr. Taff and assistants. Mr. Taff has prepared detailed maps and descriptions of these coal fields for the use of the Secretary of the Interior in selling the lands for the benefit of the Indians, as provided by law. He has also prepared a summary report for this volume.

A little-known coal field in the Olympic Peninsula of Washington was examined by Mr. Arnold, in connection with other work. As indicated by the brief report in this volume, the field, while not of great extent, promises to be of considerable importance as a source of gas coal for the Northwest coast.

The accurate determination of underground structure, on which the accumulation of oil and gas so largely depends, has been continued in connection with the work in Pennsylvania, particularly by Mr. Griswold, in Washington and Allegheny counties. This work has now been carried far enough and has been subjected to sufficiently searching tests by actual drilling to prove its great value in the economical development of an oil or gas field.

The work in the oil and gas field of Kansas has been continued by the survey, by Messrs. Schrader and Haworth, of the Independence quadrangle, which includes the southwestward extension of the Iola field. The report upon the latter by Adams and Haworth is now in press.

The active development in the Texas-Louisiana Coastal Plain oil fields since their examination in 1901 made a reexamination desirable. This work has been carried out during the past year by Mr. Fenneman, who is now preparing a full report and who contributes a summary of his conclusions to this volume. The conclusions of the former work are in the main sustained, while much more definite statements concerning the geologic conditions under which the oil occurs are warranted by the fuller information now available through the extensive drilling which has been in progress during the past three years.

BUILDING MATERIALS

The cement industry formed the subject of an extensive investigation by Mr. Eckel in 1903. This was continued during the past year, and the full report will soon be published as Bulletin 243. Important supplementary examinations were carried on in various districts under Mr. Eckel's supervision. Mr. Bassler made a thorough examination of the Lehigh district in Pennsylvania and New Jersey. By means of the contained fossils he was able to separate and map the upper limestone or "cement rock" from the lower beds, which contain too large a proportion of magnesium carbonate for use in the manufacture of cement. Mr. Bassler also differentiated and mapped the cement materials in a considerable area in Augusta and Rockbridge counties, Va. The results of the latter work are summarized in this volume.

The investigation of the cement resources in the region tributary to the Gulf of Mexico has been continued during 1904 by Messrs. Eckel and Crider. The calcareous formations previously studied in Alabama have been carefully traced across Mississippi, and their suitability for the manufacture of Portland cement has been thoroughly investigated. The results of this work have been summarized in a Congressional document on the mineral resources of the Tombigbee River basin in Alabama and Mississippi, and will be given in full in a bulletin on the geology and mineral resources of Mississippi.

Work on the summary of information regarding the slate industry of the United States, begun in 1903, has been practically completed during the past year. Prof. T. Nelson Dale has visited all the slate quarries in Virginia, Maryland, and Maine, and a report on the slate deposits of the United States is now being prepared.

In connection with the survey of the Penobscot Bay quadrangle by George Otis Smith and assistants, special attention was paid to the granite-quarrying industry. Maine ranks first among the States in production of granite, and this quadrangle contains a majority of the quarries in the State. Its survey, therefore, afforded an excellent opportunity for a thorough study of the industry. A special report on this subject will be published in advance of the geologic folio.

The investigation of clay deposits and the clay-working industry has been carried on by a large number of geologists in connection with areal mapping. In addition, some special investigations have been made. Clay forms perhaps the most important mineral resource of Mississippi, and special attention has been paid to it by Messrs. Eckel and Crider in connection with the collection of material for the bulletin above referred to. The formations containing deposits of valuable clays have been traced and mapped, and samples collected have been submitted to burning tests and chemical analysis. The results of this work will afford much needed information concerning a valuable natural resource of the State.

While State geologist of Arkansas Prof. J. C. Branner collected a large amount of information on the clays of that State, and he has since prepared a report for publication by the United States Geological Survey. Some time was spent in the field by Mr. Eckel during the past year for the purpose of bringing this report up to date, particularly with reference to the clay-working industry. It is expected that this report will go to press in a short time.

A report on the clay deposits and clay industry of Washington is being prepared by Prof. Henry Landes, and a summary appears in this volume.

Clay having peculiar physical properties which render it valuable for a variety of uses in the arts has for some time been known to occur in the Benton formation of Wyoming. This clay, called bentonite, has been investigated by Messrs Darton and Fisher. and a brief summary of its distribution, mode of occurrence, and properties has been prepared for this volume by Mr. Fisher.

GOLD AND SILVER.

In addition to the papers here included, which represent the results of recent work by the Survey in important precious-metal mining districts, other reports bearing incidentally on the subject of gold and silver will be found under the head of "Copper," on pages 211 to 248, and "Lead and zinc," on pages 251 to 303.

THE PRODUCTION OF GOLD IN THE UNITED STATES IN 1904.

By Waldemar Lindgren.

INTRODUCTION.

Although detailed statistics for the production of gold during the last year are not yet available, it may be worth while to ascertain approximately, with such data as are at hand, the distribution of the production among different classes of ore deposits. A preliminary estimate, by the Director of the Mint, of the production of each State and Teritory has been published by the technical press in its first issues of 1905. This estimate, together with information obtained by the mining geologists of the Geological Survey and reports in the mining papers, forms the basis of this review.

Production of gold and silver in the United States.

[As estimated by the Director of the Mint.]

State or Territory.	Gold.		Silver.	
	1903.	1904.	1903.	1904.
			Fine ounces.	*Fine ounces.*
Alabama	$4,400	$29,000		200
Alaska	8,614,700	9,000,000	143,600	184,200
Arizona	4,357,600	4,250,000	3,387,100	3,400,000
California	16,104,500	19,000,000	931,500	1,380,000
Colorado	22,540,100	26,000,000	12,990,200	12,500,000
Georgia	62,000	99,000	400	1,200
Idaho	1,570,400	1,960,000	6,507,400	7,000,000

Production of gold and silver in the United States—Continued.

State or Territory.	Gold.		Silver.	
	1903.	1904.	1903.	1904.
			Fine ounces.	*Fine ounces.*
Kansas	$9,700	$9,700	97,400	97,400
Maryland	500	2,800		
Michigan			50,000	50,000
Montana	4,411,900	4,960,000	12,642,300	12,750,000
Nevada	3,388,000	5,140,000	5,050,000	4,500,000
New Mexico	244,600	248,000	180,700	180,000
North Carolina	70,500	115,600	11,000	13,000
Oregon	1,290,200	1,300,000	118,000	132,000
South Carolina	100,700	113,200	300	600
South Dakota	6,826,700	7,270,000	221,200	185,900
Tennessee	800	200	13,000	59,100
Texas			454,400	454,400
Utah	3,697,400	4,700,000	11,196,800	10,500,000
Virginia	13,500	3,300	9,500	1,200
Washington	279,900	310,000	294,[illegible]00	200,000
Wyoming	3,600	40,500	200	13,800
Total	73,591,700	84,551,300	54,300,000	53,603,000

After a period of very rapid advance in the gold production from 1892 to 1900, inclusive, during which an increase from $33,000,000 to $79,000,000 took place, there were two years of nearly stationary output and one year of decided decrease. It is therefore very satisfactory to find that the production of the yellow metal has risen again to record figures, the estimate being $84,551,300 against $73,591,700 for 1903.

The sources of this increase are easily traceable. In the first place, Cripple Creek, the greatest gold-mining camp of the United States, has gained about $3,000,000, due to renewed mining activity following successful completion of a new drainage tunnel, the cessation of the strike which interfered with the production of 1903, and new discoveries of rich ore bodies. In the second place, a new mining district of great promise, named Goldfield, has been discovered in Nevada, and this during the first year of its existence has added at least $1,500,000 to the figures of 1903 for that State. In the third place, the production of California has risen nearly $3,000,000 compared with 1903—an increase due in considerable degree to the wonderful development of the dredging industry in the Sacramento Valley. Lastly, the smelting of auriferous copper ores has received a great impetus in Utah, augmenting the gold output in that State by $1,000,000. These four factors, together with moderate gains in the production of Alaska, Montana, and South Dakota, are sufficient to account for the increase of nearly $11,000,000 in the production of the last year compared with that of 1903.

In the following pages a first attempt will be made to classify the gold production according to its derivation from placers, dry or quartzose ores, copper ores, and lead ores. As far as possible a further classification according to types and age of deposits will be made.

GOLD DERIVED FROM PLACERS.

The production of placer gold for 1904 may be estimated at $12,900,000, an increase of $660,000 compared with the figures of the Mint Report of 1903. Alaska is the largest producer, and should show a gain of at least $200,000, the output being estimated at $5,800,000. California will show an increase which may reach $800,000 ($4,800,000 being the estimated figure for 1904), partly due to a favorable season for hydraulic mining, but chiefly to the great development of the dredging industry. Up to 1900 this branch of work was unimportant. From then on began a rapid increase, as shown by the returns of dredger gold as follows: 1900, $200,000; 1901, $500,000; 1902, $800,000; 1903, $1,500,000. Unexpectedly large areas in Yuba, Sutter, Nevada, Butte, and Sacramento counties have proved to be suitable for the dredging process, while the dredging machines have been greatly improved and enlarged and the expenses correspondingly reduced. At the same time the output due to drift mining and hydraulic mining is on the whole slowly decreasing. In 1903 hydraulic mining yielded $1,064,243; surface placers, $761,823, and drift mining, $581,397.

Idaho, Montana, Colorado, and Oregon have probably maintained their production at the value reached for a great number of years. During 1903 they, respectively, yielded $750,000, $482,000, $400,000, and $207,000. Since 1902 New Mexico has contributed over $100,000 annually in placer gold, derived from veins of unknown age and obtained by dredging operations in Colfax County, but none among the other States has exceeded $100,000 in output.

Considered from a geological standpoint, it is important to state that the placers of Alaska, California, Montana, Idaho, and Oregon are derived almost entirely from the erosion and concentration of deposits the origin of which antedate the Tertiary system. In California the placers are generally derived from quartz veins of Jurassic age, and the same is probably true of most placers in Idaho and Oregon. In Montana, and especially in Colorado, a part of the placers are more likely derived from veins of early Tertiary age; but at any rate these contribute a very small part to the total production. In Alaska the consensus of opinion among geologists seems to be that the Yukon placers are concentrated from older, possibly Paleozoic, veins, while a smaller part is derived from veins of the same age as those of the principal California belt.

The veins in Tertiary lavas—andesites, basalts, and rhyolites—contain gold that is so finely divided or so combined chemically with other elements that it does not readily accumulate in the stream channels below the deposits, even if grade and other conditions are favorable.

The production of placer gold from the Appalachian belt is probably about the same as last year, or $30,000. This, as well as the few ounces from Wyoming, is derived from the oldest deposits known in the United States—generally considered pre-Cambrian, although some of them may be of slightly younger age.

Summing up, we have, then:

Placers from pre-Cambrian deposits	$38,000
Placers from Paleozoic and Mesozoic deposits	11,862,000
Placers from Tertiary deposits	1,000,000(?)
Total	12,900,000

In the majority of cases the placer deposits are of Quaternary or early Tertiary age. The oldest deposits exploited are the Eocene and Miocene channels of the Sierra Nevada, generally buried underneath heavy flow of andesite breccia. These contributed about $600,000 in 1903, an unusually small amount, although the production has been decreasing slowly for many years.

GOLD DERIVED FROM QUARTZOSE, OR DRY, ORES.

Auriferous quartz veins of pre-Cambrian age are, as far as known, confined to the Atlantic States, Michigan, South Dakota, and Wyoming. Some of them may possibly be of somewhat later, or Paleozoic, age. In 1904 the yield from these veins amounted to $325,100, the bulk of it coming from North Carolina, South Carolina, and Georgia. Part of it is derived from gold-bearing pyrites and a very small amount from gold-bearing copper ores. This output is somewhat larger than that of 1903.

In South Dakota the great low-grade deposit of the Homestake mine is considered to be of pre-Cambrian age; its output has greatly increased and is reported to be $4,950,558 for 1904. The small production of Wyoming should probably also be credited to the same class of deposits; a fraction of it is derived from the pre-Cambrian copper ores of the Encampment district.

The total production of gold from pre-Cambrian veins for 1904 is estimated at $5,454,158.

The important belt of gold-quartz veins of California extends northward into Oregon and Alaska, the principal quartz mines of which, beyond much doubt, are of the same Mesozoic age. In California the output of this belt has evidently increased somewhat during 1904, and is estimated to be $13,400,000, against $12,059,725 in 1903. The quartz mines in the southern and northeastern part of Oregon have maintained their production, which will be about $1,-100,000. Alaska coast mines are credited with $3,200,000, while the scattered Mesozoic veins in Idaho have yielded only about $600,000. The total yield of the Mesozoic gold-quartz mines of the Pacific coast belt should be $21,600,000.

While the Mesozoic belt of gold-quartz veins appears chiefly in connection with intrusive rocks of the types of quartz-monzonites, granodiorites, and diorites, there is another great class of gold-bearing veins of distinctly Tertiary age, which are contained chiefly in effusive rocks, such as andesites, rhyolites, basalts, and phonolites. Most of these veins have been deposited since the Miocene epoch and form a fairly well-defined group, with several subdivisions. They are not as a rule smelting ores, rich in copper and lead, although some of them contain much pyrite; speaking from a smelting standpoint, they would be classified as dry ores. These younger veins seem to be especially characterized by great richness of ore in bonanzas near the surface. Their production may be estimated at $35,700,000, the largest item in the geological distribution of the output. California's tribute from the gold belt at the eastern foot of the Sierra Nevada remains about the normal figure of $800,000. Nevada has greatly increased its product, chiefly by the new camps of Tonopah and Goldfield, the production from the latter having approximated $2,000,000 since its discovery in January, 1904. The Comstock still yields a few hundred thousand dollars a year. Practically all of Nevada's gold has been derived from Tertiary veins, although some small deposits may be older.

Idaho contributes about $700,000 from Silver City and De Lamar, in Owyhee County, also from Thunder Mountain and various places in Custer County. Montana yielded $1,200,000 from the recently developed resources in Fergus County. South Dakota's "siliceous ores" produce about $2,270,000. The greatest increase comes from Colorado, where the combined output of the Cripple Creek, Gilpin, and San Juan veins amounts to about $21,000,000, an increase of several millions over last year. With considerable doubt $2,200,000 of Utah's gold has been classed in this group, divided chiefly between the Mercur mines, in Tooele County, and the newly discovered Annie Laurie mine, in Piute County. Little is known about the gold-producing mines of Arizona; many of them certainly belong in this class, and $2,100,000 of their gold has been credited to it.

The most productive of the late Tertiary veins are those of the fluorite class, characterized by the presence of fluorite and, normally, also of tellurides. These dry ores yielded at least $16,000,000 in Colorado; $2,270,000 in South Dakota, and $1,200,000 in eastern Montana, a total of $19,470,000. They often occur in connection with phonolitic rocks.

GOLD DERIVED FROM COPPER ORES.

Auriferous copper ores occur throughout the United States in deposits of widely differing age and form. The copper ores of Arizona, except those of United Verde, contain very little gold; the Michigan ores are practically free from it. A few copper deposits are connected with very old metamorphic rocks, and are probably of pre-Cambrian age. Among these are the Ducktown deposits of Tennessee and the Encampment mines in Wyoming; but these contain little gold. The California deposits of the Mountain Copper Company and Bully Hill are essentially sheared zones or replacement veins in altered volcanic rocks, and are probably, like the quartz veins, of late Mesozoic age. The gold from this source is estimated at $272,000, and has remained about constant. The deposits of Montana and Utah, to which the largest part of the remaining production from this source should be credited, are, as a rule, replacement veins of various forms occurring in granite or early Tertiary igneous rocks. Their age is most probably early Tertiary, in part possibly late Tertiary. Montana's yield from copper ores is approximately $1,100,000, and this amount does not differ greatly from that of previous years. The mining of auriferous copper ores in Utah has received a great impetus during recent years, and the production of gold from this source has steadily increased. It is estimated at $2,100,000 for 1904, but this includes some of the smelting ores from Tintic, which are apt to contain both copper and lead. The gold from copper ores in Colorado is difficult to estimate, as no exact statistics are available, but it probably does not amount to $500,000. Part of it come from concentrates of Tertiary veins in San Juan County; another part from the pyrite ores of Leadville, which form irregular bodies in sedimentary rocks and are connected with intrusive porphyries. The age of these latter deposits is believed to be late Mesozoic. Scattering amounts are received from almost every mountain county in the State. Idaho and Arizona derive small amounts of gold from copper ores.

The amount of gold derived from copper ores in 1904 should be about $4,300,000.

GOLD DERIVED FROM LEAD ORES.

The lead ores of the Coeur d'Alene district are practically free from gold, as are those of the Mississippi Valley. The principal contributors to this class are Colorado and Utah. Colorado comes first with about $4,000,000, of which one-fourth is derived from the Leadville mines, which, as stated, are exploiting late Mesozoic replacement deposits in limestone. The rest is largely due to auriferous and lead-bearing concentrates from Tertiary veins in San Juan, Gilpin, and Mineral counties. Utah contributes about $400,000 from lead ores, nearly the entire amount of which is obtained from the Park City silver-lead veins, which are believed to be of early Tertiary age.

The amount of gold derived from lead ores in 1904 is estimated at $4,600,000, or almost the same quantity as that derived from copper ores.

SUMMARY.

Summing up, we have the following tentative distribution of the gold production of 1904:

Placers		$12,900,000
Quartzose gold and silver ores:		
Pre-Cambrian quartz veins	$5,454,000	
Mesozoic quartz veins (Pacific coast belt)	21,600,000	
Tertiary gold-quartz veins (Rocky Mountains and Great Basin)	35,700,000	
		62,754,000
Copper ores		4,300,000
Lead ores		4,600,000
Total		84,554,000

Source of production of gold and silver in 1904.

	Gold.	Silver.
	Fine ounces.	*Fine ounces.*
Placers	619,700	64,000
Quartzose gold and silver ores:		
Pre-Cambrian quartz veins	264,000	79,000
Mesozoic quartz veins (Pacific coast belt)	1,045,000	860,000
Tertiary quartz veins (Rocky Mountains and Great Basin)	1,727,000	11,000,000
Total	3,036,000	11,939,000
Copper ores	208,000	18,600,000
Lead ores	222,500	23,000,000
Total	4,086,200	53,603,000

THE PRODUCTION OF SILVER IN THE UNITED STATES IN 1904.

By WALDEMAR LINDGREN.

INTRODUCTION.

A preliminary estimate by the Director of the Mint places the production of silver in the United States at 53,603,000 fine ounces, and in the same estimate the amounts contributed by the several States are enumerated. Although detailed statistics are not yet available, it may be worth while to attempt an approximate distribution of this product among the different classes of ore, and also, so far as possible, among the different classes of ore deposits. The data available for such classification, which is here for the first time attempted, are necessarily incomplete, and the figures given must be considered merely as estimates. Much information concerning this question is contained in the reports of the Bureau of the Mint. Besides this, many data have been obtained by the mining geologists of the Geological Survey and from reports in the technical press.

The production of silver in the United States has been practically stationary since 1890, at figures averaging 55,000,000 ounces. During 1892 and 1893 the output rose to, respectively, 63,500,000 and 60,000,000 ounces, only to drop suddenly during 1894 to 49,500,000 ounces. The estimate for 1904, as stated above, is 53,603,000 ounces, a decrease of about 700,000 ounces from the preceding year.

In subdividing this amount a basis has been adopted similar to that employed in the subdivision of the gold production. The different classes of ores to which the production can be traced are as follows:

(1) Silver derived from placers.
(2) Silver derived from dry or quartzose ores.
(3) Silver derived from copper ores.
(4) Silver derived from lead ores.

The second class is further subdivided according to the geological character of the veins, one division being formed by the pre-Cambrian veins, another by the Mesozoić gold-quartz veins of the Pacific coast belt, and a third by the Tertiary gold and gold-silver veins, which appear chiefly in connection with eruptive rocks of that age.

PLACERS.

It is well known that all placer gold contains a small amount of silver. The amount derived from this source is very slight and may be estimated at 64,000 ounces in 1904, of which by far the larger part is divided between Alaska and California, each probably contributing about 30,000 ounces. A large portion of this silver is never separated from the gold in which it occurs.

QUARTZOSE, OR DRY, ORES.

This division embraces the silver derived from quartz veins of various ages and different characters. A large part of the silver from this series is free or alloyed with gold. Many of the veins of this type contain, however, pyrite, copper ores, or lead ores, in relatively small amounts. In many cases the concentrates from these veins have been classed as copper ores and lead ores. In the present state of the statistics relating to this subject it is difficult to avoid this source of confusion. It is not, however, believed to seriously affect the figures given.

According to their age the quartz veins may be subdivided into three groups, the pre-Cambrian, Mesozoic, and Tertiary. The pre-Cambrian quartz veins of the Appalachian States yield principally gold, but also a small amount of silver, probably about 31,000 ounces. There are a number of veins in South Dakota and Wyoming which probably belong to this class, but the only one producing a notable amount is the celebrated Homestake mine, in the Black Hills, to which approximately 48,000 ounces shoudld be credited. It will be seen that the total amount derived from pre-Cambrian quartz veins is very small, scarcely exceeding the quantity derived from the placers. The amount estimated is 79,000 ounces.

A strongly developed belt of quartz veins of late Mesozoic age extends through California, Oregon, Idaho, and Alaska. There are probably veins of the same age and character in Montana and Arizona. It is possible that some of the Alaska veins may be older than those of California, and it is likewise possible that among the deposits of Montana referred to this class there may be some of early Tertiary age. All these, however, are principally gold bearing, and the total amount of silver derived from veins of this class is not very large. Alaska contributes about 167,000 ounces, California 150,000 ounces, and Oregon 130,000 ounces, while the other States mentioned supply smaller amounts from this source. The total amount of silver derived from the Mesozoic belt of gold-quartz veins in 1904 is believed to be 860,000 ounces.

The third subdivision of the dry silver ores comprises those derived from Tertiary quartz veins carrying gold and silver ore, in some cases silver exclusively. This is an important source of production, and when it is taken as a whole the contrast between the amount of silver derived from this source and that obtained from other veins is really very remarkable. The production is divided chiefly between Colorado, Nevada, and Montana. Arizona produces a great deal of silver from this class of deposits, but the statistics do not permit an accurate estimate of the amount. It is believed to be in the neighborhood of 1,500,000 ounces. California adds 200,000 ounces, derived from gold-silver veins in the belt at the eastern base of the Sierra Nevada. Colorado contributes 2,900,000 ounces, principally derived from the San Juan country and the Gilpin district, but with scattered additions by many other counties. Idaho yields 700,000 ounces, approximately, from the gold-silver veins in Owyhee County, and a small amount from deposits in the central part of the State, notably in Custer County. The amount contributed by Montana is very much in doubt, owing to the difficulty of classifying the veins in that State. At any rate it is not likely to exceed 1,000,000 ounces. Practically the whole of the silver production of Nevada, 4,500,000 ounces, belongs under this heading. The amount of silver-lead ores now mined in that State is very small indeed. Utah produces 360,000 ounces from dry ores. The source and age of many of these are very doubtful, and it is possible that a part of this amount should really be credited to gold-quartz veins and deposits of earlier age.

The siliceous ores of South Dakota contain considerably more silver than does the principal Cambrian deposit of the Homestake mine, in the same State. From this source 138,000 ounces are added. The total amount of silver derived from the Tertiary gold-quartz veins and allied deposits in 1904 would be approximately 11,000,000 ounces. This probably represents a small decrease from the figures of 1903, due to a decreased production in Colorado owing to various labor troubles.

COPPER ORES.

It is a fact, which is perhaps scarcely realized, that one-third of the production of silver in the United States is derived as a by-product from the smelting of copper ores, the larger part of which do not contain enough silver to be classed as paying silver ores. By far the largest amount is supplied by Montana, and nearly the whole amount of this is derived from the Butte copper ores, which occur in fissure veins traversing granitic rocks and are believed to be of early Tertiary age. The copper smelted in Arizona usually carries very little silver. The ores of the United Verde mine, however, contain a certain amount of both gold and silver. From this and other smaller sources a total of 1,300,000 ounces is obtained for Arizona. The age of these silver-bearing copper deposits is not known; they appear as replacement veins in dioritic rocks. The copper deposits of California are principally located in Shasta County, the two most important producers being the Mountain Copper Company mines, near Reading, and the Bully Hill mines. Both of these are working on pyritic ores that appear to be replacement veins of Mesozoic age connected with eruptive rocks of the same age. The amount yielded by California is estimated at 600,000 ounces.

On account of defective statistics the amount which should be credited to copper ores in Colorado is difficult to estimate. Much of it is produced by the Leadville deposits, which, in general, are replacements of limestone and are considered to be of late Mesozoic age. The remaining amount is derived from widely scattered sources, and part of it is no doubt obtained from concentrates of Tertiary gold-quartz veins. In a preliminary way Colorado has been credited with 1,500,000 ounces derived from copper ores.

Utah is next to Montana in the production of silver from copper ores. Most of the amount, which is estimated to be 4,000,000 ounces, comes from the smelting of copper ores from Bingham, Salt Lake County, but a part is obtained from the old mining district of Tintic, in Juab County. At both places the deposits are replacement veins, or forms allied to these. Their age is believed to be early Tertiary.

New Mexico and Washington add smaller amounts of copper ores, which, however, together do not yield more than 185,000 ounces.

On the whole, it may be said that the greater part of the production of silver from this source is derived from replacement veins of late Mesozoic or early Tertiary age. The Tertiary veins of later date do not, as a rule, contain much copper.

LEAD ORES.

Silver is usually most intimately connected with lead, so that it will not occasion surprise to learn that nearly one-half of the total output is derived from lead ores. The three largest producers are Colorado, Utah, and Idaho, the first two yielding each about 8,000,000 ounces, while 6,500,000 ounces are derived from Idaho.

In Colorado the greater part of the production still comes from Leadville, where the ores occur as irregular replacement deposits in limestone and are believed to be of late Mesozoic age. Much of the remaining amount is supplied by Aspen, the mines of which do not, however, produce nearly as much as in former years. Here again the lead ores appear as replacement deposits in limestones, more or less distinctly connected with fissure veins. Their age is not positively known. The remainder of the production is scattering, most of it being derived from the various counties in the San Juan region, and probably in many cases being concentrates from veins of late Tertiary age.

The principal source of silver-lead ores in Utah is the Park City district in Summit County. The production has decreased somewhat during 1904, but still remains very large. A smaller part of the lead ores are derived from the Tintic veins in Juab County.

The silver-lead ores in Idaho are derived from two widely distant regions. The first and more important is the Coeur d'Alene district, which is believed to have produced 6,000,000 ounces during the past year. The ores which carry galena and zinc blende, with a relatively small amount of silver, occur in probably pre-Cambrian slates near the contact with a granite mass of intrusive origin. The age of these replacement veins is probably late Mesozoic. A somewhat different class of deposits, which consist of veins containing galena and tetrahedrite, or gray copper, and which are very rich in silver, occur in Blaine County, in the central part of Idaho, the region being usually known as the Wood River district. These veins also occur in slates near the contact of intrusive granite and are considered to be of late Mesozoic age; their part in the production of 1904 may be estimated at 500,000 ounces.

The production of lead-silver ores in Montana has steadily decreased, and during the last year the amount of silver derived from this source was given in the report of the Director of the Mint as only 450,000 ounces. In most cases these deposits are veins or irregular masses occurring as replacement of limestone.

Arizona, California, Washington, and New Mexico produce small amounts of silver-bearing lead ores, but the production in no case exceeds 200,000 ounces.

To sum up, the argentiferous lead ores are believed to have contributed 23,000,000 ounces to the production of silver during the past year.

There can be no doubt that a very large proportion of silver-bearing lead ores are derived from deposits of comparatively great age. Like the copper ores, most of them are of late Mesozoic or early Tertiary age, while it would appear as if the Miocene and post-Miocene deposits contained a comparatively small amount of lead.

SUMMARY.

Summing up these statements, the following estimate represents the probable division of the silver product for 1904:

Source of production of silver in 1904.

		Fine ounces.
Placers		64,000
Quartzose gold and silver ores:		
Pre-Cambrian quartz veins	79,000	
Mesozoic quartz veins (Pacific coast belt)	860,000	
Tertiary quartz veins (Rocky Mountains and Great Basin)	11,000,000	
		11,939,000
Copper ores		18,600,000
Lead ores		23,000,000
Total		53,603,000

The market price of silver has gradually increased during the year from 57 cents per ounce in January to 61 cents in December.

Source of production of gold and silver in 1904.

	Gold.	Silver.
	Fine ounces.	*Fine ounces.*
Placers	619,700	64,000
Quartzose gold and silver ores:		
Pre-Cambrian quartz veins	264,000	79,000
Mesozoic quartz veins (Pacific coast belt)	1,045,000	860,000
Tertiary quartz veins (Rocky Mountains and Great Basin)	1,727,000	11,000,000
Total	3,036,000	11,939,000
Copper ores	208,000	18,600,000
Lead ores	222,500	23,000,000
Total	4,086,200	53,603,000

MINERAL RESOURCES OF THE INDIAN VALLEY REGION, CALIFORNIA.

By J. S. Diller.

LOCATION.

The Indian Valley district, of Plumas County, Cal., extends about 12 miles northward from the fortieth parallel and 18½ miles eastward from the one hundred and twenty-first meridian. It includes Indian Valley, North Arm, and Genesee Valley, which have an elevation of about 3,600 feet and are hemmed in by the mountains of the north end of the Sierras, which rise at a number of places to a height of over 7,000 feet. The included post-offices are Taylorville, Greenville, and Crescent Mills.

DEVELOPMENT.

Prospectors began their search around Indian Valley during the gold excitement of 1850, and the next year the Bullion ledge, a short distance northwest of Greenville, was discovered. Many locations followed, and within ten years Greenville became an active mining center. Gold was the primary object of search, but the discovery of rich copper ores in 1865 led to the erection of a small furnace, which maintained a sporadic activity for four years.

Although no great mines have been developed about Indian Valley, between forty and fifty small ones have at various times contributed to a total output of over $7,700,000. The values are almost wholly in gold, with a little silver and less copper. Iron ore, coal, building stones, and mineral springs, although present, have not yet become sources of revenue. At the present time there are many active prospects in the region, but scarcely half a dozen paying mines.

The principal producing mines have been the Crescent, Green Mountain, Indian Valley, and McGill-Standard, all of which, with many others of less importance, lie in the Crescent mining belt, which extends from the neighborhood of Taylorsville N. 50° W. through the Crescent and Greenville districts to Wolf Creek, a distance of about 15 miles, with a width of a little over a mile. In the

Crescent belt last October there were but two producing mines with one quartz mill and two arrastres.

The most continuous activity of the region has been along Wards Creek, on the border of Genesee Valley, where the Gruss mine has been in operation for over twenty years. Near by is the Five Bear mine, and across Genesee Valley is the Cosmopolitan, from which most of the ore was obtained years ago for the Coppertown furnace. Beyond are the Regal, Engel, and finally, in Lights Canyon, the Superior mine, where a body of bornite and chalcopyrite approximately 60 feet long, 40 feet wide, and 3 feet thick has been removed. These mines and several smaller ones lie in the Genesee mining belt, which extends from Wards Creek N. 22° W. to Lights Canyon, a distance of about 15 miles. While conservative estimates place the total production of the Crescent belt at $6,650,000, that of the Genesee belt has been estimated at $450,000. At the present time in the Genesee belt there are 5 mines active, with 2 stamp mills and 3 arrastras.

GENERAL GEOLOGY OF INDIAN VALLEY REGION.

The Indian Valley region has three topographic parts: (1) The prominent ridge of Grizzly Mountain and Arlington Heights, on the southwest, made up largely of Silurian and Carboniferous sediments; (2) Kettle Rock Mountain, on the northeast, composed of pre-Tertiary volcanic rocks and granodiorite, and (3) a group of valleys and lower hills in the middle part, containing, besides subordinate masses of volcanic rocks, a great thickness of Jurassic, Triassic, and some Carboniferous rocks.

The rocks of each part form a mass which may be called a block. The middle or valley block is separated from the grizzly block on the southwest by a great overthrust fault which brought the Silurian limestone in Grizzly Mountain far up over the sandstones of Jurassic age. On the northeast of the valley block, where it adjoins the Kettle Mountain block, there may have been some faulting, but it is not expressed in the topography.

Attention has already been called to the fact that the mines of the Indian Valley region are in two belts, the Genesee belt and the Crescent belt. The Genesee belt corresponds approximately to the contact on the northeast side of the valley block where it adjoins that of Kettle Rock Mountain, but the Crescent belt of mines lies a short distance southwest of the great overthrust fault, wholly within the block to which the rocks of Arlington Heights belong.

GEOLOGY OF CRESCENT BELT OF MINES.

The Crescent mining belt has in it two long, narrow masses of granodiorite, one southwest of Taylorsville, cutting the Paleozoic sediments, the other between Crescent and Greenville, cutting the quartz-porphyries of that district. The metalliferous deposits are confined chiefly but not wholly to the igneous rocks, and in none of the cases examined are they definite contact deposits, such as occur in a portion of the Genesee belt. The deposits throughout the Crescent belt are in more or less well-defined quartz veins, running generally parallel to the course of the belt, but in a few cases there are small veins at nearly right angles to the others. The ore is auriferous pyrite, sometimes in small bodies, but generally disseminated in the narrow strip of sheared rock of the partially formed vein, in which there is usually some quartz. The pyrite is nearly always changed to limonite, setting the gold free and staining the incomplete vein as well as its walls. One of the best defined and most complete quartz veins of the Crescent belt occurs in the Premium mine. It is vertical, about 2 feet in thickness, and cuts granodiorite.

In the Green Mountain mine one subordinate vein carries a small amount of chalcopyrite, but in general copper is absent in the belt, except at the Pettinger mine, near Taylorsville, where a small imperfect vein in the Taylorsville slates is impregnated with carbonates of copper, sometimes blue, but generally green.

An exceptional deposit for the Crescent belt, and, indeed, for the whole region, is a mass of pyrrhotite a mile and a half nearly south of Taylorsville. It lies in a narrow strip of sheared sandstone running north and south, but the largest body, about 10 feet in thickness, is at a point where the sheared sediments end against serpentine. The pyrrhotite was tested for nickel by Mr. Hillebrand, but none was found.

GEOLOGY OF THE GENESEE BELT OF MINES.

The Genesee mining belt follows approximately the northeastern limit of the Mesozoic sediments where they come in contact with the granodiorite and other igneous rocks. The deposits are variable in form; some are more or less complete veins following narrow belts along which the rock has been crushed and sheared; others follow the line of contact bounding the granodiorite. In some deposits the ore is auriferous quartz and limonite, but in others it is chiefly bornite, chalcopyrite, chalcocite, or copper carbonates. Quartz is the most common gangue mineral, but in one case barite appears, and in another a green mineral like actinolite.

The Gruss mine, on Wards Creek, is on both sides of the contact between andesite-porphyry and slaty shale. In the shale the partially formed veins follow narrow shear zones, in which there is some auriferous quartz associated with limonite that deeply stains the richest portions of the crushed mass. The adjacent andesite is often decidedly slaty, and its ores are chiefly chalcopyrite or bornite, with copper carbonates near the surface.

The rocks along the contact are generally much sheared and the shear zone is apparently somewhat richer than those on either side. No characteristic contact minerals were observed to suggest that ores in this case were originally contact deposits modified after the development of the slaty cleavage.

The Five Bear mine, in the slates, is much like the Gruss, but the Green Ledge, Pilot, and others in the porphyry have small veins of quartz, with bornite and some chalcocite. The veins are generally less than 5 inches in thickness.

The Cosmopolitan mine is on the contact of the granodiorite with the Triassic limestones and shales. The ore is bornite and chalcopyrite, forming solid bodies up to 15 feet in thickness, with greater dimensions in the plane of contact, along which other smaller bodies of the same ore occur. On the surface the contact is marked by masses of garnet and epidote which were not seen beneath, but in the Duncan mine the garnet and epidote are associated with the ore.

The Bluebell mine is in the Triassic limestone, near the contact, and from one of its shafts some tons of carbonate of copper have been brought up in connection with cave breccia, suggesting a secondary deposit within the limestone. A small vein of barite occurs in altered andesites at the Indian Valley silver mine and locally contains traces of copper ore.

Near the northwest end of the Genesee belt is the Superior mine, in which the gangue of the bornite is a green fibrous mineral like actinolite. A number of parallel vertical veins of this mineral are well exposed in the open cut and contain disseminated particles and nodules of bornite. The larger ore bodies are free from gangue. The wall rock is the same on both sides, and the veins are sharply defined.

AURIFEROUS GRAVELS.

Development.—In the Taylorsville region modern stream beds have been mined in Lights Canyon and on Indian Creek, above Flournoys, as well as below Arlington bridge. The total yield of these modern gravels is in the neighborhood of $10,000 annually.

About the head of Lights Creek, Mountain Meadows, and Moonlight, high gravels have been mined irregularly in a small way for over twenty years, and the total yield, according to a conservative estimate, is nearly $500,000.

Geology of the high gravels.—In the Taylorsville region the high gravels are well illustrated by those at Peale's and Taylor's diggings, which lie on the flat crests of divides over 1,000 feet above the streams on either side. They belong to the moderate slopes of the gentle relief which characterizes the broad summit of the northern end of the Sierra Nevada. The pebbles in the gravel where best exposed incline to the southwest, indicating the course of a stream that flowed during the gravel period from near Haskell Peak northward by the Cascade mine and Peale's and Taylor's diggings to Moonlight, where it entered a shallow lake that covered the whole of that portion of the Sierra summit as far south as Thompson Peak. Other streams flowed into the lake from the south, and carried into it at first chiefly sand and finally a great mass of gravel, which now covers many square miles to a depth of hundreds of feet, forming the largest continuous body of auriferous gravel now known in the Sierra Nevada. In the lower portion of this deposit sand prevails, and in the upper half gravel, often coarse, but always well rounded and smooth. Interstratified with the gravel are layers of sand, frequently containing leaves of a flora belonging to a much lower altitude than that at which they are found to-day. Since then the Sierras have been uplifted along a fault which has cut the gravel as far north as Diamond Peak, leaving a ridge of it on the very crest, but north of Diamond Peak, where the range dies out, the gravel bends down over the eastern slope and is completely indurated, converting it into a solid conglomerate. Much of the gravel of this great field is too firmly cemented to be mined by ordinary means. There are, however, large masses loose enough to be easily mined by water delivered under pressure. The chief difficulty is the lack of water at this high level.

ORE DEPOSITS OF THE OURAY DISTRICT, COLORADO.

By J. D. Irving.[a]

LOCATION AND GENERAL FEATURES OF THE DISTRICT.

The town of Ouray, Colo., long an important mining center and now chiefly known as the place from which one may most readily reach the Camp Bird mine, is situated in the San Juan Mountains, in the southwestern part of Colorado.

It occupies a broad, flat bottom land, nearly circular in form and about one-half mile in circumference, which lies at the center of the forks formed by the junction of Canyon Creek and the Uncompahgre River.

The two streams enter the valley from deep precipitous gulches, while the Uncompahgre River leaves it by a narrow canyon which is cut through the dark red sedimentary rocks of the Carboniferous system. A mile farther north the canyon widens and the Uncompahgre emerges into cultivated bottoms that stretch away to the northwest. The valley in which the town is situated has the appearance of being almost completely encircled by abrupt cliffs, but these are broken on the west by the gorge of Oak Creek and on the east by the green hills that rise above the town and form the bottom of the steep-sided Portland amphitheater.

The metalliferous deposits, which it is the chief purpose of this paper to discuss, are all near the town and mainly occupy the precipitous country on the two sides of the Uncompahgre River. No one of the important mines is at a greater distance from Ouray than 3½ miles.

The ore deposits, although they include only a few highly productive mines, form a series of very unusual scientific interest, one which it is thought may throw some light on a number of the vexed questions of ore deposition.

Their salient features are intimately related to the geology of the region, and the following summarized discussion of the geology (by Dr. Ernest Howe) is essential to a clear comprehension of their character:

[a] With a note on the geology, by Ernest Howe.

GEOLOGY.[a]

Introduction.—The geology of the mining region in the immediate vicinity of the town of Ouray includes nearly all of the features that are characteristic of the San Juan Mountain area. Sedimentary rocks, representing various periods, from the Algonkian to the Tertiary, are more or less typically developed, and fourteen different formations have been recognized from fossil evidence or on lithologic and stratigraphic grounds. A great thickness of volcanic rocks, andesites, and rhyolites, erupted during Tertiary time, covers the sediments, while still younger porphyries intrude both the sedimentary and volcanic rocks. At several periods during the history of the region faulting and folding occurred, which have affected all of the rocks, some more than others.

Unlike the adjoining districts of Silverton and Telluride, the important mines are in the areas of sedimentary rocks and stratigraphy becomes an important factor in the discussion of the ore deposits.

Sedimentary formations.—The oldest rocks that are found in the region are the massive quartzites and slates that are exposed south of Ouray in the Uncompahgre Canyon, where a thickness of fully 8,000 feet is known to occur. The beds dip steeply to the north, and although neither the top nor the bottom of the formation has been seen, it is believed that the upper portion lies to the north. The name Uncompahgre has been applied to this formation, which is assumed to be of Algonkian age.

At Ouray, a short distance southeast of the Mineral Farm mine, the Paleozoic section begins with a series of calcareous shales and sandstones, not more than 50 feet in thickness, which rest on the upturned edges of the Uncompahgre quartzites and slates. Upper Devonian fossils have been found preserved in corresponding beds on the southern slopes of the Needle Mountains, and the formation has been named the Elbert. A series of Upper Cambrian quartzites, the Ignacio formation, is usually found directly beneath the Elbert, but at Ouray this is lacking, although its presence is indicated in Cow Creek by a few fossils that have been obtained from the bottom of an old shaft.

The Ouray formation, which succeeds the Elbert, consists mainly of light-colored limestones, thin bedded below and very massive above. A late Devonian fauna characterizes the formation, except in the upper portion, where Mississippian fossils have been found, but this part can not be differentiated on lithologic grounds from the underlying beds. These limestones occur in a limited area south of Ouray,

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[a] By Ernest Howe.

the upper massive portion being particularly well exposed in Box Canyon of Canyon Creek and in the vicinity of the Mineral Farm mine.

The Molas formation, consisting of 50 feet of red shales and chert conglomerates, rests uncomfortably on the Ouray limestones and is followed by about 1,400 feet of the Hermosa formation. The beds are of Pennsylvanian (" Upper Carboniferous ") age. The Hermosa consists of fossiliferous limestones, sandstones, and shales in the lower part, while thick massive sandstones and grits of a pink or reddish color predominate above. These are the rocks that form the prominent cliffs about the mouth of Oak Creek, directly west of town. The Hermosa is followed by 1,500 feet or more of Permian red beds, called the Cutler formation, consisting of coarse conglomerates, sandstones, and shales, all of a bright-red color. They were sharply folded and their upturned edges beveled off by erosion before the Triassic Dolores formation was deposited, so that in the immediate vicinity of Ouray they are poorly represented. They are best seen 4 or 5 miles north of Ouray, in the neighborhood of Dexter and Cutler creeks.

The Dolores formation consists of about 100 feet of bright red sandstones and shales, with a very characteristic conglomerate containing limestone pebbles at the base. The unconformable relations of the Dolores to the underlying beds is well shown in the cliffs east of Ouray, between Portland and Cascade creeks, where the Triassic beds have transgressed the Cutler formation and rest upon the Hermosa.

The four other Mesozoic formations that occur in this area—the La Plata, McElmo, Dakota, and Mancos—are of particular interest because it is with them that the more important ore deposits are associated. In areas where they have not been metamorphosed by intrusions of igneous rocks they are easily recognized by their lithologic characteristics, but in the neighborhood of the American Nettie and Bachelor mines they have been deformed to some extent and altered by intrusive porphyries so that they can not always be readily distinguished.

The La Plata formation, immediately above the Dolores, consists of two massive light-yellow or almost white sandstones separated by a peculiar silicified breccia of limestone and calcareous shale. The whole formation is 100 feet thick. This is followed by 700 or 800 feet of thin greenish and reddish shales and sandstones, with some more massive sandstones near the base. This is the McElmo formation, which in the vicinity of Bridal Veil and " Blowout " creeks has, together with the red Dolores, been bleached, and many of the sandstone members have been converted into quartzites. The La Plata and McElmo are of Jurassic age.

The Dakota formation, locally known as the "Upper quartzite," has a maximum thickness of about 150 feet. It consists of two or three massive quartzite or hard sandstone beds separated by thin bands of black shale. It is one of the most persistent horizons of the region and usually forms prominent cliffs or escarpments, easily identified and traced. It is in this formation that the ore deposits of the American Nettie and in part of the Bachelor occur. In a few places near Ouray the soft black shales of the Mancos formation are found above the Dakota. They occur in small patches that were left after the great erosion that preceded the period of volcanic activity. The whole formation has a thickness of over 1,000 feet.

The only sedimentary formation of Tertiary age known to occur in this region is the Telluride conglomerate. It has extremely variable characteristics in different parts of the San Juan Mountains, and southwest of Telluride has a thickness of 1,200 feet. Near Ouray, however, it is seldom more than 50 feet thick, and is often altogether absent. It consists of materials derived from the older sedimentary rocks—sandstone and limestone pebbles—embedded in a calcareous cement. The color is usually a dull pink. It is of economic interest because an occurrence in Cobbs Gulch, Cow Creek, has been reported to carry free gold in small amounts.

Volcanic rocks.—The next rocks in point of age are those of volcanic origin that make up a very great part of the San Juan Mountains and consist of a number of well-known eruptive types. The only member of this great series that needs to be considered in this connection is the oldest one, the San Juan tuff. It has a maximum thickness in Canyon Creek and the amphitheater of over 2,000 feet, and is easily recognized by its dull blue color. It has the appearance of a conglomerate composed of angular fragments or coarse sand derived from lavas known as "andesites." Parts are soft and crumble readily under the influence of weather; others are well consolidated and form the precipitous cliffs of Bear Creek and the upper part of Canyon Creek. In many places a well-defined bedded structure may be observed.

For a long time after the period of the San Juan tuff other lavas were poured out, and toward the close of the eruptions the tuff itself, as well as the sedimentary rocks beneath it, were invaded by certain lavas that were unable to reach the surface and forced their way between the sedimentary strata or along the base of the San Juan. These intrusive rocks are the porphyries that occur so prominently as dikes or sheets or large irregular bodies near Ouray. The sedimentary formations, especially between Cascade Creek and Bridal Veil Creek, were extensively altered as a result of these intrusions, and the mineralization of the region probably occurred shortly after this time.

Structure.—It is not possible, within the limits of the present report, to discuss the structural features of the area except in a very general way. Only three periods of deformation since the beginning of Paleozoic sedimentation are clearly shown, although more are known to have occurred. The first of these took place at the close of the Paleozoic, and produced the sharp flexures seen in the Red Beds just north of Ouray, and also in the Ouray limestone south of the town. All of these beds were at the same time given a moderate dip to the northwest. The second period occurred somewhere near the close of the Mesozoic, and belonged to the series of movements that were felt all over the Rocky Mountain area. It is recorded in the gentle northerly dip of the Mesozoic rocks. These later movements were accompanied by comparatively unimportant faulting, which possibly followed lines initiated during the earlier period. The final period followed the intrusions of porphyry, and, except at few places, accomplished little more than local fracturing or fissuring, accompanied by very slight displacements. The most striking of the faults is the one passing across the lower end of the Box Canyon of Canyon Creek and extending a little south of east to the southern wall of the Amphitheater. By this the older Paleozoic rocks have been dropped 300 feet to the north, with Uncompahgre quartzites on the south side of the fault.

ORE DEPOSITS.

GENERAL FEATURES.

A few of the larger ore bodies are situated in localities where the sion of a group of metalliferous deposits that is widely developed in the Silverton quadrangle, which adjoins the Ouray quadrangle on the south. While they are thus in a sense closely related to the Silverton deposits they form a group which possesses marked individual features—features that are in many cases unique and of such scientific interest as to warrant a somewhat fuller description than would be justified by the statistics of their production.

The region in which the ores occur is of small area and may all be included in a semicircle with a radius of 4 miles, described to the north of Ouray and having its center about a mile south of the town.

A few of the larger ore bodies are situated in localities where the rocks are much broken and disturbed, and where intrusive dikes and sheets of porphyry occur in the near neighborhood, but many are found in formations which have been only slightly disturbed. In the case of the Black Girl and Newsboy mines, on the east side of the Uncompahgre River, the veins occur in strata so regular and so free from intrusions that it is with no little surprise that one encounters indications of mineralization.

The ore deposits are difficult to classify on account of the insensible gradations between even the most diverse types. A single deposit frequently displays very different characters in different rocks, so that it will conform to one type of deposit in one part of its course and another type at another.

For convenience of description the classification below is given. It will serve to bring into the same group the types of ore bodies most readily discussed together.

1. Fissure veins.
2. Replacement ores in quartzite.
3. Replacement ores in limestone.

These three main classes of ore bodies owe their existence to the presence of fissures, generally nearly vertical, in the country rock through which mineralizing waters have circulated. The form of the ore body deposited is dependent on two factors:

1. The amount of open space in the fissures.
2. The kind of rock through which the fissures pass.

Where the fissures have been open the resulting vein frequently exhibits a roughly parallel alignment of minerals, and little replacement of the wall rock is noticeable. Where, on the other hand, they have been narrow and more or less discontinuous the maximum replacement is to be observed along soluble beds. In the latter case narrow fissures are apt to be developed in considerable number, and large flat masses or shoots conformable to the bedding are formed.

Of far more wide-reaching importance is the nature of the rocks in which the fissures occur. Most of the veins are found passing through an immensely varied series of rocks and may frequently be traced from the red beds of the Hermosa formation into the andesite breccias of the San Juan, which form the massive gray cap rock of all the higher hills and mountains.

The ore bodies are, therefore, as widely different as the rocks in which they occur. Where a fissure penetrates only impervious rocks but little replacement occurs and no lateral shoots are developed. Where there are replaceable limestones, or in some places even quartzites capped by impervious shales, lateral enrichments have been developed, often of great extent.

The Bachelor mine is an example of the simple fissure where replacement has operated only in a small degree. No flat ore bodies of any size are observable in the mine workings, because the latter have not yet penetrated deep enough to reach beds of limestone.

The Newsboy mine is an instance of a vein of twofold character where a simple fissure in impervious rocks gives rise to large lateral shoots on passing through beds of limestone.

The Bright Diamond and Mineral Farm mines are instances of immense flat bodies of ore where the fissures are so small as to be often difficult to detect.

The accompanying section of Gold Hill (fig. 1), very much generalized on account of the thinness of the beds, will give a somewhat inadequate idea of the varied rocks through which the fissures pass and will also serve to illustrate roughly the horizons in which a lateral extension of the veins most frequently takes place.

The influence of the wall rock on the form of the ore deposit may be further understood by the detailed diagrammatic drawings (figs. 2 and 3, pp. 58, 59).

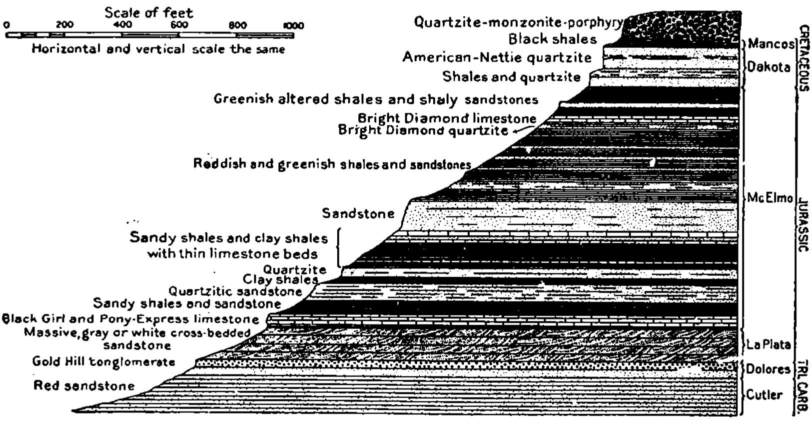

FIG. 1.—Geological section of Gold Hill.

The ore deposits will be briefly considered in the following order:

1. Fissure veins:
   Silver-bearing veins.
   Gold-bearing veins.
2. Replacement deposits in quartzite.
3. Replacement deposits in limestone.

FISSURE VEINS.

The fissure veins are readily divisible into two distinct groups, (1) silver-bearing veins and (2) gold-bearing veins.

SILVER-BEARING VEINS.

Location and general features.—The silver-bearing veins are developed largely in Dexter Creek, where the chief interest has centered about the Bachelor, Wedge, and Calliope mines, and on the east side of the Uncompahgre Valley about 4 miles north of Ouray, the chief mines being the Newsboy and Black Girl. A few minor developments, as yet only of prospective value, occur on the uplands lying west of the river, among which the Gem and Teller mines might be mentioned as the most important.

The veins are fissures in the country rock filled with high-grade ores of silver and the gangue minerals which accompany them. The strike of the fissures is in general quite uniform, approximating an east-west direction. Thus in the Bachelor mine the strike is N. 83° E.; in the Black Girl it is N. 85° E., and in the Calliope N. 83° E. The dip of the fissures varies from a vertical position to about 60°. Instances of a dip of 45° are known, but are rather uncommon. The fissures usually show a slight displacement, rarely reaching as much as 7 feet and generally so small as to be distinguished only by close observation. The width varies from a few inches to as much as 8 feet, a fair average being about 3 feet. Most of the veins are rather uniform and retain their width for the larger portion of their course without marked variation although pinches and swells are to be observed in many parts of the mines.

The country rock in which the veins occur is the varied series of sedimentary rocks lying below the andesite breccia cap and comprising from above downward:

1. Mancos black shale.
2. Dakota quartzite and sandstones alternating with black shale.
3. A highly varied series of clay shales, sandstones, sandy shales, calcareous shales and limestones, belonging to the McElmo group of the Jurassic.
4. Red sandstones and conglomerates with some reddish shales.

These sediments have as a whole a gradual downward inclination toward the north by east, which eventually brings them down across the bed of the Uncompahgre River along its northward course. The dip in undisturbed localities is about 10°. Local disturbances have sometimes increased or reversed these dips, as in the Bachelor mine, where the strata dip southeastward at an angle of about 10°. Steeply inclined beds occur only in a few of the mines. The beds at the Calliope and Iowa Chief mines dip southeastward at an angle of about 25°, but this inclination holds good for only a limited area. In some places the ore is contained within two fairly well-defined walls; in others the fissure is divided into branches that separate from and unite with one another many times. Cross fractures further unite the divided branches, so that the resulting network often passes into a more or less brecciated structure.

Relation of the fissures to the wall rock.—The relation of the ore in the fissures to the wall rock is peculiar. The ore is much more abundant and of very much higher grade when included between walls of quartzite, and is either absent or of a low grade when the fissure passes into shales. In some mines, such as the Iowa Chief in Dexter Creek, this is due to the very narrow character of the vein in the clay shales. It is so narrow as to be in most places a mere fracture in the sediments, with no appreciable open space. On passing into the quartzite, a rock more capable of supporting large cavities, the vein widens and rises so much in value as to furnish very considerable profits. In other cases, however, the vein suffers no appreciable diminution in size, but the ore minerals seem to have been deposited only between the layers of quartzite, the portion of the vein in the shales being occupied by barren-gangue material and clay.

Again, where the vein passes through a limestone flat shoots of ore are developed parallel to the bedding and running along the main fissure. Such shoots often extend laterally for 25 to 30 feet or more from the main ore body. They are formed by replacement of the limestone with ore and gangue minerals and are clearly derived from the main vein. Such replacement bodies constitute a class of deposits so distinct from the fissure veins in their general character that they will be further described under the head of "Replacement deposits in limestone."

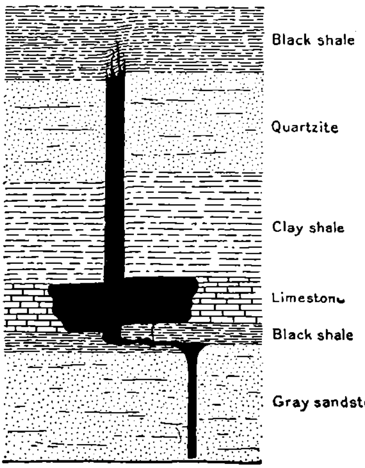

FIG. 2.—Type of silver-bearing vein modified by replacement and bedding fault, Ouray, Colo.

The silver veins of the Dexter Creek and Uncompahgre districts do not pass upward into the andesite breccia of the San Juan formation. Those in the Portland amphitheater, on the contrary, extend upward into that formation. The reason for this difference is that heavy black shales of the Mancos formation lie above the ore in the Dexter Creek country, but these are absent in the Portland amphitheater. The veins, being of but slight displacement, seem to have been lost in these shales. This is particularly true of the Bachelor and Wedge mines, where the ore and vein terminate abruptly and bluntly at the shale horizon.

The fissures have been frequently affected by bedding faults which invariably follow the shale beds. This faulting often, as in the Black Girl and Newsboy mines, shifted the upper portion of the vein as much as 30 feet away from its downward continuation. It seems to have occurred before mineralization, as the ore is usually unbroken and follows the shales in a thin band between the two separated portions of the fissure.

Ore and gangue minerals.—The ore minerals found in these silver veins are of three classes: (1) Original sulphides, (2) oxidation products, (3) secondary sulphide enrichment minerals.

The original sulphides occur in largest amount in the deeper portions of the mines, but in many cases, as in the Bachelor, extend upward to the top of the vein beneath the black shales. They are argentiferous galena and an antimonial sulphide of copper—locally called gray copper—which carries very high values in silver and is probably related to freibergite. Chalcopyrite and pyrite often occur intermingled with the other sulphides, and sphalerite is generally present, though often subordinate in amount. Extensive oxidation has taken place near the surface and native silver has been developed in large amount. Its position shows that it has in all cases been reduced during the process of oxidation.

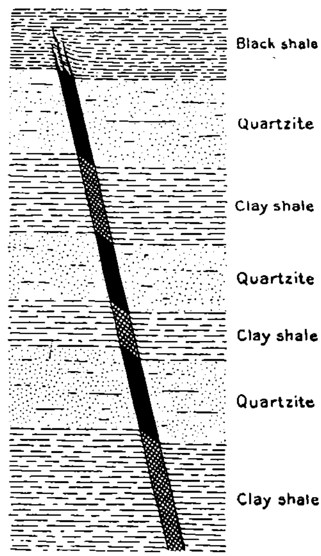

FIG. 3—Type of silver-bearing vein unmodified.

This is strikingly true in the Calliope mine, where a deep gulch cuts directly across the strike of the vein. The line that separates the native silver from the unaltered sulphide ore follows closely the topography, passing down beneath the gulch at a depth slightly less than that between it and the tops of the hills on either side. Thus in a profile of the vein the outcrop would show a deep U-shaped depression where intersected by the gulch, and the line between the two kinds of ore would show the same profile, slightly less accentuated. The same relations occur also in the Black Girl vein.

Bodies of ruby silver occur occasionally in the veins, but are rarely found at great depths below the surface. They are thought to be the result of secondary sulphide enrichment of the gray copper ore, between the zone of oxidation and the zone of unaltered sulphides.

The gangue minerals are quartz, barite, secondary silica, a pinkish carbonate, probably containing magnesium and manganese, and country rock. The secondary silica is usually light grayish in color and clearly secondary when examined microscopically. The barite is very abundant and occurs in places in such large amounts as to almost completely fill the vein. Among the silver veins the Bachelor vein is of the greatest economic importance, and is the most important silver producer in the district as well as the most productive of the fissure veins. It possesses so many features that can not readily be presented in a general discussion, and is in some respects so peculiar that an account of the silver veins would hardly be complete without a detailed description of this mine. The mine has been described in considerable detail by Dr. F. L. Ransome, of the United States Geological Survey, in a paper entitled "A clastic dike and its associated ore deposit near Ouray, Colo."[a] The observations upon which the accompanying description is based were the result of an extended personal examination by the writer, covering a considerable period of time, and were independent of Doctor Ransome's work.

The Bachelor mine.—The Bachelor vein has been opened in three places: (1) At the Bachelor tunnel in Dexter Creek, (2) at the Wedge shaft on Gold Hill, (3) at the Neodesha mine, at the base of the cliff in Uncompahgre Canyon. The main openings are those in Dexter Creek. A tunnel here driven southward into the hill intersects the vein at a distance of 720 feet. The country rocks through which the vein passes are sediments of the Mancos and Dakota Cretaceous and the McElmo series of the Jurassic. (See columnar section, fig. 1, p. 56.) Beginning with the highest level of the mine, they consist of (1) a series of very fine black shales, in places highly bituminous and often containing thin beds of blackish sandstone; (2) layers of quartzite varying from 2 to 30 feet in thickness, separated from one another by varying intervals of black and clay shales. The overlying black shales belong to the Mancos group and the upper quartzites and the black shale layers in them belong to the Dakota group. The clay shales and other interbedded rocks belong to the McElmo series. The latter shales are usually greenish in color, and at times nearly white, but are so much altered by the action of near-by eruptive rocks that they break with conchoidal fracture into large, angular masses. Weathering will sometimes disintegrate them so that they do not show much difference from ordinary greenish shale unaffected by metamorphism, but in many cases they retain their porcelain-like character even after prolonged exposure.

The black shales which occur in the upper levels of the mine are repeated at various depths, but in thinner layers, and finally give way entirely to the greenish variety.

Prior to the formation of the ore body the fissures were filled with a peculiar material, now consolidated and locally termed a "dike." It consists of a dense, homogeneous rock containing an immense number of angular fragments of black shale and other country rock,

[a] Trans. Am. Inst. Min. Eng., vol. 30, 1901, pp. 227-236.

with a fine-grained greenish groundmass closely resembling an eruptive rock. This is a consolidated friction breccia formed in the fissure. A later opening of the fissure furnished the cavities in which the ore was deposited.

This breccia is usually 3 or 4 feet wide, but varies greatly in width and often makes out in excessively small stringers into the wall rock, sometimes showing compact stringers only one-sixteenth of an inch in width which are yet perfectly solid and exhibit all of the clastic characters of the wider occurrences. It is formed so largely of the clayey and aluminous material that result from the comminution of the shales and limestones which make up the larger part of the country rocks of the McElmo group that it may originally have had the correct composition for a natural hydraulic cement. The seepage of hot mineralizing waters into the fissure would have supplied the necessary moisture, so that the consolidation was perhaps accomplished more by virtue of the chemical composition of the material than by a high degree of lateral compression, as suggested by Ransome.

From the Bachelor tunnel the vein has been opened for more than 1,000 feet to the east, when it becomes barren, and to the west through the workings of the Wedge and Neodesha mines into Uncompahgre Canyon. At the Wedge shaft, about midway of its course, it divides, both branches passing across Gold Hill and emerging in the cliffs which form the east bank of the Uncompahgre River. The two branches are separated by an interval of about 200 feet in this outcrop. The northern branch is worked by the Neodesha mine and the southern presumably by the Pony Express, although no connection has yet been made. The eastern portion of the vein is vertical, and likewise that portion of it operated by the Neodesha mine, but the branch that extends into the Pony Express mine is reported to have a slight dip to the south. The trend of the vein before its division is N. 83° E., or very nearly east and west. In this respect it follows very closely all the other fissures which outcrop in the region about the Uncompahgre River and Dexter Creek.

The fissure, as well as the ore deposited in it, was formed subsequent to the solidification of the breccia or so-called "dike," as it breaks across from one side of it to the other or is entirely included within it. A faulting on the vein of about 7 feet may be observed, by which the south side has been lowered. This faulting is observable only along certain portions of the vein. It must have been followed by other lateral movements before the deposition of the ore, as the slickensides on the harder rocks which form the walls are invariably horizontal.

Subsequent to this movement bedding faults occurred which have shifted the upper portion of the breccia to the north. These occurred before the vein formation, as there is no evidence that the ore was broken. The ore follows the bedding planes of the strata along the fault connecting with that in both portions of the dislocated fissure.

The ore occupies mainly what must have been open spaces, as it frequently shows the parallel banding known as crustification. It also enters the breccia material along cracks and fissures and seems to have replaced it in some measure, although much action of this kind has been prevented by the highly insoluble aluminous nature of the material.

The ore is a high-grade silver ore carrying from $20 to $75 per ton. Pockets of ruby silver (said to be pyrargyrite) were discovered shortly after the writer's visit, and are reported to have contained 15,000 ounces per ton in silver. Gold is either absent or present in very small quantities.

The ore minerals are argentiferous galena and an argentiferous antimonial sulphide of copper locally called "gray copper," but probably closely related to freibergite. It is either scattered irregularly through the galena or occurs alone in irregular patches in a pinkish white carbonate which presumably carries a considerable amount of manganese.

The gangue minerals are quartz, barite, and country rock, angular fragments of which are frequently found in the eastern portion of the mine. The ore contains increasingly large quantities of barite as one passes westward from the tunnel toward the Wedge mine, where some parts of the vein are no more than a solid tabular mass of massive white barite about 3 feet in width. A little of the manganese-bearing carbonate occurs and is usually associated with the gray copper. It is not a prominent gangue mineral. The Bachelor mine alone, exclusive of the Wedge, has produced between $1,000,000 and $2,000,000, although unfavorable conditions have materially lowered the profits derived from its exploitation. If the Wedge, Neodesha, and Pony Express were included in the estimate, the total production would be very much increased. Exact figures on these properties have not yet been obtained.

The vein does not outcrop at the surface, but owing to the very slight faulting involved in the formation of the fissure it is lost in a mere distortion of the black shales which form its cap. These show an irregular twisting and distortion in the near neighborhood of the vein, but no fissure is observable and not even the dike itself can be traced upward into them. They have acted essentially as a plastic medium, and even in the often repeated differential movements—the formation of the breccia, the later lateral, vertical, and horizontal movement—they have not been sensibly ruptured. The black shale fragments in the clastic dike are generally arranged with their flat surfaces parallel to the walls of the vein. They were probably derived in part from the overlying black shale and partly from the numerous black-shale beds which occur just above the La Plata sandstone at depths not yet reached by the mine workings.

The high-grade ore is shipped to the smelters and gives no trouble other than that involved in a careful sorting.

For the treatment of the lean ore a small mill has been erected at the mine. It is fitted with jigs, Bartlett tables, slime-settling tanks, and canvas slime tables. Great difficulty has been experienced here, as in the other silver veins, in saving the silver values contained in the gray copper. This mineral is converted into slime, even with the most careful crushing, and floats on the top of the water so that a large part of it is lost. The canvas tables save a little, and are a very commendable feature of this mill, but even by their aid a considerable loss of silver values can not be avoided.

Veins in Portland amphitheater.—A group of silver-bearing fissure veins of a very different character is found at the head of the Portland amphitheater, in the almost inaccessible cliffs which surround the glaciated valley. They exhibit many different strikes and dips and pass from the limestones and shales into the andesite breccias of the San Juan formation.

They contain both silver and gold, in about equal proportions. The silver usually preponderates, but the reverse is occasionally true. The gangue is usually white quartz and rhodochrosite, or some carbonate intermediate between that and calcite. In many of the veins the gangue is entirely quartz. They vary in width from a few inches to 4 feet, and are apt to pinch out within short distances. In the sediments below the andesite breccia they often form lateral enrichments in the limestone, although none of those noted were extensive. Ore minerals occur in very small quantities in the gangue. Those observed are galena and gray copper. Stephanite and other rich silver minerals have been reported from these veins. The ore deposits of this district are as yet of merely prospective value.

Commercial considerations.—The ore from the silver mines ranges in value from $30 to $800 per ton. Very high values have been obtained from the oxidized portions where the native silver is in large amount, and the occasional bonanzas of ruby silver found have also yielded exceptionally high returns. In the majority of cases, however, values of from 60 to 200 ounces per ton may be regarded as an average grade of shipping ore. The rich ore is usually shipped by rail to smelting centers and there smelted, and where lean ore is concentrated, as in the case of the Bachelor mine, the concentrates are shipped in like manner. A local smelter at Ouray was in operation at the time the district was visited, and treated the lower-grade material, but it has not yet received from the mine owners the encouragement necessary for profitable operation.

GOLD-BEARING VEINS.

General character.—The gold-bearing veins are very subordinate to the silver mines in their economic importance. They are developed along the course of the Uncompahgre River between the mouth of Dexter Creek and the town of Ouray, and outcrop in the steep cliffs on either side of the canyon.

The country rocks which form these cliffs are, from below upward, (1) the red sandstones, conglomerates, and sandy shales of the Hermosa and Cutler formations of the Carboniferous; (2) the red shales and sandstones of the Dolores formation of the Triassic lying unconformably above at a slightly different angle; (3) the white and gray sandstone of the La Plata Jurassic; (4) the alternating shales, sandstones, and limestones of the McElmo Cretaceous, and (5) the Dakota quartzite and black Mancos shales of the Cretaceous.

The inner and steeper walls of the canyon are formed of rocks of the lower part of this column; that is, the red beds below the La Plata sandstone.

Irregular intrusions of quartz-bearing monzonite-porphyry cut diagonally across the sedimentary series, some of them vertical, others with marked dip toward the south.

On the west side of the river irregular sheets extend outward from these dikes and pass between the sedimentary beds. When small the dikes weather so much more readily than the sandstones that they may be found only at the bottom of deep clefts in the cliffs, although the larger ones often lie nearly flush with the canyon walls. The veins occur either wholly within the dikes or are closely associated with them. They comprise a group of highly inclined sheeted zones, made up of a series of irregular and closely spaced fissures, usually of small throw, and often aggregating 5 or 6 feet in width. The ore consists of gold-bearing pyrite and chalcopyrite in a gangue of country rock and clay—the clay having been derived partly from intercalated shale beds and partly from porphyry. The filling of open spaces seems to have been subordinate to the replacement of the wall rock, which has ocurred to a considerable extent. The ore occurs in small shoots in the vein, and is so irregular in its distribution that the veins are mined with some difficulty.

The veins are later than the porphyry, as they may be seen distinctly faulting that rock. Both the dikes and the associated veins strike approximately east and west, parallel to the majority of silver-bearing fissures. The dip is sometimes vertical, but in other cases is as shallow as 50°. Nearly all of the mine workings are situated high above the bottom of the canyon, in the steep faces of the cliffs, and the ore is brought down by means of wire-rope tramways, all of which are of antiquated model and now in disuse. Owing to their prominent position these mines were among the first to be operated in the district. They have never been very productive.

The values are largely in gold, although a little silver is generally present. Exact and reliable data on the values are difficult to obtain, but the gold values, when present, are undoubtedly high. The average yield is probably between 2 and 3 ounces gold per ton, making a high-grade ore of $50. In some instances, as in the Grand View, the ore occasionally runs up to 8 ounces, and in a few cases as much as 30 ounces is reported.

The mines are now either idle or operated under lease. They were never very profitable, presumably because the irregularity of the veins and their small size rendered their working uncertain, and the methods of treatment were not adapted to the ore.

REPLACEMENT DEPOSITS IN QUARTZITE.

Character and genesis.—The ore bodies that have been grouped under the class "replacement deposits in quartzite" form a series of gold ores, with very subordinate silver, which occur in irregular masses in strata of massive quartzite. They are termed "replacement ores" because they have been formed, not by the filling of open spaces existing previous to their deposition, but by a chemical interchange of ore material for original country rock. The mineralizing waters by which they were produced have been both the solvents of the country rock and the agents which have effected the ore deposition. In some cases the solvent action of these waters has been greater than their depositing action, so that cavities exactly similar to solution caves in limestone have been produced, and yet no ore has been deposited.

Inclosing rocks.—These ores are found in a number of the quartzites which outcrop on either side of the Uncompahgre Canyon. The uppermost—the one in which the majority of occurrences have been found—is the Dakota quartzite of the Cretaceous. The others lie at varying intervals below this formation and constitute a portion of the McElmo formation of the Jurassic, but there are many similar beds, and they vary so much from place to place that they can not be correlated with one another. It is a prevailing impression in the district that there are two ore-bearing quartzites, an "upper" and a "lower," which are readily traceable for great distances. This impression is founded on error. The Dakota quartzite alone is a prominent and constant stratum. Below this are many other quartzite beds, and it can not be proved that any two of the ore bodies in them occur in the same bed. This may readily be understood from the geological section, fig. 1 (p. 56), although even here it has not been possible to represent all of the thinner quartzite beds.

The Dakota quartzite, in which the majority of occurrences are found, is a dense white quartzite, varying from 25 to 100 feet in thickness and containing intercalated beds of shale, usually at the center, but not constant either in position or amount. In the upper portions it becomes finer grained, the bedding planes are closer together, fine shaly partings are observable, and it is slightly blackish, owing to included carbonaceous material. Above it is a series of black shales extremely thin bedded, and so highly charged with coaly matter as to strongly resemble those which are usually associated with coal. It is underlain by the greenish shales of the McElmo, and, owing to the comparative ease with which these are disintegrated and worn away, it usually forms an abrupt cliff. It outcrops on either side of the Uncompahgre Canyon, about 1,800 feet above the bottom of the valley, and follows the indentations made by the steep gulches on either side.

Distribution.—The ores are widely distributed along the outcrop of the formation. Among the mines and prospects are the American Nettie mine, the Valley View, Rock of Ages, and Stenographer. In form, mode of occurrence, and contained values all of these deposits are precisely similar, differing only in unimportant details. In but one mine, however, have the ore bodies yet proved sufficiently extensive to be of commercial value. This is the American Nettie mine. The general description of this class of ores would therefore best be accomplished by a description of this mine.

The American Nettie mine.—The openings of this mine are located near the lower portion of the steep cliff which forms the top of the canyon wall on the east side of the Uncompahgre, 1,800 feet above the bottom of the valley. The buildings which have been erected near the entrance are about 100 feet above the base of the perpendicular bluff, and so little support does the rock face afford that they are partly kept in place by wooden brackets, and except for their modern construction might well pass for cliff dwellings. The position occupied by the country rocks may most readily be understood from fig. 4. Above the mine is an immense sheet of quartz-monzonite-porphyry, aggregating about 500 feet in thickness. Below this are 40 to 50 feet of fine black shales, very heavily charged with carbonaceous matter and containing a few thin beds of black sandstone.

Conformably below these shales is the ore-bearing quartzite, a massive white rock, fine grained and blackish at the top and white and more coarse grained below. It is separated into two portions somewhat below the middle by a thin parting of light-colored shales.

Below this come the variegated shaly series of the McElmo formation. The series dips into the hill at a low angle of from 5 to 10° slightly to the east of north. The dip is much steeper locally. The rocks are cut by a number of dikes of dark-colored, fine-grained porphyry, probably connected with the monzonite sill above, and ore is sometimes found beside them, although more frequently widely separated.

A heavy fault fissure filled with a consolidated breccia similar to that observed in the Bachelor mine runs east and is followed by the

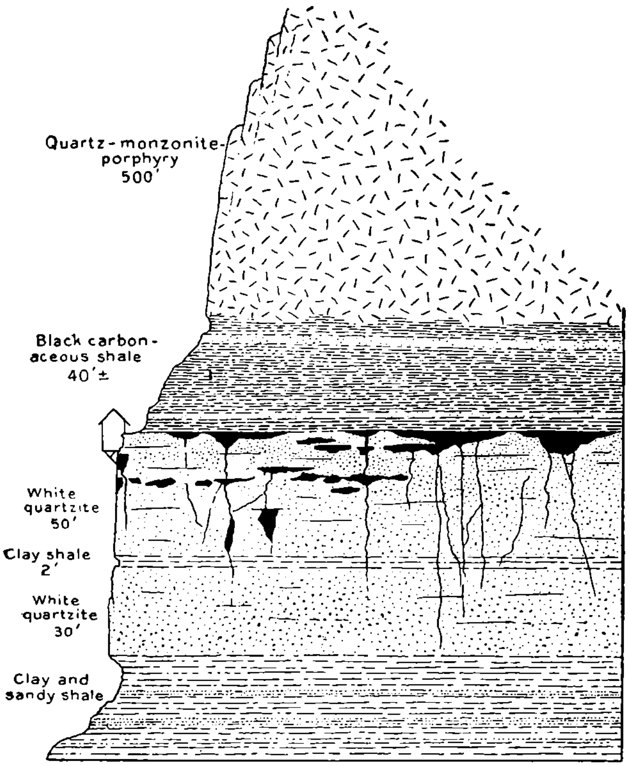

FIG. 4.—East-west section of the rocks and diagram of the ore bodies in the American Nettie mine, Ouray, Colo.

main tunnel of the mine. It is sometimes simply a fault fissure with no filling material in it. The breccia is termed a "dike," but is not correctly so considered. It is the impression of the miners that the ore emanates from this fault breccia and makes out from it into the country rock, but an examination of the mine and a glance at the mine map, as well as a comparison with a large number of precisely similar occurrences in quartzite, where no fault breccia and no porphyry dikes are present, shows that there is no connection between the two.

The quartzite is seamed by irregular branching fissures, generally nearly vertical in position, sometimes extremely narrow and at others as much as 2 inches or even 6 inches in width. The displacement along these is very slight. The maximum observed was 10 inches. These are filled with white crystalline quartz and almost always show a perfect comb structure. The wider portions show open vugs lined with quartz crystals. The fissures intersect one another in two prevailing directions, though many local variations and irregularities occur. Usually they pass upward into the shales, where they are generally lost, but on Cascade Creek they pass up into the porphyry sheet, which rests directly on the quartzite. They are therefore later than the porphyry. A few of the fissures are wide enough to be termed "fissure veins," and carry ore minerals in sufficient quantity to be mined as such, but these are uncommon.

Along the course of the fissures ore bodies or shoots extend outward for sometimes as much as 20 feet. In the most typical cases these shoots are irregular bodies, ranging from a few inches to 15 feet in thickness, longer in the direction of the fissure than across it, and with their larger dimensions in a horizontal position. They are often exceedingly irregular, wandering through the quartzite in all directions, but generally being concentrated along a definite bed, usually just under a very fine shale band, which is sometimes so thin that it can be detected only when the rock is broken parallel to it. In the vicinity of the supplying fissures the shoots are at times pear-shaped, with their longer axes in a vertical position and with the fissure passing down through the small end, but away from the fissures they are flat and have their longer axes parallel to the planes of stratification of the quartzite, the ore solutions having seemingly passed laterally along the bedding. The largest shoots lie immediately beneath the black shale at the top of the quartzite. Several tiers of shoots sometimes occur along a single fissure.

The ore in these masses is located chiefly near the supplying fissures, where it forms a solid mass, but outward along the strata it but partially fills open cavities, often merely lining the interior of the open space. On the extreme outer limit of the shoots nothing but empty cavities lined with quartz crystals are to be seen. These contain no ore whatever, and frequently extend for 30 feet beyond the ore shoot. It is a saying among the miners that as soon as one finds crystals in the quartzite there will be no more ore. These empty cavities have all the characteristics of cavities produced by solution in limestone and can in no wise be distinguished from them except for the lithological character of the parent rock. There can be no question that they were produced by solution.

The ore was first discovered on the face of the quartzite cliff and occurred in irregular open cavities, which were exposed by the breaking away of the outer portions of the rock. Here, and for a long distance into the side of the hill, it consisted of a brownish iron-stained material resembling limonite and containing free gold, either too fine for observation or in the form of wire gold. It did not entirely fill the cavities, but was concentrated in the lower portions of the open spaces. The gold was crystalline and was almost invariably richer at the bottom of the mass. The present foreman reports only wire gold, but it is stated that large nuggets were found, some of them of great size. The brown material is undoubtedly limonite in great part, but in all probability further examination will show that it contains a large percentage of ferric sulphate. Mixed with the oxidized ore are found siderite, barite, kaolin, and sulphur.

Often a lining of honeycombed quartz is observable, as much as 4 or 5 inches in thickness, either lining the cavity or completely filling it. The cell-like spaces in this quartz are sometimes irregular, but often have the form of pyrite crystals, showing clearly that they are caused by the oxidation and removal of former masses and crystals of iron sulphide. Much of the oxidized ore was shoveled directly from the cavities into ore sacks and shipped without further sorting. More careful sorting is now necessary.

On penetrating farther into the hill the ore gradually changes to pyrite. This is either massive, with occasional cavities into which complete crystals of pyrite project, or is composed of crystalline grains of pyrite embedded in a matrix of gray and white secondary quartz. Large admixtures of chalcopyrite and galena and other sulphides are found, among which are sphalerite, telluride of gold and silver (perhaps hessite, found usually in the Jonathan mine), molybdenite, and gray copper (probably argentiferous tetrahedrite).

Barite is also of very frequent occurrence in the sulphide ore, and fibrous bands of gypsum were seen between the ore and the overlying black shales.

The sulphide ore is more common directly beneath the black shales, as are also the more extensive ore bodies.

The contact between the ore and the quartzite is usually very sharp and shows the irregular and undulating surface so often seen in replacement deposits.

From these facts it is not difficult to form a connected history of the mine.

First occurred the intrusion of the porphyry, producing the dikes and sheets. After this rock had cooled a shattering took place, which produced fissures in the massive quartzite—fissures which were usually lost in the fissile black shales above, but in some instances extended into the porphyry itself.

Hot waters, presumably alkaline, charged with metallic sulphides, then ascended through the fissures until their upward progress was barred by overlying bands of impervious shales, or until they found some porous layer along which it was possible for them to circulate in a lateral direction. The alkaline waters dissolved the quartzite, depositing at the same time their burden of metallic sulphides by molecular interchange. With the sulphides much of the dissolved quartzite was redeposited as a matrix between the grains. The alkaline waters being now deprived of their metallic contents, still continued to flow, and penetrating beyond the deposit which they had formed, dissolved out immense empty cavities in the quartzite. As a final phase of their activity some of the silica was deposited as crystalline druses of quartz on the walls.

A period of rest then ensued and erosion carved the Uncompahgre Valley, leaving the quartzite in its present elevated position. Meteoric waters charged with oxygen percolated through the outer portion of the rocks near the brow of the hill and oxidized the outer portions of sulphides to ferric sulphates. These ferric sulphates attacked the gold and carried it down in solution to the unoxidized sulphide in the lower portions of the ore masses and were then reduced to ferrous compounds. As ferrous salts have no solvent effect on gold, it was precipitated in the free condition in the lower portions of the deposits.

The value of the ores is almost entirely in gold. Silver is subordinate, although as much as 120 ounces is sometimes found, especially when gray copper and galena occur mingled with pyrite. The values are unusually high, some of the ore yielding as high as 30 ounces in gold. At the time the mine was visited the ore would average when sorted about $60 per ton. Owing to high freight and smelter charges $35 per ton is considered the lower limit for sulphides. In the early days of mining the values were uniformly higher than at present.

Between 1889 and January, 1905, the mine has produced 23,641,316 pounds of ore, valued at $1,464,923.35. This would give an average value of $123.12 per ton, or, roughly, 6 ounces of gold per ton of sorted rock.

This agrees very closely with the average values obtained from the Bright Diamond quartzite ores and the most important of the other similar though smaller deposits found along the outcrop of the Dakota quartzite.

Much of the ore is shipped direct. It is transported in a wire-rope tramway from the mouth of the mine across the Uncompahgre Canyon to the ore bins along the side of the railroad. A mill adjoining the ore bins has been used to concentrate the leaner sulphides. It is not in operation at the present time.

The tramway is a striking feature of the mine. It has a total length of 4,100 feet and a span across the canyon of 1,800 feet. The highest point of this span is 900 feet above the bottom of the valley.

Except in point of production the other deposits in quartzite exactly resemble those of the American Nettie mine. From a lower quartzite in the Bright Diamond mine high-grade ore to the value of $32,000 was obtained from small shoots. It is probable that further exploration may reveal other important bodies of ore similar to those of the American Nettie.

REPLACEMENT DEPOSITS IN LIMESTONE.

The replacement deposits in limestone are a series of broad, flat ore-bodies which are found in beds of limestone either adjoining fissure veins or associated with numerous small vertical (or nearly vertical) fissures which intersect the stratified rocks. They have been formed by the removal of limestone and the simultaneous substitution of ore minerals for it by mineralizing waters which here gained access to the more soluble rock by means of the fissures. They are more regular than the replacements of quartzite just described, and much more extensive, a few of them being fully 300 feet wide. Gold predominates in some of them, silver in others, but the ores which they furnish are uniformly of lower grade than their prototypes in quartzite. The silver-bearing deposits are associated with the silver-bearing fissure veins already described, and are found only where these veins penetrate strata of soluble limestone. They may be most conveniently divided and subdivided according to the prevailing gangue minerals which are present, as:

1. Baritic siliceous ores (silver bearing).
2. Magnetite-pyrite ores (gold bearing).

All of the ores of both groups differ a good deal from one another, so that collective description will give only a most general idea of their character, but since space is not available for individual discussion, the reader is referred for a full treatment to the paper which will appear a little later.

BARITIC SILICEOUS ORES.

The baritic siliceous ores are lateral enrichments of silver veins or flat masses associated with small vertical fissures. The most important are in the Newsboy mine, the Pony Express mine, and the Mineral Farm mine. In the Newsboy and Pony Express a fissure elsewhere productive as a vein is connected with the deposits; in the Mineral Farm no important vertical fissure veins are found, and it is only by close observation that the knife-edge fissures may be noticed.

At the Newsboy mine the limestone which carries the ore is bluish-black in color, and is overlain by a clay shale and sandstone and underlain by thin-bedded black shales and a heavy gray sandstone.

It is about 5 to 7 feet in total thickness. The shoots of ore here are flat masses and generally fill the entire space between roof and floor. Laterally the valuable portions of the ore material extend from 5 to 30 feet from the fissure, although the silicification goes much farther. The shoots run nearly east and west, parallel to the direction of the fissure, for distances often of 300 feet or more. Most of them lie north of the vein. The ore-bearing limestone bed is at the base of the McElmo formation of the Jurassic, immediately above the La Plata sandstone. Its position may be seen in the Gold Hill section shown in fig. 1 (p. 56).

The same limestone bed extends along the canyon to the Pony Express mine, where it is about 30 feet in thickness, and is overlain by shales. The shoots in this mine are much larger and thicker. They extend into the hill for 1,000 feet along the course of the vein, and are frequently 100 feet wide. The stopes now form great chambers, separated by irregular pillars of limestone or ore, and are very suggestive of a coal mine. The ore sometimes occupies the entire 30 feet of rock, but is more usually 8 to 10 feet thick. It is richer immediately beneath the shale roof, but is not always in contact with it. The limestone where unmineralized is much brecciated and full of cavities, which have probably been more important in determining the mineralization of the rock than the overlying shales.

In the Mineral Farm mine the limestone belongs to the Ouray epoch of the Devonian. The ore shoots are here from 8 to 10 feet in thickness and 6 to 50 feet in width. The workings follow one shoot for a distance of perhaps 600 feet. This shoot has a strike of N. 63° E. The narrow fissures with which the ores are associated may be often seen in the roof of the ore, but are not noticeable without careful examination.

The ores.—The ores of the limestone replacement bodies are bluish-gray or buff colored, according to the color of the original limestone. They consist of fine-grained silica heavily charged with crystalline barite and containing argentiferous gray copper (freibergite), galena, and sometimes chalcopyrite. The metallic minerals are either disseminated in small grains through the silica and barite—especially the gray copper—or are concentrated in bunches of irregular form and character that are distributed at uncertain intervals through the siliceous gangue rock.

Irregular cavities lined with druses of quartz-crystals form a prominent feature of the ore. In the nonoxidized portions silver chloride and secondary black copper sulphide may frequently be observed. The silica extends to great distances beyond the metallic replacements and continues at times for the entire visible outcrop of the limestone bed. In one mine, however, the Pony Express, the siliceous replacement is slight, and the gangue of the ore often consists of immense masses of barite in otherwise unaltered limestone.

In the massive sulphide bodies the gray copper can be readily seen, but in the usual run of ore it is often disseminated through the gangue in grains so small as to be hardly perceptible to the éye.

The larger structures of the country rock, such as brecciation, bedding planes, layers of shale, etc., always extend uninterruptedly into the ore, except where the mineralization—as in the case of the bodies of sulphides—has obliterated them.

The values are mainly in silver. The gold occasionally rises to $4 or $5 per ton, but is generally so low as to be negligible. In the largest masses, such as the Pony Express and Mineral Farm mines, the values in the ore are extremely irregular and are uniformly low. The ore from the Pony Express is reported to average as a whole about $30 per ton, although much higher values are encountered.

In the Mineral Farm mine the average is so low and the richer portions of the ore are so irregularly distributed that the deposit has never yet paid for exploitation.

In the Newsboy the values are uniformly higher, and frequently carload lots will carry as much as 100 ounces of silver.

It is difficult to form a correct estimate of the production of this class of ores, as they have generally been worked intermittently under lease.

MAGNETITE-PYRITE ORES.

The magnetite-pyrite ores are of greater scientific than commercial interest. They have been found at only one locality—in the Bright Diamond and Iron Clad mines, on the east wall of the Uncompahgre Canyon, about 600 feet below the American Nettie mine. The ore occurs in a fine-grained, dark-blue limestone, apparently quite pure and, where unmineralized, without any evidence of alteration. It is about 10 or 15 feet thick and is overlain by green shales that have been altered by the monzonite-porphyry intrusions into a green porcelain-like argillite heavily charged with epidote and other metamorphic minerals, and of an exceedingly dense, impervious character. The ore occurs in broad, flat shoots, conformable to the stratification and of a uniform thickness of about 6 feet. It lies in close contact with the shale roof. The strata are nearly horizontal but show local dips, and are intersected by a series of widely spaced fractures which run in a nearly east-west direction and frequently fault the strata as much as 10 feet, with downthrows now to the north and now to the south. The ore outcrops for a long distance in the cliff near the mines. In the Bright Diamond mine a porphyry dike 10 to 30 feet in width occurs north of the ore, and the heavy monzonite-porphyry sheet above the American Nettie mine lies some 700 feet above. The ore is not in contact with the dike, but is some distance north of it.

All the rocks except the unmineralized portions of the blue limestones have been profoundly altered by the intrusions, so that they are now very porcelainlike in their character. The shoots where explored are about 300 feet wide, and have been followed into the hill in one place for 400 feet. Wherever the workings emerge from the ore they pass into the unaltered blue limestone, which seems to be singularly free from the contact metamorphism which has altered the more argillaceous rocks of the series.

The ore lies in close contact with the shale roof. It is an intimate mixture of a dense, granular magnetite and pyrite, with a little chalcopyrite, interwoven in the most complicated manner with epidote, actinolite, garnet, quartz, and calcite. In the Bright Diamond mine a large fault-fissure vein lies on the north side of the ore, between it and the monzonite-porphyry dike, and it was in the prospecting work on this fissure that the ores were first discovered.

The ore carries $10 to $14 in gold and is of nearly uniform value, but is concentrated with difficulty and has not yet proved profitable. It is not improbable that magnetic separation may be of material assistance in its exploitation.

So much interest has centered of late on deposits of magnetite and pyrite intergrown with metamorphic minerals that a brief statement of the conclusions which may be drawn from these peculiar deposits seems warranted. Magnetite-pyrite ores of this kind are usually believed to have been produced by emanations from igneous intrusives, which have not only altered the sedimentary rocks in their vicinity but have deposited ore minerals among the metamorphic minerals that were produced from the substance of the stratified rocks.

In this instance there are facts which suggest some modification of this view:

1. The metamorphic minerals in the blue limestone terminate abruptly at the sides of the ore shoots; that is, they are coextensive with the ore. When the ore minerals are no longer found the metamorphic minerals also cease and only the inclosing blue limestone is found.

2. Unaltered blue limestone intervenes between the ore and the porphyry dike that forms the nearest intrusion observed.

3. The blue limestone, at a distance from the fissures, does not contain metamorphic minerals, although the shale beds do contain them.

To the writer it would seem that these facts lead to the following conclusions:

1. That the blue limestone, owing to its purity, was not altered by the porphyry intrusion which affected the more impure shales.

2. That the metamorphic minerals were formed by the same solutions as the ore minerals, and these solutions reached the limestone by means of the fissures.

3. That ore minerals were deposited by circulating waters subsequent to the porphyry intrusion and were not derived from them.

4. That the circulating waters supplied not only the ore minerals but also the silica and other ingredients necessary to produce metamorphic minerals in a limestone otherwise too pure to be affected by the contact with igneous rock.

5. That both ore and metamorphic minerals were produced by mineralizing waters and are not due to contact metamorphism.

Too little space is available for a full discussion of this question, but these conclusions are here briefly stated preparatory to a fuller discussion in a forthcoming paper.

GEOLOGIC AGE OF THE ORE DEPOSITS.

In all cases where the geologic age of the ore deposits can be ascertained with measurable accuracy the evidence points to a single period of mineralization for all of the deposits discussed. They are of very recent formation; in all cases later than the latest of the igneous rocks, as the fractures from which they have been formed frequently extend into the eruptives and some of the veins lie wholly within the dikes.

These eruptives were formed later than the andesites of the San Juan formation, often cutting the latter and spreading out beneath it in the form of horizontal sills. The eruptives are therefore later than the andesite breccia, which is of Eocene age. We can then conclude that the ores were formed during or later than the Miocene epoch.

SUPPOSED GOLD-BEARING CONGLOMERATES.

Underlying the San Juan andesite breccia, which forms the cap rock of the hills in the Ouray quadrangle, and rests unconformably on the stratified rocks below, is a conglomerate known as the Telluride conglomerate. This is not always present, but occurs in large development in the vicinity of Cobbs Gulch of Cow Creek. It has been prospected recently for gold, and an experimental stamp mill has been erected near the mouth of Cobbs Gulch to test its value. The possible occurrence of placer gold in this rock forms a problem of unusual scientific interest on account of the bearing it has on the geological period during which the ore deposits of the region were formed.

If the conglomerates carry placer gold, there must have been ore bodies containing free gold in existence before their deposition. It can be proved that the known ore bodies were formed during or later than the close of the Eocene epoch. The conglomerates, however, were formed in the early Eocene and were clearly in existence before any of the known gold ores were deposited. The source of the placer gold therefore—in case it were proved to be present—must be sought in deposits belonging to an earlier geological period—deposits for whose existence there is as yet no evidence.

Gold may, of course, have been deposited in these gravels long after they were consolidated into rock, but in that case the character of the gold present would show clearly that it was not deposited by placer action.

With these facts in view it seemed necessary to determine two points: (1) Whether the gravels contained appreciable quantities of gold; (2) the physical condition of the gold, if present. For this purpose a series of nine carefully selected samples were taken and tested for gold. The samples were taken from portions of the rock most favorable for the occurrence of gold, and from widely separated localities. Some samples were collected from places recommended as especially rich; others at points where no prospecting had been done.

The samples were very carefully assayed and four of them panned, the concentrates being tested microscopically. The results are given below:

Analyses of Telluride conglomerate, Ouray district, Colorado.

No.	Gold.	Value.	Panning test.
	Ounces.	*Cents.*	
1	0.005	10	Small grains of magnetite sand, but no colors.
2	.005	10	Do.
3	.005	10	Do.
4	.005	10	Do.
5	.005	10	Do.
6	.005	10	Do.
7	.005	10	Do.
8	.005	10	Do.
9	.005	10	Do.
Average	.005	10	

While these determinations are by no means the result of an exhaustive sampling, they clearly show that if gold be present in this rock in appreciable quantities it must be contained in those portions of the deposit from which no samples were taken. A content of 10 cents per ton in gold is so small that it can hardly be determined even by the most careful methods of assay, and since almost any rock in a mineralized region in the neighborhood of ore deposits may contain values equal to or slightly in excess of this amount the inference seems justifiable that no gold-bearing lodes existed prior to the deposition of the conglomerate. The purely negative results shown by these samples seem also to afford to those interested in mining in this region a strong reason for the exercise of extreme caution in the exploitation of these Eocene gravels.

ORE DEPOSITS IN THE VICINITY OF LAKE CITY, COLO.

By J. D. Irving.

INTRODUCTION.

The town of Lake City, which has a population of 700, is situated in the San Juan Mountains in the southwestern portion of Colorado, at the junction of Lake Fork, a tributary of Gunnison River, and Henson Creek.

The region in which the mining developments have been carried on is extremely rugged and precipitous, and cliffs in many places rise 1,000 feet above the level of the streams. The mountain peaks in the vicinity are among the highest summits in the State of Colorado, Uncompahgre Peak, 9 miles to the northwest of Lake City having an altitude of 14,306 feet.

The ore deposits described in this paper are located along the courses of Lake Fork and Henson Creek. They extend along Lake Fork to a point 5 miles south of the town, and along Henson Creek westward through Henson and Capitol City for a distance of 10 miles. Very little prospecting has been done at any considerable distance from the streams, and practically all of the active mining has been carried on along the comparatively accessible bluffs adjacent to them.

GEOLOGY.

All the rocks exposed in the mining region are of igneous origin. They may be divided into the following fairly distinct groups:

1. Volcanic: Rhyolitic flow breccias, tuffs, and agglomerates; andesitic tuffs and agglomerates.
2. Intrusive: Intrusive andesite-porphyries; intrusive pyroxene andesites; intrusive diabase; intrusive latite.

The exact sequence of these various rock types has not yet been determined in detail. It is possible, however, to give a brief preliminary outline of the more prominent geologic features. The hills which form the sides of the canyon of Henson Creek are composed largely of rhyolite flow breccias. These frequently form perpendicular cliffs which rise 500 or 600 feet above the stream bed. They are characterized by a prominent banding, which often imparts to the rock a strong resemblance to sedimentary material, but the bands are undulating and their continuity is broken by innumerable inclusions, either lenticular—owing to the action of flow—or sharply angular and scattered without regularity through the rock. These inclusions are either broken fragments of the rhyolite itself or masses of different rocks which have been caught up during the movement of the rock magma. They vary in size from merely microscopic pieces to 10 or 15 feet in diameter. In most cases their diameter does not exceed an inch. Into and through these rhyolite breccias intrusions of andesite-porphyry have forced their way and may now be seen either in great irregular masses, such as near the Red River mill, in irregular dikes which often show columnar structure, and in widely extended, nearly horizontal sills, which frequently break down and form abrupt cliffs. One of these can be seen in the vicinity of the mine workings in Yellowstone Gulch.

Irregular beds of volcanic tuff and agglomerate that belong to both the rhyolite and andesite groups are mingled with the rhyolite breccias in a confused manner. South of Lake City the geology is slightly different. While the flow-breccias extend in that direction to the limit of the mining region, they become subordinate in amount to the rhyolitic and andesitic tuffs which are very largely developed. The andesite-porphyries seem to be absent in this vicinity. The hill above the Golden Fleece mine is capped with a very thick sheet of latite, a pink porphyritic rock of very massive character. At the base of the cliffs formed by this rock alternating rhyolitic and andesitic tuffs form the canyon walls. A small dike of diabase or related rock is also found in the vicinity of the Golden Fleece mine.

Other eruptive rocks undoubtedly occur in the region, but they are not exposed in the vicinity of the mines. The entire rock series is traversed by faults, which in some cases involve considerable displacement. These faults are at some places heavily mineralized and at others are without any indications of alteration. Their age does not seem to be determinable with accuracy.

The geologic age of the volcanic rocks can not be determined from the exposures in the region under discussion, but the westward extension of some of them into the Ouray quadrangle furnishes evidence that they are probably of Eocene or post-Eocene age.

In the vicinity of Lake City landslides have brought great masses of apparently massive rock from higher levels into the bed of the canyon.

HISTORY.

The Lake City mining region is among the oldest mining camps in Colorado. It is not at present a heavy producer, but the mines which have supported the town in former years have been some of the most productive properties exploited during the earlier history of the State. The history of Lake City begins with the discovery of the Ute and Ulay mines on August 27, 1871. Among the mines which have been productive since that discovery the following may be regarded as the most important: Ute and Ulay,. Ocean Wave, Hidden Treasure, Golden Fleece, Black Crook, Lellie.

ORE DEPOSITS.

The ore deposits of the Lake City region may be grouped under the single head of fissure veins. They are capable of a further subdivision into (1) silver-bearing fissure veins, (2) gold-bearing fissure veins.

SILVER-BEARING FISSURE VEINS.

General features.—The series of veins which are described under this heading in most cases carry silver and lead. Gold is generally absent or very subordinate in amount. At a few mines considerable values in gold occur in certain parts of the ore, especially in the deeper portions of the mines, but these are exceptional. The Black Crook mine might be mentioned as one of them. The veins are contained in fissures in the country rock which have been filled with ore and gangue minerals. The fissures are frequently vertical or dip at a high angle, very few of them showing a dip less than 60°. One or two instances occur where the inclination is as little as 45°. The width of the fissures ranges from a few inches to upward of 10 feet and varies very much in different portions of the vein, pinches and swells being a characteristic feature. Generally a narrow portion of the vein alternates both vertically and horizontally with larger masses and there are formed irregular, tabular shoots of ore and gangue material, separated from one another by pinches in which the two walls of the fissure are frequently in contact. No prevailing direction of ore shoots can be observed. The irregularity in the width of the vein is undoubtedly caused by the deviations of the original fissure from a straight course before the displacement occurred. No distinct systems of fissures can be determined, as the strikes vary within wide limits even in those localities which contain the largest number of veins. Some of the veins correspond closely with the jointing of the country rock. Others are entirely at variance with it, showing that the vein formation has probably preceded the jointing.

In detail the fissures are usually of composite character, large masses of country rock being frequently included within the walls. In some cases the veins have almost a brecciated character. The hanging wall is frequently more irregular than the foot wall, for lateral fissures often intersect the vein on the hanging-wall side. In the Hidden Treasure and Ute mines the veins are singularly uniform in width and more nearly approximate the ideal type of fissure veins. The filling of gangue materials and ore extends often uninterruptedly from one wall to the other.

The veins usually outcrop in the high hills which border the canyons, so that they have generally been worked first in their upper portions high above the stream bed and later at a very much lower level, either by drifts on the vein or long tunnels through barren rock. On account of the large vertical extent of vein materials thus developed it has been possible to gather considerable evidence as to the behavior of these fissures in depth. While there are many exceptions and it is a little difficult to form an accurate conclusion, the mass of evidence seems to show that the fissures tend to die out in their deeper portions. They frequently branch as they are followed downward, inclusions of rock material become more frequent, and the open spaces of the fissures become more constricted and narrower. It is also observable that the ore minerals become leaner, less in amount, and of a different character from those exploited in the higher levels of the mine. It is for these reasons that many of the long tunnels which mark the latest phase of mining development on these fissures have been costly and unprofitable. It is probable that a clear understanding of the geologic features which have produced these characteristics may avert some loss of capital in ill-advised exploration.

Minerals.—The minerals which fill the fissures may be grouped in two classes—ore minerals and gangue minerals. The ore minerals are galena, tetrahedrite, chalcopyrite, sphalerite, and pyrite, which collectively constitute the unaltered sulphides representing original ore minerals. In the upper portions of the veins are found ruby silver, argentite, anglesite, limonite, pyrolusite, and cerussite. These have been produced by downward-moving waters, either by processes of simple oxidation or secondary reactions between material dissolved from the upper portions of the deposits and the unaltered sulphides below. Anglesite is quite a common oxidation product, and often occurs in large masses, the carbonate of lead being usually subordinate owing to the absence of calcium carbonate from the country rock. The ruby silver is usually irregularly distributed and often occurs as bonanzas in the deeper portions of the mine. It is thought to have been produced as a secondary mineral by reduction of antimonial sulphates from downward-seeping solutions in contact with the unaltered sulphides below. Such argentite as is present, and also native silver, can also be ascribed to the same oxidizing agency. It is due in large measure to the absence of such secondary enrichment that the poverty of the deeper portions of some of the lodes must be attributed. Sphalerite is variable in amount. In the Ute and Hidden Treasure ores it is subordinate; in others it is higher in amount in the upper lodes and abundant below; and in some cases, as in the Moro mine and the Yellowstone Gulch properties, it forms more than 50 per cent of the ore minerals, so that its removal constitutes one of the most serious problems of exploitation.

The gangue minerals are quartz, rhodonite, rhodochrosite, and barite. The ore minerals are usually scattered through the gangue minerals in more or less irregular bands. A definite sequence of deposition can frequently be determined, but space is hardly available here for such discussion. A replacement of the country rock by silica has often extended for considerable distances from the vein, and the fragments of the country rock which are included within the vein are usually altered to a dense black silica. Alteration of other kinds also extends to even greater distances from the fissures, but replacement has not been a serious factor in the extension of values into the wall rock, and commercial operations are confined to the vein filling. Clay selvages may often be observed in the upper portions of the ore body, but they disappear in depth, the veins being tightly frozen to their walls.

Values.—In the upper portions of the veins the values have been uniformly high, especially where pockets of ruby silver have been discovered. A single bonanza at times produces as high as 15,000 ounces of silver per ton. These masses are, however, exceptional, and in the zone of unaltered sulphides the silver values are contained in two of the ore minerals, the galena and tetrahedrite. The galena, where solid, usually carries about 22 ounces of silver per ton, rarely running above 30 when unmixed with tetrahedrite. The tetrahedrite, or antimonial copper sulphide, usually carries the larger portion of the silver, and is thought to be related to the argentiferous variety known as freibergite. It carries silver ranging in value from 30 to many thousand ounces per ton, and where richest in silver has usually a more brilliant, greasy luster than where it is barren of values. Where galena carries very high values in silver, it will be generally found to be mingled with large proportions of this freibergite.

Treatment of ores.—A small smelter, known as the Crook smelter, was originally operated at Lake City for the Ute ores, but was in operation only a short time. Most of the ore mined has been shipped for treatment to other smelting centers or concentrated at the mine and the concentrates shipped for further treatment. Ores containing high percentages of lead usually gain the precedence over the other ores in the cost of treatment. Large mills are located at the Hidden Treasure and Ute mines in Henson Creek. From the smaller mines only such ores as may be profitably shipped are now mined.

GOLD-BEARING FISSURE VEINS.

The gold-bearing fissure veins are those which produce chiefly gold, with usually subordinate silver. Only two veins of this character have so far been at all productive. These are the Golden Fleece and Black Crook. The Black Crook vein can hardly be distinguished as a gold vein, as it has produced much silver ore; but its upper portions contained large quantities of fine-grained, brownish, iron pyrite with high values in gold. Except for this occurrence it might be placed among the less prominent silver-bearing veins.

According to a statement made by the management the Golden Fleece mine has produced $1,400,000 and has been sufficiently prominent to warrant a brief description. It is situated on the west bank of Lake Fork, about 5 miles south of Lake City, opposite Lake San Christobal. The country rock consists of tuff and breccia interbedded with andesite flow breccia and cut by a small dike of diabase or related rock. The bedding of the tuffs dips in a general way toward the west, although it is so much disturbed and distorted and so confusedly related to the flow breccias that it can not be said to show any constant dip. The workings of the mine consist of four tunnels, the upper three running in on the vein in a westerly direction. The highest is about 1,000 feet from the bottom of the creek. The two successively lower ones are 100 and 200 feet below. The fourth and lowest is an adit a short distance above the stream bed level. It is 2,100 feet in length.

In its outcrop the vein formed a ridge about 25 feet in width, with a nearly westerly strike projecting above the surrounding rocks for a distance of about 125 feet. This ridge, together with the rocks at its base, slopes eastward in the direction of strike at an angle of about 60°. In depth the vein assumes a more regular character, but even in the lower levels the ore is a more or less broken and confused mass of tuff fragments, gangue, and ore minerals. The uppermost tunnel of the mine, 570 feet west of the opening, encountered an abrupt wall of rock dipping west about 30°. This wall, or roof, as it may more properly be called, reappeared in the two lower levels, but has not yet been encountered in the lowest tunnel. The rock on the western side of this plane consisted of a very coarse breccia composed of large bowlders of yellowish-colored tuff cemented together by a volcanic material of the same character as the bowlders themselves. There is little doubt that it is a true volcanic breccia. It was at first considered to be a simple fault, but a tunnel was run into it for a distance of more than 1,500 feet and failed to reveal any other rock than the breccia first encountered. It therefore seems probable that there is here a heavy volcanic breccia which has been faulted into its present position. That the plane is distinctly a fault plane is shown first by the brecciation of the ore along the contact, and second, by the fact that the vein terminates abruptly against it. The chief ore present in the vein is the telluride petzite. The gangue minerals of this ore have not yet been carefully determined. Through the kindness of the managers the following statement of ore values is given, showing the very high grade of the ore which has been mined:

Analysis of ore of Golden Fleece mine, Lake City district, Colorado.

Class.	Gold per ton.	Silver per ton.	Value.
	Ounces.	*Ounces.*	
Dump	0.40	15.00	$15.50
Third class	2.00	53.00	66.50
Second class	6.11	238.00	351.20
First class	134.10	3,077.00	4,220.50

The telluride ore occurs in an irregular tabular shoot which is close against the fault plane in the uppermost level. It dips steeply to the west at an angle of about 60°, a very much steeper angle than the dip at the fault plane (30°). The shoot, therefore, from its contact with the fault plane gradually diverges from it as it is followed downward.

THE GEOLOGICAL RESURVEY OF THE CRIPPLE CREEK DISTRICT, COLORADO.

By Waldemar Lindgren and Frederick Leslie Ransome.

INTRODUCTION.

The Cripple Creek gold deposits were discovered in 1891. Shortly afterwards, in 1894, an examination of the new district was undertaken by the United States Geological Survey, Mr. Whitman Cross having charge of geology and petrography, and Mr. R. A. F. Penrose, jr., undertaking the examination of the mines. Their report, accompanied by a geological map, was published in the Sixteenth Annual Report of the Geological Survey, Part II, pages 1–207, and has for the last ten years served as a useful and accurate geological guide to mining operations.

With the astonishingly rapid development of the Cripple Creek mines the opportunities for geological study multiplied, revealing great complexity of vein phenomena and stimulating a desire for further investigation, particularly with a view of obtaining some evidence as to the persistence of the veins in depth. This desire found expression in a request by citizens of Colorado for a reexamination of the district by the United States Geological Survey and in an offer of cooperation, whereby the cost would be equally divided between the State of Colorado and the National Survey. The necessary amount having been subscribed in Cripple Creek, Colorado Springs, and Denver, the State contribution was put in the hands of Mr. John Wellington Finch, State geologist of Colorado, and by him disbursed. The cordial thanks of the geologists in charge of the work are due to Mr. Finch for his hearty and efficient cooperation.

The geological and mining work was undertaken jointly by the authors of the preliminary report.[a] The examination began in June, 1903, and, with some interruptions, due to various causes, the field work was concluded in April, 1904. Practically every accessible mine in the district was examined in greater or less detail. Mr. L. C.

[a] Lindgren, W., and Ransome, F. L., Report of progress in the geological resurvey of the Cripple Creek district, Colorado: Bull. U. S. Geol. Survey No. 254, 1904.

Graton served as assistant throughout this time, actively participating in all branches of the work. Messrs. A. M. Rock and J. Bruce also rendered very efficient aid as draftsmen.

PRODUCTION.

Though situated close to the centers of population in Colorado and in an easily accessible region, the gold deposits of Cripple Creek were not discovered until 1891. In 1894, when the first survey was made, the production was a little less than $3,000,000, but the next year this amount was more than doubled, and in 1900 the maximum production of a little over $18,000,000 was attained. In 1901 and 1902 the production declined slowly, and dropped the next year to $13,000,000. The sudden decrease in 1903 was to some extent brought about by the impoverishment of several mines, but the labor troubles of that year had also much to do with it. From August, 1903, to the summer of 1904 many mines experienced more or less difficulty from this cause. It is probable, however, that the output for the current year will show a considerable increase over that of 1903.

Production of the Cripple Creek district according to the reports of the Director of the Mint.

Year.	Gold.	Silver.
		Fine ounces.
1891	$449	
1892	583,010	
1893	2,010,367	5,019
1894	2,908,702	25,900
1895	6,879,137	70,448
1896	7,512,911	60,864
1897	10,139,709	57,297
1898	13,507,244	68,195
1899	15,658,254	82,520
1900	18,073,539	80,166
1901	17,261,579	90,884
1902	16,912,783	62,690
1903	12,967,338	42,210
Total	124,415,022	646,193

TOPOGRAPHY.

The mines are situated in a group of bare, rounded hills forming part of the high plateau extending southwestward from Pikes Peak, and are only about 10 miles distant from that prominent landmark.

The elevations range from 9,000 to nearly 11,000 feet above sea, the highest point in the district being Trachyte Mountain (10,836 feet). Bull Hill and Bull Cliff are but slightly lower. The drainage is chiefly southward toward the Arkansas River. The district contains two important towns. Cripple Creek is situated on the northwest side of the producing area, while Victor, 3 miles distant, lies on the southwest edge of the same area. Two railroads connect the district with Colorado Springs, the Colorado Midland circling around the north side of Pikes Peak, while the Short Line descends to the valley along the picturesque eastern slope of the same mountain. The Florence and Cripple Creep Railroad runs southward to Florence, in the Arkansas Valley. An excellent system of electric-car lines connects the towns with all the important mines.

GENERAL GEOLOGY.

FIRST GEOLOGICAL SURVEY OF THE DISTRICT.

When Mr. Whitman Cross made his careful study of the geology of the Cripple Creek district, ten years ago, mining had barely begun and the various hills were not, as now, perforated by deep underground workings. That his work has in general stood the test of subsequent underground exploration and continues to be highly regarded in the district is convincing proof of its high quality. Later workers, however they may modify or amplify its results, should acknowledge their debt to the pioneer who first deciphered the history of this volcanic district. The account of general geology, as given by Cross, may be very briefly summarized as follows:

The Cripple Creek hills lie near the eastern border of an elevated and much dissected plateau, which slopes gently westward for 40 miles, from the southern end of the Colorado Range, dominated by Pikes Peak, to the relatively low hills connecting the Mosquito and Sangre de Cristo ranges. The prevailing rocks of this plateau are granites, gneisses, and schists. The granites inclose masses of Algonkian quartzite and are therefore post-Archean, but they are older than the only Cambrian sediments known in Colorado, and on the Cripple Creek map have been indicated as Algonkian. During Tertiary time volcanic eruptions broke through these ancient rocks at several points and piled tuffs, breccias, and lavas upon the uneven surface of the plateau. The eruptive rocks of the Cripple Creek district are the products of one of the smaller isolated volcanic centers of this period, a center characterized by the eruption of phonolite, which does not occur elsewhere in this general region.

The most voluminous products of the Cripple Creek volcano now preserved are tuffs and breccias. They occupy a rudely elliptical area in the center of the district, about 5 miles long in a northwest-southeast direction and about 3 miles wide. According to Cross these breccias and tuffs rest in part upon an earlier flow of andesite, but mainly upon an unevenly eroded surface of the granites and schists, although along the southwest edge of the area the contact was found to be so steep as "to support the idea that the central vent or vents of the volcano were adjacent to this line." The breccia is much indurated and altered, but was thought by Cross to consist mainly of andesitic fragments, although it was recognized that fragments of phonolite are locally abundant. The most characteristic massive rock of the Cripple Creek volcano is phonolite, which was erupted at several periods and more abundantly than any other type. It occurs as dikes and masses, not only in the breccia, but in the surrounding granitic rocks.

The general succession of igneous rocks, according to Cross, is as follows: The earliest rocks were andesites containing some orthoclase. Then came a series of allied phonolitic rocks, rich in alkalies and moderately rich in silica, together with some andesites. Among them are trachytic phonolite, nepheline-syenite, syenite-porphyry, phonolite, mica-andesite, and pyroxene-andesite. Phonolite was erupted at several periods. The nepheline-syenite he considered as probably younger than the trachytic phonolite. At the close were intruded a small number of narrow dikes of basic rocks, the so-called basalts, which contrast very markedly with the phonolite.

MODIFICATION OF EARLIER RESULTS.

In the course of the present investigation the geology of the district has been entirely remapped upon the carefully revised topographic base. The granites, gneisses, and schists have been differentiated and outlined in greater detail than was practicable in the earlier investigation. The oldest rocks in the district are muscovite- and fibrolite-schists. These are closely associated with the fine-grained granitic gneisses such as underlie most of the town of Cripple Creek. This gneiss, in the earlier report, was mapped partly as schist and partly as granite. Both gneiss and schist are cut by a reddish granite which occupies a considerable area extending from Anaconda westward beyond the limits of the area studied. This granite is well exposed along Cripple Creek in the vicinity of Mound.

A second type of granite distinguished and mapped is the coarsely porphyritic rock referred to by Cross as the Pikes Peak type of granite. This rock occupies over half of the district and is the prevailing type along the northern, eastern, and southern borders of the area.

The present investigation indicates some necessary modifications of the earlier report in the way of stronger emphasis on the intimate genetic relationship of the rocks. The "phonolite," "nepheline-syenite," "trachytic phonolite," "syenite-porphyry," and "andesites" of Cross are all very closely related and have been found to be in most cases connected by intermediate types. None of the massive rocks can properly be called andesite, and although it can not be affirmed that andesitic fragments are entirely absent from the usually much altered volcanic breccia, the term "andesitic breccia" does not seem applicable to this formation as a whole. It would be more accurate to describe it as a phonolitic breccia, although in places it consists chiefly of particles of the older rocks through which the Tertiary eruptives broke.

While it is undoubtedly true that some of the breccia in the northeastern part of the volcanic area rests upon a very uneven surface of granite, gneiss, and schist, the results of field work during the last season, favored by deep workings not in existence when the district was originally surveyed, have emphasized the fact that the breccia lying southwest of a general northwest-southeast line drawn through Big Bull Mountain and Gold Hill occupies a chasm of profound depth in the fundamental rocks of the region. From the Conundrum mine on the western slope of Gold Hill to Stratton's Independence mine on the south slope of Battle Mountain the contact plunges steeply down, with dips ranging in general from 70° to vertical. In some instances the granite walls of this chasm actually overhang the breccia. It is probable that this entire southwest contact represents a part of the wall of the great pit formed by the volcanic explosions that produced the breccia. It is further probable that an arm or branch of this volcanic abyss, now filled with breccia and intrusive rocks, extends northeastward past Bull Cliff and the town of Altman.

ECONOMIC GEOLOGY.

EARLIER WORK.

To the excellent work of Mr. R. A. F. Penrose, jr., apply statements similar to those made in the discussion of the purely geological branch of the subject. Few shafts had then attained a depth of 400 feet, and most of the exposures were masked by surface oxidation. It would be surprising, in view of the facilities created by the later development of hundreds of mines, if a subsequent investigation should not bring out some slight modifications of earlier results.

EXTENT OF PRODUCTIVE TERRITORY.

There is nothing in the history of the district since 1894 warranting any extension of the bounds of the productive territory as then known. Now, as then, a circle of 3 miles radius described from the summit of Gold Hill would include all deposits of known or prospective value, while the really important mines would be embraced by a circle of about half that radius, with its center near the summit of Raven Hill. That scattered deposits of greater or less value may be found in outlying portions of the district is by no means improbable. But the close dependence of the typical Cripple Creek ores upon the main volcanic center, and the consequent remarkable compactness of the gold-bearing area, are features highly characteristic of the district and are likely always to remain so.

UNDERGROUND DEVELOPMENT.

At the time of the earlier survey the deepest shafts, those of the Moose, Pharmacist, and Anna Lee mines, were down only about 400 feet, while few of the other mines were over 200 feet in depth. Many subsequently prominent mines were then mere prospects or had not been located.

The deepest shaft at present is the Lillie, which is over 1,500 feet deep, although the Stratton's Independence shaft, 1,400 feet deep, has the lowest sump in the district. The American Eagle shaft is nearly as deep as the Lillie, while there are about twenty other shafts over 1,000 feet in depth, and at least 100 shafts deeper than the deepest workings existing in 1894.

The amount of drifting and crosscutting accomplished since the earlier survey is more than commensurate with the increased number and depth of the shafts, and the district is further intersected in various directions and at different levels by two long tunnels run for drainage purposes and by a dozen or more extensive adits.

CHARACTER OF THE ORES.

The characteristic feature of the Cripple Creek ores is the occurrence of the gold in combination with tellurium, chiefly as calaverite, but partly also as the more argentiferous sylvanite,[a] and probably to a minor extent as other gold, silver, and lead tellurides. The tellurides are frequently associated with auriferous and highly argentiferous tetrahedrite, with molybdenite, and occasionally with stibnite. While these minerals have not yet been closely studied, preliminary examination indicates that their contents in gold are due to an intimate mechanical mixture of tellurides. Pyrite, while widely disseminated through the country rock and of common occurrence in the fissures, is rarely sufficiently auriferous to constitute ore. Such of the pyritic ores as have been tested reveal the presence of tellurium, indicating that the ore is a mixture of pyrite and gold-silver tellurides. Galena and sphalerite occur in small quantities in many of the mines,

[a] Calaverite (AuAg) Te_2: tellurium, 57.4 per cent; gold, 39.5 per cent; silver, 3.1 per cent. Sylvanite (AuAg) Te_2: tellurium, 62.1 per cent; gold, 24.5 per cent; silver, 13.4 per cent.

but rarely contain enough of the precious metals to form ore. Native gold appears to be absent from the telluride ores, except as it may be set free by the oxidation of these tellurides.

The usual gangue minerals of the ores are quartz, fluorite, and dolomite. Roscoelite and rhodochrosite are also found in places. Celestite, or sulphate of strontium, while never present in large amount, frequently occurs as little acicular crystals in the quartz vugs of the lodes. Calcite occurs interstitially in much of the breccia near the ore bodies, but is rarely found in distinct crystalline form with the ore minerals. Secondary potassium feldspar is common in the ores; it is especially abundant in the ores inclosed in granite, particularly those in the Pikes Peak type. This feldspar has the composition of orthoclase or microcline, and is formed by the recrystallization of the original potassic feldspar contained in the rocks. In the granitic ores of the Stratton's Independence, Portland, Ajax, and Elkton mines this secondary feldspar is the principal gangue mineral.

Oxidized ores, while still worked in many properties, are of relatively less importance than when Penrose described the district. They contain the characteristic dull gold, often in pseudomorphous skeletons, resulting from the oxidation of the tellurides, associated with tellurite (tellurium dioxide), emmonsite or durdenite (both hydrated ferric tellurites), and probably other oxidized compounds of tellurium and iron. These minerals occur in association with kaolin, alunite, and ferruginous clays. The deep workings of the present day show that kaolin is always connected with oxidation, and is not a product of the original mineralization of the district, as was supposed by Penrose.

The Cripple Creek ores, as a rule, contain very little silver, the average proportion being about 1 ounce of silver to 10 ounces of gold. In the Portland and Stratton's Independence mines the proportion is very much less, the silver from the Portland in 1901 amounting to only 2.4 ounces for each 100 ounces of gold. In the Blue Bird, Doctor-Jack Pot, Conundrum, Pointer, and other mines containing notable amounts of tetrahedrite or galena, the proportion of silver rises considerably above the average.

The average value of the Cripple Creek ores lies probably between $30 and $40 per ton. In some of the larger mines the average value sinks to about $25 per ton. From a lower economic limit of about $12 per ton the values of individual shipments swing through a wide range up to ores carrying $3,000 or $4,000, or even $8,000, per ton. Occasionally smaller amounts—1 or 2 tons—have yielded as much as $50,000 per ton.

STRUCTURAL CHARACTER OF DEPOSITS.

With few exceptions the ore bodies, of whatever shape, are causally connected with fissures, and most of them constitute fissure veins of various types. The fissure system of the district appears to radiate from a point near the northern limit of the volcanic area. In the eastern part the prevailing directions are northwest or north-northwest, gradually changing to a northerly strike in the southern portion and to predominate north-northeast or northeast courses in the western side of the district.

Individual veins are rarely over half a mile in length, but linked vein systems often extend for a mile in the same direction. The dip is generally very steep. The movement along these fissure planes appears in all cases to have been very slight. The fissures charged with ore are sometimes simple veins with one fracture plane; much more commonly, however, they are composite veins or lodes which consist of several closely spaced and frequently linked fissures, all more or less ore bearing. A better expression for this structural type as it appears in Cripple Creek is the term "sheeted zone."

TYPES OF DEPOSITS.

The most important types of auriferous ore bodies occurring in the district are:

1. Tabular in form and strictly following simple fissures or sheeted zones. A subtype comprises lodes in which the sheeted zone follows "basalt" or phonolite dikes.

2. Irregular bodies adjacent to fissures and formed by replacement and recrystallization of the country rock—usually granite.

These types are not always sharply distinct, but may be connected by deposits of intermediate character.

All the ore bodies, of whatever type, exhibit certain common features which serve to distinguish the deposits of Cripple Creek from those of most other mining districts. In the first place, the actual openings in the rocks available for the deposition of ore are, as a rule, remarkably narrow. In the second place, the amount of material carried in the mineralizing solutions and deposited as gangue and ore minerals was comparatively small. In consequence of these two conditions, the district contains no such massive veins, solidly filled with quartz or other vein minerals, as are characteristic of the San Juan region in Colorado or the Mother Lode region in California. Even the small fissures of the Cripple Creek district are rarely completely filled, but exhibit a characteristic open or vuggy structure. Where the fractures are of unusual width, or where the rocks are extensively shattered, as in the Midget and Moose mines, the small volume of available vein matter is particularly noticeable. The walls of such fractures and the fragments of the shattered rock are usually merely coated with a thin deposit of quartz, fluorite, and other minerals. As the rich tellurides were usually among the minerals last to form, and are particularly abundant on the walls of the vugs, it is probable that had quartz, fluorite, or other gangue minerals been more abundantly deposited the ores would have been of much lower grade.

Sheeted veins.—The mineralized sheeted zones constitute the most characteristic deposits of the district and occur in practically all the rocks, although particularly common in breccia. They consist of a varying number of narrow, approximately parallel fissures, together composing a sheeted zone that may range from a fraction of a foot to 50 or 60 feet in width.

As a rule, the fissures are mere cracks, showing no brecciation, slickensiding, or other evidence of tangential movement of the walls. Usually the tellurides are exclusively confined to the narrow fissures and cracks, and rarely, in this type of deposit, constitute a replacement of the country rock. The rocks in the vicinity of the fissures are partly replaced by dolomite, pyrite, and a little fluorite. The fissures are not, in general, planes of faulting. Appreciable movement has undoubtedly occurred in some instances, but the displacement probably rarely exceeded 1 or 2 feet.

Although found most abundantly in the breccia or trachytic phonolite, sheeted zones and single fissures are often well developed in the granite, as in the El Paso, C. K. & N., and Gold Coin mines. While in some of these lodes the ore minerals are as plainly confined to the fissures as in the breccia, in other cases the ore to some extent permeates the granite alongside the fissure, this constituting a deposit intermediate in nature between types 1 and 2. They also frequently follow phonolite dikes, the general tendency of these dikes to develop a platy parting parallel to their walls being particularly favorable to the production of a well-defined sheeted zone when the direction of fissuring happens to coincide with that of the dike.

The metasomatic alteration accompanying these sheeted zones is surprisingly slight, and consists of a partial replacement of the breccia, phonolite, trachytic phonolite, or "basalt" by dolomite and pyrite accompanied by a small amount of sericite and a little secondary potash feldspar. The alteration in granite exhibits a somewhat different phase, described in a subsequent paragraph.

Not all the sheeted zones carry ore, nor is the ore of a productive sheeted zone necessarily coextensive with the fissuring. The ore occurs in pay shoots up to 2,000 feet in length and 1,000 feet in depth, but usually very much smaller than is indicated by these limits.

Replacement deposits in granite.—The replacement deposits in granite all occur in close proximity to the contact with the breccia, and are well developed in the Elkton (Thompson), Ajax, Independence, and Portland mines. Although these bodies of ore are related to fissures and occur particularly where several fissures intersect, or where they meet a dike, the ore is not confined to the actual fractures. The rock in the vicinity of these fissures is often extensively altered. The most obvious characteristic of the metamorphosed rock is a porous texture and a change of the reddish color of the normal granite to grayish or greenish tints. Closer examinations shows that the rock, consisting originally of microcline, oligoclase, quartz, and biotite, may be completely recrystallized as a porous, vuggy aggregate of secondary orthoclase (valencianite), quartz, fluorite, pyrite, calaverite or sylvanite, and, in exceptional cases, sphalerite and galena. The ore minerals are partly inclosed in the other secondary minerals, but occur most abundantly, with little projecting crystals of fluorite, quartz, and valencianite, on the walls of the irregular pores characteristic of the altered rock.

While the replacement deposits in granite are important because of their size and the readiness with which the ore may be mined free from waste, the ore itself is usually of lower grade than that formed in the fissures of the sheeted zones.

Mineralized "basalt" dikes.—The ore bodies formed by the mineralization of basic dikes are in some ways closely related to the sheeted zones already described. Like the phonolite dikes, the "basalt" exhibits a pronounced tendency to split into thin sheets parallel with the dike walls. Normally, the minute fissures so formed are filled with veinlets of calcite and contain no ore. When, however, a zone of fissuring coincides with the dike the latter may be traversed by veinlets of quartz and flourite carrying sylvanite or calaverite, while the body of the dike may be impregnated with pyrite. Such ore differs from that of the usual sheeted zones in breccia or phonolite in that the tellurides are not so clearly confined to the actual fissures, but appear to some extent to permeate the rock with the pyrite. The richest portion of the ore, however, undoubtedly occurs in the small veinlets in the dike, and usually near one or both walls, where the fissuring is best developed.

DEPTH OF OXIDIZED ZONE.

At a few points, as in the Abe Lincoln and El Paso mines, tellurides are found almost at the surface. It is much more common, however, to find an upper zone, from 200 to 400 feet deep, in which free gold prevails and which gradually changes to the zone of pure telluride ores. As may be expected from the varying surface form and conditions of drainage, there is great range in the depth attained by oxidation. Partial oxidation extends in many mines to a depth of over 1,000 feet, especially along the often more or less open fissures.

RELATIONS OF ORE BODIES TO DEPTH.

It is well known that the payable ores in auriferous lodes are rarely equally distributed in the lode, but form tabular bodies of more or less regular outline. The projections of these ore bodies on the plane of the lode often appear as elongated areas with greater vertical than horizontal extent. The ore bodies or shoots of Cripple Creek show great similarity to those of other gold-bearing veins; their limit in depth is usually as well defined as their extent in a horizontal direction.

In the case of shoots reaching the surface, a certain part has probably been removed by erosion. The shoots which distinctly began below the surface show the normal form of the ore bodies to be elongated, vertical, or pitching sharply northward, the ratio of vertical to horizontal extension varying from 1½ : 1 to 5 : 1. Some of these shoots are, however, of about equal dimensions vertically and horizontally, while in a few the horizontal dimension is the greater.

Of the known ore bodies, as few exceed 1,000 feet in length, so very few exceed 1,000 feet in depth or extend more than 1,000 feet from the surface. Speaking broadly, explorations below that limit have not proved very satisfactory. Drawing the lines a little closer, it may be said that in proportion to the amount of exploration the upper 700 or 800 feet have yielded more than the interval from that limit to the lowest levels reached—about 1,500 feet. It must not be overlooked, however, that four or five mines still have good ore bodies at a depth of 1,200 to 1,400 feet from the surface. The developments of the next year or two will probably give a safer basis for generalization.

Roughly speaking, the above-mentioned distribution holds good for any elevation within the district. In other words, the principal productive zone everywhere occupies the space from the surface down to about 1,000 feet below it, and its lower limit thus forms a curved surface approximately parallel to the surface of the ground.

The general features of the vertical distribution of the known ore bodies recorded above have of late years received more or less recognition, and there has been a decided tendency to attribute them to a process of secondary enrichment effected by waters moving generally downward from the surface. It has been supposed[a] that such waters

[a] Bancroft, Geo. J., Eng. and Min. Jour., vol. 74, 1902, pp. 752–753, and vol. 75, 1903, pp. 111–112.
Finch, J. W., Proc. Colorado Sci. Soc., vol. 7, 1904, pp. 193–252.

have carried down a part of the auriferous contents of those portions of the lodes now removed by erosion and have enriched originally lean pyritic ores by the secondary deposition of gold and silver tellurides and argentiferous tetrahedrite, with associated gangue minerals.

Careful study of the Cripple Creek ore deposits has failed to discover that the hypothesis of secondary enrichment is supported by crucial evidence. The minerals are not arranged in any discoverable definite sequence, nor does the present investigation find much to support the view that the rich telluride ores, as a rule, pass with increasing depth into low-grade pyritic ores. Frequently such ore as occurs below a depth of 1,000 feet is precisely the same in character as ore found within 100 feet of the surface. Tetrahedrite, which has been regarded by some, without definite proof, as a secondary mineral, occurs sporadically throughout the district and at all depths reached by present workings. The richest ore does not uniformly occur immediately below the oxidized ore. There is, in fact, little indication of enrichment in the oxidized zone such as is so often found in gold-quartz veins of the normal type. Frequently the fresh telluride ore is extremely rich, and high-grade pockets occur impartially in oxidized and fresh portions of the veins. Neither would it be correct to say that there is a gradual decrease in the value of ore in depth. It is quantity, not value, which decreases.

While it is certain that pyrite, and possibly other minerals, has formed at more than one period during the mineralization of the district, and while it is equally clear that in general the rich tellurides were the last of the ore minerals to be deposited, there is apparently no evidence that any one of these minerals has been formed by enriching solutions at the expense of primary minerals. So far as definite conclusion is warranted in an investigation as yet incomplete, it appears that the unoxidized ore deposits of the Cripple Creek district represent the product of one general period of mineralization and that they have not been appreciably modified by secondary enrichment during the subsequent erosion of the region.

UNDERGROUND WATER.

The conditions of underground waters are unusual. A dry climate and a heavy percentage of run-off minimize the annual additions to the underground supply. Nevertheless, the ground-water level is not unusually deep, and large quantities of water are encountered in all the mines below that level. The original water surface of the district in the volcanic rocks stood at elevations of 9,400 to 9,700 feet, or 100 to 600 feet below the surface of the ground. At first pumping was commenced by individual mines, but it was soon found that the radius of drainage had unusual length—that is, that one mine would drain others situated at a distance. Drainage tunnels were then undertaken, and the Chicago and Cripple Creek, the Ophelia, the Standard, and lately the El Paso tunnels were driven, each of which practically accomplished the drainage of a large part of the district almost down to its own level, thus showing that the ground water is limited in quantity and is more of the nature of a local reservoir than a "subterranean sea."

The El Paso tunnel, completed in the winter of 1903–4, has an elevation of 8,783 feet at the portal. Within a short time it effectually drained not only the Beacon Hill mines but also the Gold Hill mines, and its influence extended even to the Last Dollar and the Elkton mines. But the foregoing statement in relation to draining the district must be so modified as to exclude a certain part on the eastern side, comprising the mines about Independence on the east side of Bull Hill and those on Battle Mountain and in the town of Victor, in which the effect of the El Paso tunnel is slight. The Findley, Hull City, Vindicator, and Golden Cycle mines about the town of Independence seem to occupy a separate drainage basin, probably divided from the main area by masses of relatively impermeable rock.

The Portland, Stratton's Independence, and the other mines near Victor occupy another drainage basin. Of these the Gold Coin and the Stratton's Independence have shafts below the level of the El Paso tunnel, and their pumps have probably drained the surrounding territory to a considerable extent. The influence of the drainage tunnel on the Portland mine is a question upon which opinions differ.

SUBTERRANEAN GASES.

During the earlier years of Cripple Creek no unusual amount of mine gases was observed, but, as the shafts and workings deepened, several properties began to experience much annoyance and even serious interference with work, often in spite of vigorous measures for ventilation. These gases appear to issue chiefly from the breccia, especially where it is of porous and loose texture; but they sometimes flow from partly open vein fissures in such quantity that a light held up to the fissures is immediately extinguished.

The characteristics of the gas seemed to point to carbon dioxide, and it is generally so termed. Preliminary determinations of carbon dioxide by a portable apparatus yielded percentages which seemed far too small in comparison with the effects of the gas examined, and led to the belief that some other substance was present. Samples were then collected and analyzed. The analysis showed the gas to be a mixture of nitrogen with about 20 per cent carbon dioxide and a small amount of oxygen.

The occurrence of these exhalations over a large part of the ore-bearing area is of much interest. They certainly increase in quantity with depth, and it is to be feared that in some cases they may seriously affect mining operations. The evil has proved very difficult to cope with. Ventilation alone has rarely proved efficient, and the only practicable remedial measures appear to be cementation of drifts at particularly bad places and working the mine under air lock at a pressure slightly exceeding the normal.

The origin of these gases can not reasonably be sought in any such explanation as the oxidizing of sulphides and accompanying absorption of oxygen. They probably represent the last exhalations from the throat of the extinct Cripple Creek volcano.

PRELIMINARY REPORT ON ORE DEPOSITS IN THE GEORGETOWN, COLO., MINING DISTRICT.

By J. E. Spurr and G. H. Garrey.

LOCATION.

The Georgetown mining district includes the mining territory in the vicinity of Georgetown, the county seat of Clear Creek County, Colo. Georgetown, with a population of 1,418,[a] is about 50 miles due west of Denver, on a branch of the Colorado and Southern Railroad. The district named embraces all mines in the neighborhood of Silver Plume and Empire, as well as of Georgetown. Silver Plume is approximately 2 miles west-southwest of Georgetown, while Empire is about 4 miles north and slightly east of the same place.

DISCOVERY AND DEVELOPMENT.

The first discovery of "pay gold" in Clear Creek County, and probably in Colorado, is said to have been made in placer deposits at the junction of Chicago and Clear Creeks, near Idaho Springs, in the winter of 1858–59. "The Empire gold lodes and placers produced largely in 1862–1864. The first silver discovery was made late in 1864 on McClellan Mountain,"[b] which is located several miles to the southwest of Georgetown. From this time on prospecting became very lively. It was not until the completion of the railroad in 1877, however, that active development of the mining resources of the district began. The subsequent development was very rapid up to 1893, when the financial panic and the fall in the price of silver temporarily put an almost complete stop to mining. The mines in the eastern end of Clear Creek County, where gold ores were then found in greater predominance, recovered first from the panic. Gold-bearing lodes, however, were afterwards found throughout nearly the entire mineral belt of the county. By the gradual development of these lodes the limit of the known "gold belt" migrated westward until at present Georgetown must be considered a gold as

[a] Census Report, 1900. [b] Fossett, "Colorado," 1880.

well as a silver camp. The high average value of the silver ores in the vicinity of Silver Plume and Georgetown also caused the resumption of mining in these localities. The average value per ton for all the silver ore shipments from the Silver Plume region from 1891 to 1902 is reported to be $96.[a]

The Georgetown district is one of the oldest mining districts of Colorado and has been almost constantly worked since the first discovery of precious metal in it; consequently it is one of the best exploited mining camps in the country. The writers have not been able to ascertain even approximately the total yield of the district, for official reports have usually been made on the whole of Clear Creek County, or even on Clear Creek and Gilpin counties combined. Clear Creek County includes, besides the region treated in this paper, the Idaho Springs district, as well as a number of smaller areas. Although there are no reliable records to be obtained from most of the mines, the total production has certainly been many millions of dollars.

Prospecting and mining are chiefly prosecuted through tunnels. This is because the steepness of the mountains makes the situation ideal for the employment of this economic method of extraction and drainage.

The value in the ores are in silver, gold, lead, zinc, and copper. These metals occur in different localities in an infinite variety of percentage combinations. The result is numerous chemically distinct but intergrading groups of veins. The gold, although occasionally occurring native, is usually associated with chalcopyrite or copper-bearing pyrites. The occasional occurrence of gold-bearing telluride, as in the Griffith mine at Georgetown, is exceptional. The silver is often associated with tetrahedrite ("gray copper"). It also often occurs in independent silver compounds, such as polybasite, argentite, and ruby silver, though the last two are not very common. The galena of the district is typically argentiferous to a greater or less extent, as is also to a less degree the blende. Of the precious metals, silver occurs predominantly between Silver Plume and Georgetown, and gold between Georgetown and Empire. At Silver Plume the values are silver with practically no gold; at Empire gold with practically no silver.

TOPOGRAPHY.

The lofty, rugged mountains around Georgetown are spurs of the main ridge forming the Continental Divide, which runs along the western boundary of Clear Creek County. The mountains rise to heights ranging between 11,000 and 14,000 feet. Grays Peak, in the

[a] By Mr. J. H. Eaton, Silver Plume.

extreme western part of the county, has an elevation of 14,341 feet,[a] while Mount Evans, 8 miles south of Georgetown, is 14,260 feet[b] above sea level. From a point where the deep, narrow valleys form a conspicuous part of the scene the mountains appear extremely steep and rugged. From a higher point, however, the aspect is that of an old, rolling, hilly plateau, deeply trenched by valleys which have not usually worn back far enough to cause sharp intervening ridges—that is, a considerable portion of the upland has been left undissected. These trenched valleys are chiefly pre-Glacial; their upper portions, however, have often been occupied by glaciers, which have left lateral, terminal, and ground moraines. Near the base of steep slopes there is often a heavy coating of talus.

A topographic survey of the Georgetown and Central City quadrangles, on the scale of 1 mile to the inch, was made by Mr. Frank Tweedy during the summer of 1903. The maps are now being engraved. A special topographic map of the Silver Plume mining area, on the scale of 1,000 feet to the inch, was made by Mr. Pearson Chapman during the summer of 1904.

GENERAL GEOLOGY.

The rocks of the Georgetown district belong almost entirely to the oldest, presumably pre-Cambrian, formations of the Rocky Mountains. Later than these are intrusive bodies of porphyry, and the surficial deposits of glacial and fluviatile origin. The pre-Cambrian formations which comprise the main mass of all these mountains include gneisses and schists, granites, pegmatites, and basic igneous rocks resembling diorites or metagabbros.[c]

The basal gneisses.—Certain gneisses and schists are the oldest rocks of the region. The commonest of these is a black biotite-gneiss or schist with varying proportions of biotite, feldspar, and quartz as the chief constituents. There are also limited areas where a hornblende-gneiss of apparently contemporaneous origin is found. The older gneisses in certain places are much metamorphosed and crumpled. Over large areas, moreover, the gneiss is very thoroughly intruded by varying amounts of an acidic rock which usually has the form of pegmatite, but occasionally shows that of granular alaskite and more rarely that of an acidic granite. These intrusives often occur in tongues and lenses, following the contorted laminæ of the gneiss in such a way that both the intrusive and the gneiss appear to have been folded together. The connection between pegmatitic dikes cutting across the schists and the interlaminated pegmatitic layers is,

[a] U. S. Geol. Survey Terr. [Hayden].

[b] Topographic map of the Georgetown quadrangle, by Mr. Frank Tweedy.

[c] Microscopic work not yet undertaken.

however, often perfectly displayed in a single outcrop, and there seems to have been little visible folding or contortion subsequent to this injection. The layers of pegmatite have been injected between the laminæ of the schist in all proportions, so that sometimes the original black schist or gneiss greatly predominates; sometimes half gneiss and half pegmatite is present; again the pegmatite predominates over the gneiss, and in other places simply shreds or breccia-like fragments of gneiss may be found as inclusions in almost pure pegmatite.

Where the pegmatite is very abundant the intervening gneiss is often metamorphosed to a gray granitic gneiss, evidently the result of saturation with the alaskitic fluid. This mingling with the original gneiss and recrystallizing has apparently sometimes produced a granitic rock more basic than the injected material.

One phase of granitic or quartzitic gneiss, which contains nodular or pebble-like masses scattered through it, occurs rather frequently. These nodules, which are composed chiefly of quartz, with some sillimanite, vary in size from one-fourth inch to over 3 inches in diameter. Their general arrangement is like that of conglomerate pebbles. Further study may justify the already strong opinion that this particular gneiss is of sedimentary origin and is a metamorphosed conglomerate.

The gneisses often have biotite as the predominant mineral, with clear to smoky quartz and whitish feldspar in about equal proportions. The accessory minerals include muscovite, sillimanite, magnetite, and garnets. The compact, vitreous gneiss is composed almost entirely of quartz, while biotite, feldspar, and muscovite, as well as magnetite, garnet, and sillimanite, may be termed accessory minerals.

Diorites.—Basic, igneous hornblendic rocks of dark color, resembling diorites, occupy comparatively limited patch-like areas, and in a few cases form narrow dikes. These rocks are very likely of two or more ages.

Outcrops near the Illinois and Wisconsin mines were noted where the diorite appears to be sheared, and seamed thoroughly with pegmatite. On close observation, however, the masses are seen to be practically unsheared and the pegmatite to be a contemporaneous segregation product. From a single locality may be obtained excellent specimens which show all the phases of segregation of the diorite through a basic-growing series culminating in a hornblendite and through an acidic-growing series culminating in pegmatite or even in pegmatitic vein quartz.

A very basic formation, chiefly biotite with a small amount of hornblende, is sometimes found in dike-like bodies. This rock is probably a sheared and metamorphosed form of diorite.

The diorite is ordinarily composed of black or greenish-black hornblende, white to gray plagioclase feldspar, and black or brownish biotite, in about equal proportions. At times, however, differentiation processes have resulted in a rock composed almost entirely of any one of these minerals. Accessory minerals are quartz, epidote, calcite, magnetite, and pyrite. The rock usually has a mottled white and black appearance, but by segregation a greenish-black rock may result, where hornblende predominates, or a gray rock where the feldspars predominate.

Granites.—Granites belonging to several successive intrusions and differing often in habit and appearance are found. All, however, are mineralogically very similar and consist principally of quartz, feldspar (mainly orthoclase), and biotite. Minor constituents are muscovite, magnetite, pyrite, etc. The granites differ chiefly in structure and in evidences of shearing.

Small areas of a muscovite-granite are found in some minor areas in the Georgetown district—for example, in the northwest corner of the area shown on the Silver Plume special map. This muscovite-granite is equivalent to the oldest pegmatite and grades directly into it.

The biotite-granite, which is the predominant granite of the region described, assumes a variety of phases—massive, even-grained forms, highly porphyritic phases, or massive varieties with a porphyritic habit of feldspars. The most common of all these forms is a massive granite containing phenocrysts of feldspar from three-sixteenths to one-half inch in length. These feldspars usually show twinning after the Carlsbad law. In some areas the feldspar phenocrysts are exceptionally well developed. For instance, near Empire Pass and the town of Empire phenocrysts of feldspar from one-half inch to 3 inches in length are scattered fairly abundantly through a groundmass of biotite-granite.

Some forms of the granite become so highly porphyritic that the bulk of the rock is composed of phenocrysts of feldspar in a finer groundmass. When this coarse, porphyritic granite has the somewhat altered condition characteristic of the vicinity of veins, it is termed "cornrock" by the miners. Some phases of the fine-grained porphyritic granite, especially in the vicinity of Empire, resemble certain of the "porphyry" so completely that the two are not readily distinguished macroscopically when they occur together. The porphyritic granite also has a pegmatite phase, which is segregated from the granite in all degrees of perfection and in all textures.

Pyrite appears as an original accessory of the granites in small quantities throughout the district; it is subordinate in amount to the original magnetite, but contemporaneous with it. Near Empire pyrite can be detected in nearly every specimen of granite. Whether the rock is comparatively fresh or much decomposed apparently makes little difference in the abundance of the pyrite. In most cases the pyrite is found in tiny seams or gashes in the more or less altered rock, a habit indicating that it originated subsequent to the other minerals. Frequently, however, the pyrite occurs in such a way as to seem a primary constituent and one of the first. For example, it occurs as inclusions in feldspar phenocrysts, also as isolated particles in fresh rock. On the whole, the pyrite here appears indigenous to the granite, and its occurrence as secondary streaks seems to be due to rearrangement. The easy solubility of iron sulphide and the insolubility of magnetite explains why original pyrite should have been rearranged while the magnetite was not. Pyrite, like magnetite, is decidedly more abundant in certain pegmatites near Empire and in the pegmatitic portions of the granite than in the finer-grained granite mass.

Pegmatites.—Besides the old pegmatite spoken of as intercalated between the laminæ of the gneiss, there is a series of several other pegmatites. It is impossible to always classify these pegmatites as to age on account of their similarity. Nevertheless, it is not difficult to ascertain that there have been intrusions at several different periods, for pegmatites have been observed which are contemporaneous associates of several of the granites of the region, and even of the dark, basic, diorite-like rocks.

The pegmatites contain varying proportions of one or more of the following minerals: Quartz, feldspar, biotite, and muscovite. Magnetite and pyrite are common accessory minerals. Occasionally the pegmatite consists almost entirely of white or red feldspar, and at other times it assumes the phase of veins composed essentially of pure quartz. The pegmatites are usually rather siliceous, but magnetite is frequently found in them in large quantities. The granites and other igneous rocks often contain magnetite as an accessory constituent, but the magnetite is vastly more abundant in the pegmatite than in the other rocks. Places were observed where the segregated magnetite in the pegmatite or in the quartz veins of pegmatitic origin was nearly equal in volume to the rest of the rock mass, and in consequence almost formed an iron ore. Pyrite is also an original constituent of the pegmatites at times.

Porphyries.—Dikes of porphyry are found scattered throughout the portion of the mineral belt studied. The porphyries are, so far, of unknown age, but are certainly younger that the gneisses, granites, pegmatites, and diorites, as they are found intersecting and also including fragments of all of these formations.

The porphyries consist of a great many varieties, or at least phases of several different forms. These rocks may be divided into two main groups—(1) felsitic porphyries and (2) granitic porphyries.

The felsitic porphyries are those which have a fine cryptocrystalline or felsitic groundmass, either with no phenocrysts or with sparsely scattered phenocrysts of one or more of the following minerals: Feldspar, quartz, biotite, hornblende, pyroxene.

In the granitic porphyries the number of these phenocrysts is increased to such an extent that little or practically no groundmass is left, and the rock has a holocrystalline, somewhat granite-like appearance. Some dikes observed are more granitic in the centers than on their borders.

One phase of the felsitic porphyry is porphyry-obsidian or glassy porphyry, which is a result of the sudden cooling of borders or of narrow tongues of intrusive porphyry masses. This obsidian was observed in the Colorado Central mine, in the Baltimore tunnel, in a prospect tunnel belonging to the Elizabeth group at Empire, and in a small tunnel south of the Silver Plume station.

The porphyries embrace a wide range of colors, which include gray, brown, green, pink, white, black, red, and violet. Some of the dikes are fresh, but in many of them the porphyry is in all stages of decomposition and alteration. The agents involved in the processes of silicification, kaolinization, and serpentinization have been actively engaged in different dikes or in different portions of the same dike. As a result the porphyries vary in hardness from the hard, brittle, comparatively fresh rock, or the silicified and well-indurated altered rock, to the soft "gouge"-like kaolinized or serpentinized forms. Surface outcrops of dikes are often weathered to such an extent that the original nature of the porphyry is distinguishable with difficulty, if at all. The granitic forms often weather to a coarse sand composed of the more resistant crystalline constituents, or to a friable rock but slightly resembling the original. The porphyry is often very much discolored. Various shades of brown and red are the commonest discoloration colors; these are probably due to limonite and hematite. More rarely manganese tends to stain the rocks dark brown or black.

The dikes of porphyry often vary in width within short distances. Usually they continue in comparatively straight directions, but instances of sharp angular bends were noted in two cases. The porphyries ocur in the gneisses, both parallel and transverse to the laminæ, and also intersect the granites, diorites, and pegmatites.

The porphyry is undoubtedly earlier than the veins. In many cases transverse mineral-bearing veins pass directly from granite or gneiss areas into and through a porphyry dike, and continue uninterruptedly into the granite or gneiss on the other side. Instances where dikes appear to cut off veins, as for example in the Pay Rock and Queen mines, probably result from a displacement of the vein due to faulting along the contact, or are due to the losing of the vein fracture in porphyry which had become decomposed and softened previous to the period of fissuring.

Conglomerate.—A few small patches of conglomerate were observed. The rock consists usually of coarse, well-rounded pebbles and cobblestones of gneiss, granite, pegmatite, and quartz, up to one foot in diameter, embedded in a well-indurated matrix resembling arkose sandstone. The rock is so well consolidated that when broken the fractures often pass through instead of around the pebbles. Two outcrops occur midway up the southeast slope of Lincoln Mountain. Conglomerate-like rocks are found to the north of Empire at a lower level, and also on the top of Leavenworth Mountain. It has not been possible so far to correlate the different patches of conglomerate or to determine definitely their origin. Perhaps they are in part at least stream deposits of late Tertiary or Quaternary age, formed at various stages of the down cutting of the region.

Pleistocene deposits.—Glacial deposits of at least two different epochs are found in certain parts of the region up to elevations of 1,500 feet or more above the valleys. Ground, lateral, and terminal moraines occur in the district; glacially striated and grooved rock surfaces are also numerous. Terraces and alluvial flats occasionally occur as a result of the damming of the streams by morainic material or by débris from landslides.

Faulting.—Numerous minor faults are known to intersect the rocks of the district. It is, however, almost impossible to follow faults on the surface, as the pre-Cambrian rocks form a "complex," and the surface is weathered and frequently covered with débris. In tracing out one of the porphyry dikes above Silver Plume, however, two faults involving an offset on the surface of about 200 feet each were encountered. Most of the more intimate knowledge of the faulting is derived from the underground workings of mines. Here small faults are frequently encountered. In the cases definitely determined the displacement is only from a few inches to 15 or 20 feet; but it is probable that in some instances it has been much greater. Most of the veins have formed along fault planes, and there has often been subsequent or post-mineral movement, both along the vein zones and transverse to them. Around Silver Plume and Georgetown the dip of movement striæ on slickensided fault surfaces as a rule does not exceed 20° from the horizontal. Instances of dips up to 35° or 40° are rare. Around Empire, however, dips of from 45° to 75° are much more common than the more nearly horizontal ones.

Contacts between two rock formations of unequal resistance, such as granite and gneiss, or some other older rock and porphyry, have evidently been especially favorable to faulting. The porphyry dikes themselves were probably intruded in part along old faults in the gneisses, granites, diorites, and pegmatites. Along these old lines of weakness the later movements probably successively occurred.

NATURE OF THE ORES.

The Georgetown district possesses a great variety of ores. The values are principally in silver, gold, lead, zinc, and copper, in the order named. Silver is found in small amounts in the native state as "wire silver," associated with ore minerals or by itself in seams of fractured rock. As a rule, however, the silver occurs in various mineral compounds associated with galena and zinc blende. In the low-grade ores the values lie in the galena and zinc blende, and separate silver compounds ordinarily can not be distinguished. The light-brown or yellow "resin zinc" seems to be more favorable for carrying silver values than the dark-brown or black sphalerite. In high grade sulphide ores the silver values lie chiefly in tetrahedrite and polybasite; ruby silver and tennanite also occur. Tetrahedrite, polybasite, and tennanite come under the miner's term "gray copper." The so-called strictly silver ores often average $2 in gold, especially if considerable pyrite is present.

Gold in the free state was formerly obtained in considerable amounts from placer deposits and from surface outcrops of veins in the vicinity of Empire. This gold was recovered by sluicing methods and through the agency of stamp mills. A limited number of stringers or "seams of native gold up to the width of a lead pencil in thickness "[a] were found several years ago in granite in the Hidden Treasure mine, near Empire.

At present the gold is obtained chiefly from pyrite-chalcopyrite ores. While free gold is found in this class of ores in very limited quantities, the major portion is intimately combined with the sulphides. The copper content of the minerals seems to be closely connected with the gold values, for unless chalcopyrite is present or the pyrite is more or less copper bearing the ore is usually too low grade to ship. Assays of pure chalcopyrite have given as high as 25 ounces in gold. Around Empire ores carrying $10 or over in values can be profitably mined.

A small mass of rich silver-gold telluride ore was also found in the Griffith mine, at Georgetown.

The ore in many of the mines is chiefly galena and sphalerite, with some pyrite and chalcopyrite and a small amount of silver. The percentages of the minerals, galena, blende, chalcopyrite, and pyrite, in the ore change so in different parts of the region that an infinite

[a] Verbal communication, Mr. David Ward, Empire.

variety of ores is a result. Bornite is prominent in ores of the Centennial and Gold Fissure mines.

The chief gangue mineral is quartz. Siderite appears prominently as a gangue mineral in the Griffith, Annette, Sceptre, and some other mines, and barite, aragonite, calcite, magnesite, and fluorite are occasionally met with in the veins.

VEIN GROUPS OF THE DISTRICT.

Grouping according to the form of vein systems.—In the Georgetown district, geographically different groups of veins differ from

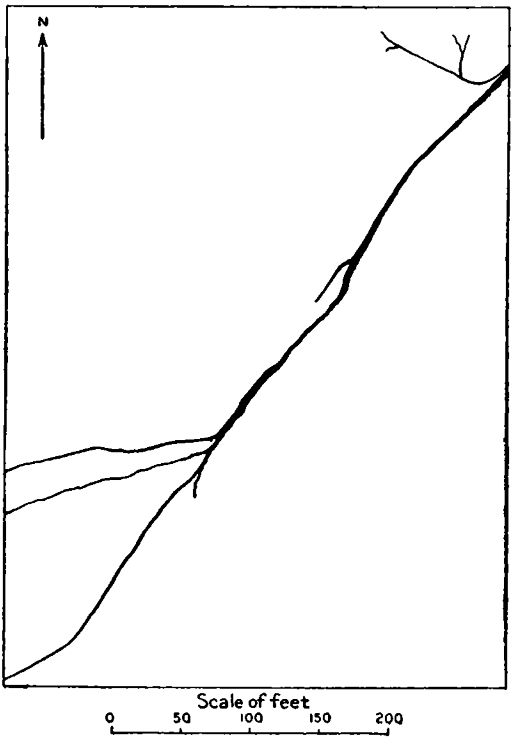

FIG. 5.—Horizontal plan of portion of Kirtley vein, showing the branching and the location of the ore bodies near junction of branches.

one another markedly in their internal arrangement. Following are some of the principal types of vein systems:

(1) The branching system consists of a main or master vein from which smaller veins branch (see fig. 5). These smaller veins may successively subdivide until they finally die out. The main vein itself dies out in a similar manner. In exceptional cases a branch may curve and return to the trunk vein, so that the two veins inclose

a "horse" of rock. This may take place in both a vertical and a horizontal direction. Most of the Silver Plume veins (Seven Thirty, Mendota, Pay Rock, etc.) belong to this type. This system is due to faulting, the movement having been horizontal along usually steeply dipping fault planes, as proved by numerous observed movement striæ whose dips range from very nearly horizontal to 25° or 30° from the horizontal.

(2) The crossing or Democrat Mountain system. This consists of at least two distinct sets of strong veins crossing each other—for example, a northwest set and a northeast set (exemplified by the Fletcher-Polar Star veins and the Rogers vein). The lodes cross each other, or may run into each other and stop. The branching type of veins is rare in the Democrat Mountain locality. This vein system is different from that just described as following branching fissures due to horizontal faulting. It resembles more the fractures in a solid shattered by concussion. Moreover, the rock appears to have been fractured without a great amount of slipping. Although slickensides and movement striæ were not observed in these veins, observations lead one to suspect that the force causing the fracturing was an almost vertical one.

(3) The Empire system of combined branching and crossing veins is intermediate between the Silver Plume branching type and the Democrat Mountain crossing type. The lodes undoubtedly cross in many cases; in others they merge at the junctions. The Gold Dirt group of veins at Empire is the best representative of this system. Two steeply inclined (50° to 75° from the horizontal) crossing sets of movement striæ on the vein walls indicate strains intermediate between those which caused the vein system of Silver Plume and those which probably affected the rocks of Democrat Mountain.

(4) A fourth system consists of one or more practically non-branching veins arranged along or parallel to the contact between a porphyry dike and the neighboring rocks. The Sunburst-Sceptre vein illustrates this class.

Grouping according to mineralogical differences.—A classification may also be made on characteristic mineralogical and chemical differences, often with attendant physical differences. Among the characteristic ore types resulting from such a study are the following:

(1) Seven Thirty–Bismarck type (Dunkirk, Wisconsin, Pay Rock, etc.) is marked by relatively high-grade silver ores containing considerable galena, some zinc blende, usually of a dark-brown color, considerable polybasite and gray copper, a little copper-bearing pyrite, and a small amount of pyrite. There is little evidence of fissure-filling in this group. Junctions of different veins or branches usually make ore bodies.

(2) The Colorado Central type, of high-grade silver ore, is composed of considerable galena, some zinc blende (usually yellowish "resin zinc"), characteristically large amounts of ruby silver, polybasite and tetrahedrite, and only faint traces of pyrite and calcite.

(3) The Mendota-Frostberg type (Maine, Terrible, Ocean Wave, etc.) is composed of broad and exceptionally strong low-grade zinc and lead ore veins. They are usually large fissures containing rubble cemented by heavy dark-colored zinc blende, considerable galena, varying amounts of pyrite and chalcopyrite, and a relatively small amount of silver. Besides the fissure cavities, there are frequently ore-filled spaces of dissolution in crushed portions along the vein zone, and also in the granite near the vein. The ore is chiefly at the junctions of veins.

(4) The Republican Mountain type (Mineral Chief, Boston, Beecher, Muscovite, Sunburst, Sceptre, etc.) is characterized by predominance of lead, small amount of zinc, considerable pyrite, low content of silver, a little siderite, copper pyrites, gold, and sometimes gray copper. Physically these lodes are likely to be strong and large, but are in places entirely unmineralized. The ore seems to be richer at vein junctions. The Sceptre-Sunburst ore is a variation of this class, containing a characteristically large amount of siderite, with comparatively small amounts of galena, blende, and pyrite, and slightly more silver.

(5) The Democrat Mountain type is distinguished from the Republican Mountain type by being relatively high-grade ores, composed chiefly of galena, with a high percentage of silver, scarcely any iron, and very little zinc. The ore bodies, though small, are well defined, and are usually located near crossings or junctions. The ore bodies are all located near the surface, the veins not being much unmineralized, so far as known, below a depth of 200 to 300 feet.

(6) The Empire type. The ores of this type are made up almost entirely of low-grade gold-bearing pyrite and chalcopyrite, with no lead and zinc and only a trace of silver. Normally the pyrite is practically without gold values, while the wholly chalcopyrite ores contain the most gold values. These ore bodies appear to be chiefly due to impregnation and replacement of the wall rock, and to be little affected by junctions or crossings.

(7) The Griffith type. This is a gold-silver ore, with varying amounts of lead, zinc, and cupriferous pyrite, chalcopyrite, etc. To this class belong the Griffith-Annette ores, which are predominantly low-grade gold-silver ores consisting of crystalline iron pyrite, chalcopyrite, galena, and sphalerite, with a gangue of siderite, quartz, and some barite. The better grades of ore usually have the most galena, blende, and chalcopyrite. Phenomena show that the galena-blende-

chalcopyrite ore formed the original vein, and that the vein was reopened and the pyrite-siderite filling deposited in the fissure thus formed. The pyrite has been deposited in such abundance that it ordinarily predominates over the other sulphides in the present veins.

The Centennial ores, which come under this general type, are distinguished from the above in being chiefly pyrite-chalcopyrite ores, containing less amounts of galena, zinc blende, and siderite, and a greater percentage of copper. Bornite is a characteristic mineral of the ores of this mine at times. The values are chiefly in gold.

Fairly high-grade ores, composed of chalcopyrite, pyrite, galena, and zinc, are found in limited quantities in the Mint mine at Empire, and the Ramsdale, on Lincoln Mountain. Here also the values are chiefly in gold.

OCCURRENCE OF ORES IN THE VEINS.

Structure of the lodes and ores.—Many of the veins of the district represent the filling of open fissures (the Frostberg, Terrible, etc.). These veins vary from one-half inch to 6 or 7 feet wide: usually when of the latter width they consist of numerous vein branches looping around "horses" of country rock. In places the fissure has been filled completely with ore, but almost invariably a layer of comb quartz is found between the ore and the wall rock. Many vugs are found in some of the veins; these often show crustification. Quartz, barite, siderite, and calcite are the commonest crystals found in vugs, although galena and sphalerite crystals are not uncommon. In many cases the veins have the nature of rubble-filled fissures in which angular fragments of the wall rocks have been cemented together by ore, thus forming a breccia. By subsequent movements the veins have sometimes been reopened and the ore cement, above mentioned, brecciated in turn and recemented by pyrite, siderite (see fig. 6), or quartz. Many good examples of brecciated fragments of zinc blende, galena, and comb quartz in a later cementing matrix were found in the Terrible, Frostberg, Mendota, Griffith, Sceptre, Sunburst, and other mines. Economically important pyrite acting as such a cement is found in some of the gold-bearing veins, as the Centennial. In the Griffith-Annette mines, near the Centennial, intercrystallized siderite and pyrite, the former predominant, cement the antecedent galena-blende ores and make up at present far the larger part of the vein. Some cases show that later than this the siderite itself was brecciated, and recemented by a dark-gray jaspery quartz, as in the Sceptre and Sunburst mines.

Many veins show little evidence of fissure filling. Others show in portions crustification and the cementing of angular rock fragments, while in other parts of the same vein these evidences of cavity filling may be entirely absent. Such fissure veins sometimes con-

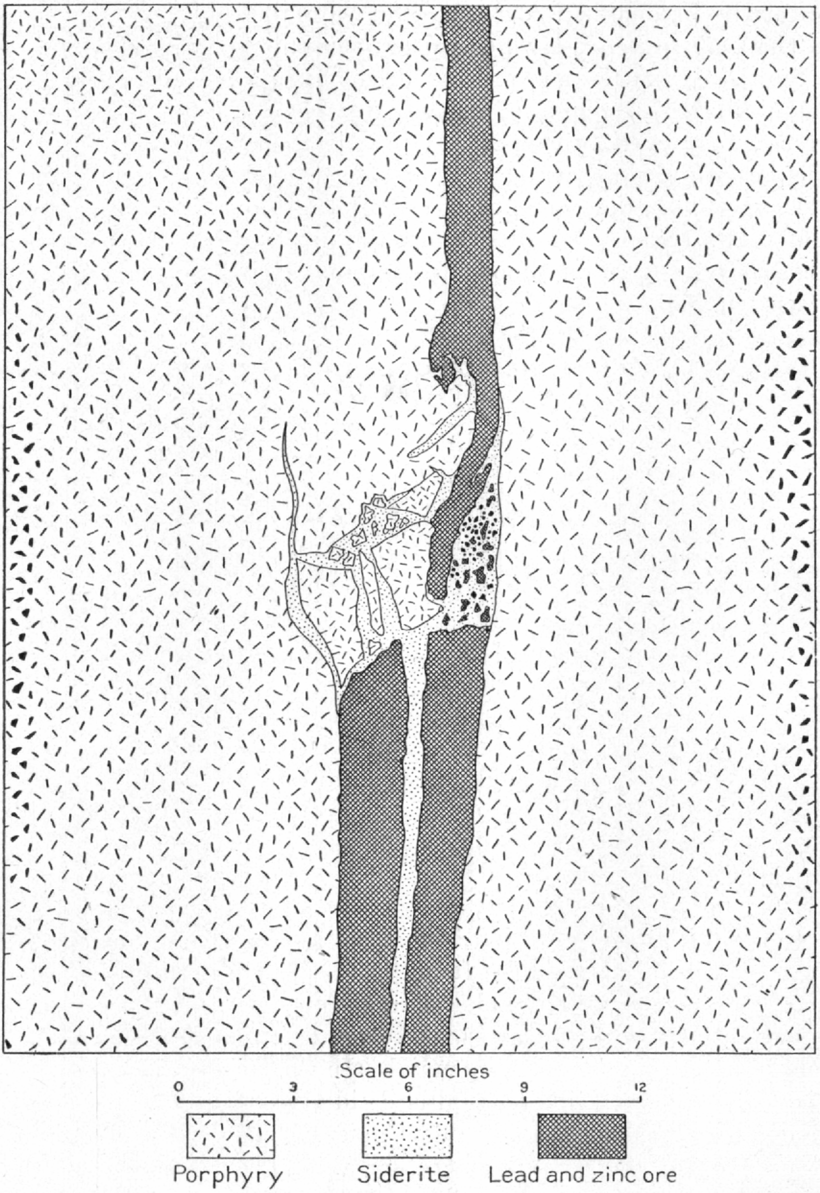

FIG. 6.—Vertical section of portion of the Sceptre vein, showing reopening of fissure in primary galena and blende ore filling, with subsequent siderite.

tract or pinch and the vein becomes reduced in width to a mere crack, so faint that miners are unable to distinguish it from the joints of the country rock.

Veins which are usually straight and regular single fissures sometimes locally split up into small stringer lodes. This is likely to happen near the ends, especially if the vein enters soft micaceous gneiss. In this latter case stringers of ore often spread out between the laminæ of the gneiss, and dwindle in size until they disappear.

The ore in the veins is sometimes found adhering or "frozen" to the walls. Again, however, there has been sufficient movement along the vein to cause the ore to come away readily from the walls, due to the formation of a narrow streak of gouge or selvage between the two.

In many instances veins consist entirely of a zone of crushed, pulverized, and more or less altered country rock. This vein filling differs little from the wall rocks except in being slightly more silicified and kaolinized. A crushed zone of this kind offers a natural channel for the circulation of underground waters; but as a result of the retardation to the flowage of water, due to the obstructed condition of the passage, these zones would be favorable to ore deposition. Instances were noted where parts of the crushed zone, more particularly next to the walls, had become changed to quartz; others where quartz and ore formed a sort of network with regular outlines between the two walls. It is easy to imagine this process continued further until the whole space between the two walls is filled with ore. This, then, may be the origin of some of the lodes which now have the appearance of having formed in open cavities and are completely filled with ore. Occasionally such veins contain small patches of quartz which show crustification, and comb quartz, which give the impression of fissure filling. However, these spaces are very irregular in shape and are not true fissures, but undoubtedly cavities of dissolution resulting from the action of the mineralizing waters.

Another type of ore is that resulting from the impregnation and replacement of wall rocks bordering fractures which acted as water-courses for mineralizing solutions. As a combined result of the process of replacement and impregnation there are all gradations between rock sprinkled with small amounts of the ore minerals to solid ore. The ore bodies of the Empire mining region are usually very irregular in outline, have ill-defined boundaries, and are composed of ore gradations similar to those above described.

Location of ore bodies.—Among the factors which are especially favorable to the formation of ore bodies in the district are the following:

1. Junctions of two large veins, or junctions of branches or feeders with the main vein, where different solutions have mingled and thus caused precipitation.
2. Intersections or crossings of veins, for the same reason as No. 1.

3. "Linked" nature of portions of a vein, producing a widening of the vein zone and intersecting channels for circulation, with crushed "horses" between.

4. Broad zones of weakness in rocks, permitting thorough saturation by mineralizing waters (vicinity of Empire).

5. Mechanical connection with porphyry dike. Along such dikes fault movements have frequently taken place and vein deposition has followed. The decomposed porphyry has also frequently acted as an impervious barrier to solutions, inducing precipitation in the opened zone which follows along it.

6. Rigid wall rocks, producing good openings.

7. Abundance of water, and conditions suitable for mingling of chemically different waters.

8. Proximity to the surface.

While the last three of these factors, (6) nature of wall rocks, (7) abundance of water, and (8) proximity to the surface, are of importance in practically all parts of the mining district, the first five factors are of variable importance in different parts of the district. For example, around Silver Plume and in the immediate vicinity of Georgetown the factor "junction of veins" is very important. At least three phases of vein juncture, with varying location for the ore bodies, are found in the Silver Plume region:

1. When two minor veins of like dip unite to form a main or trunk vein, or when a branch vein unites with a main vein, the rich ore body may be located on the main vein a *short distance beyond the junction.* Often the two veins which unite carry no ore whatever, or at least none of any economic value. Examples of this type are numerous. Among them may be mentioned the junction which caused the richest ore body on the Pay Rock, the union of the Brown and Philips veins in the Burleigh tunnel, and the junctions which form the Carnahan stopes in the Colorado Central.

2. When two minor veins of like dip unite to form a main or trunk vein, or when a branch vein unites with a main vein, the rich ore may be located *directly at the point of juncture* on the trunk vein, and usually also on both uniting veins for a short distance away from the junction. Excellent examples of this type occur in the Lebanon and Kirtley mines. (See fig. 5.)

3. When two veins of different dip unite, the ore shoot ordinarily occurs in the V-shaped, usually pitching trough on the upper side of the junction. Examples are found in the junction of the John J. Roe vein with the Seven Thirty and the Vice-President lodes. The union of the flat vein with the South vein in the Colorado Central mine is another illustration.

Occasionally ore bodies have been found in the Silver Plume area which apparently have no connection whatever with ordinary vein junctions. Some of these have every appearance of having originated as a result of the "linked" nature of that particular portion of the vein. By the "linked" nature is meant the splitting and reuniting of the vein, often in both a vertical and a horizontal direction, about a "horse" of country rock. The ore body results from the gradual impregnation and replacement of the isolated mass of rock by quartz and ore through the agency of the mineralizing solutions from the inclosing channels.

In the Republican Mountain group the richest ore shoots, in most cases, have some connection with vein junctions. An example is the junction of the Boston and Beecher veins.

The point of intersection or crossing of veins is the favorite location for ore bodies in the Democrat Mountain area, although ore in large quantity does not always occur at such a place. Proximity to the surface is also a characteristic feature of the Democrat Mountain ore deposits. Good ore here has rarely been found below 200 to 300 feet, and the ore shoots tend to pitch with the slope on both sides of the ridge of the mountain. Ore shoots also occur in this region near but not at the junctions of branches with the main veins.

In the mining region about Empire broad zones of weakness in rock inclosed between intersecting or uniting veins, or in crushed rock zones extending indefinitely away on both sides of a central fault plane, are locations for large irregular and faintly outlined ore masses. These ore bodies represent areas of strained or crushed rock where there has been impregnation of sulphide ores from the centrally located small fissures. As a rule the ore bodies in the Empire region occur away from the vein junctions.

In connection with porphyry dikes ore shoots have several modes of occurrence. According to Mr. F. A. Maxwell[a] the ore on the Schively vein at Silver Plume all occurred in the portion of the vein between two parallel porphyry dikes which run at right angles to and are intersected by the vein. The explanation of this is probably that the dikes became decomposed and impervious, and that the waters rising along the vein fissures were confined in some way to the portion between the dikes, and so rose in a sort of chimney, where the circulation was unusually vigorous.

In the case of veins parallel with and at or near the contact of a porphyry dike (such as the Bismarck or Colorado Central veins), the fault movements which have produced the vein openings have followed these courses on account of their being zones of mechanical weakness. Moreover, after the formation of the fault opening, the solutions have doubtless often been checked by the porphyry, where

[a] Verbal communication.

impervious and decomposed, and the deposition localized along the dike. In this class of veins, also, the ore shoots in detail are often due to the juncture of branches with the main vein.

Influence of the wall rocks.—The nature of the country rock along the line of fracture of a vein influences greatly the character of the fracture formed, and consequently the nature of the ore deposited in the vein. Brittleness seems to be the especial quality which enables rocks to form strong fractures. Of all the rocks of the district the granites and the hard gneisses as a rule answer this qualification best. On the basis of this theory we might expect to find the broadest and strongest veins (not necessarily with the highest grade of ore) in these rocks. The facts tend to uphold the theory in the case of the strong fissure veins of the Mendota-Frostberg system and also in other instances. Highly porphyritic granite seems especially likely to occur as a wall rock of veins. The altered form of this granite occurring in the vicinity of veins has white altered phenocrysts. In this altered form the rock is locally termed "corn rock," and is regarded by the miners as a "good rock for ore." This porphyritic phase, which may represent more rapid cooling than in the ordinary granite, occurs near the contacts of the more granular masses and also in numerous dikes. It is thus frequently in contact with gneiss or other rocks of less or at least different resistance to strain. Therefore, as in the case of porphyry dikes, fault movements have taken place by preference along these contacts. This consideration, together with that of the natural rigidity of the porphyritic granite, explains its frequency as a wall rock of strong veins.

A fissile gneiss usually gives rise to a much weaker vein, while a soft micaceous gneiss or schist is exceptionally poor for vein formation. Many cases were noted where strong veins in granite upon entering soft micaceous gneiss pinched to a faint slip or else scattered and disappeared entirely, by sending ramifying branches between the laminæ of the gneiss.

As far as observations could detect, the porphyry of the district did not seem to have any influence upon the formation of the ore deposits other than that exerted by the other rocks of the region. The relations between the veins and the porphyry dikes all tend to show that the porphyry dikes were not only well consolidated long before the veins were formed, but that in many cases they had undergone considerable alteration prior to the fracturing. As a general rule the veins of the district do not "make" much ore when porphyry forms both walls of the fracture. In many cases a strong lead in granite or hard gneiss dwindles in size while passing through porphyry, which is usually somewhat soft from alteration. This indicates that the ores were deposited after the softening of the porphyry took place, for normal fresh porphyry ought to afford as good fractures as granite. Fig. 7 illustrates the general tendency of the veins of the district to diminish in size and economic importance on passing from granite or hard gneiss to somewhat altered porphyry. An ex-

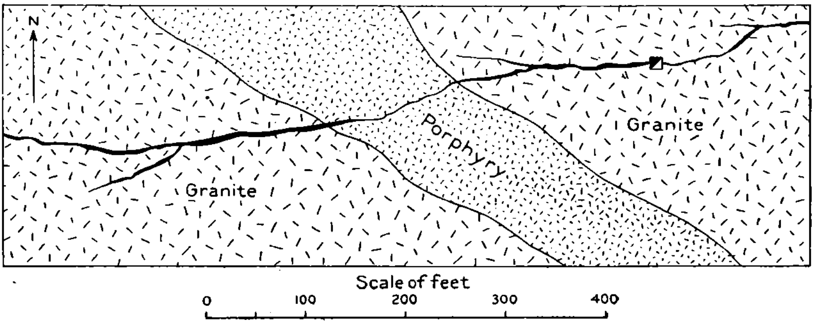

FIG. 7.—Horizontal plan of a portion of the Seven Thirty vein on the 80-foot level, showing a diminution in size of the vein in its passage from granite into porphyry.

ception to the general lack of ore in the porphyry, which, however, proves the main contention, is illustrated in fig. 8, which represents the vein in one of the upper tunnels of the Maine mine. Here the still comparatively fresh porphyry was evidently more rigid and brit-

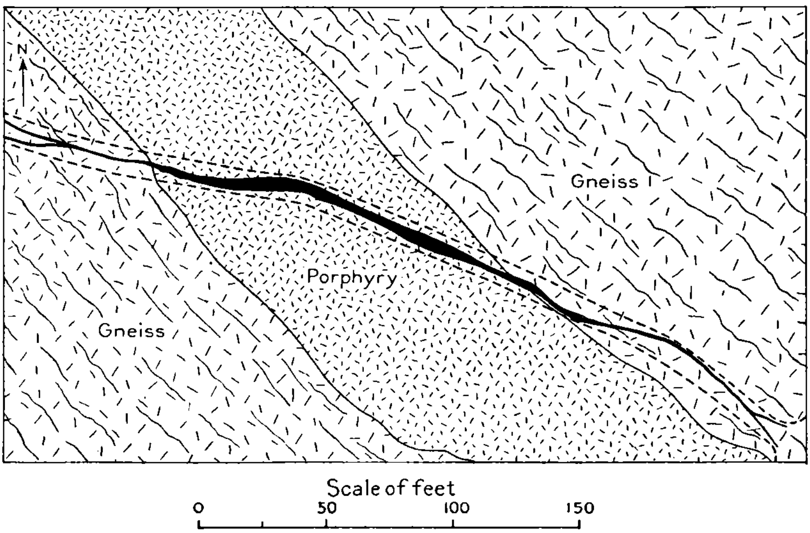

FIG. 8.—Horizontal plan of vein in tunnel of Maine mine, showing thickening of vein in passing from gneiss into harder porphyry.

tle than the gneiss which lies on both sides of the dike, and accordingly fractured better. The vein in the porphyry consists of a mixed ore and rock lode, varying from 2 to 4 feet wide and containing solid, low-grade, coarse blende, pyrite, and galena ore seams up to 1 foot in thickness. On entering the gneiss this strong vein diminished in size, became less mineralized, and very shortly dissipated itself by successive branching. This illustration tends to show that when fresh and hard the porphyry has afforded as good fissures for the location of ore deposits as any of the rocks of the district.

Although two porphyry walls are usually unfavorable to ore in the Georgetown district, exceptionally strong veins are found parallel to porphyry dikes and often at the contact of porphyry with other formations. At times the mineralized parallel vein is not immediately at the contact, but several feet away, entirely in gneiss, pegmatite, and granite. In some cases, as in the Sceptre, Sunburst, and Colorado Central mines, the porphyry dike is not decomposed, and therefore could not have been the source of the ores by leaching. Veins along porphyry contacts frequently diverge from the dikes and leave them. Strong veins entirely unconnected with any porphyry are perhaps as numerous and productive as those that are.

CHEMICAL ALTERATION OF ORES.

Primary sulphides.—The greater part of the immense masses of galena and zinc blende of the Georgetown district undoubtedly belong with the primary ores. Considerable of the chalcopyrite and pyrite associated with these lead and zinc sulphide ores are also probably to be classed with the primary minerals. There are two classes of the original lead-zinc ores: (1) a low-grade, coarse, zinc-blende ore carrying some galena and a small amount of silver, (2) high-grade ores containing a larger quantity of galena, less zinc blende, and a higher percentage of silver. Possibly the greater richness of this latter class of primary ores is due in part to the fact that a portion of the polybasite and tetrahedrite found in the secondarily enriched ores existed as primary minerals in the original sulphide ores. Without doubt the large, very low-grade pyrite and copper-pyrite deposits found in the lowest mine workings about Empire also represent primary deposits.

Secondary sulphides.—Polybasite and argentiferous tetrahedrite (" gray copper ") generally contain the values of the rich silver ores of the region. Ruby silver (pyrargyrite and proustite) and silver-bearing tennantite, though not so widespread, also aid in forming the rich deposits. These minerals are probably largely dependent upon the action of subsequent waters upon the primary ores; yet, as already intimated, a portion of them may have existed previous to the enrichment. The largest amounts of these rich secondary minerals have formed in the originally large and lower grade lead and zinc bodies, but usually only in those portions favorably opened by fractures. These rich minerals do not seem to be concentrated from the oxidized zone, which is itself the richest of all, but seem rather to have been segregated from the surrounding sulphides. Specimens were found in which seams of massive polybasite mixed with ruby silver cut through primary massive lead and zinc ores. The frequent existence of well-crystallized polybasite and ruby silver lining vugs and fissures in galena-sphalerite ore also points to the secondary origin of the greater portion of these minerals.

That all of the galena and zinc blende is not primary is shown by the occurrence along open crevices of fresh and apparently recently deposited crystals of these two minerals, and also by the presence of crystals of galena and sphalerite on top of crystals of siderite, a mineral which sometimes occurs lining reopened lead-zinc filled fissures. A specimen[a] from the Maine mine shows large crystals of polybasite with good-sized crystals of blende and galena on their faces. The polybasite crystals are also covered with minute specks of native silver which is evidently secondary to the polybasite. Native silver in the wire or flake form is also frequently found in crevices and along fault fractures partly or wholly filled by vein material. This is probably the effect of descending waters.

Considerable chalcopyrite and pyrite are also secondary. These last-named minerals are found in isolated seams in rock and also coating the sides of crevices. Many of the more cupriferous ores of the Empire area doubtless owe their greater richness to the enrichment which has resulted from the leaching of the ores nearer the surface.

The bornite which is found in some of the mines is later than and secondary to the chalcopyrite, as shown by its occurrence in definite streaks along fractures cutting both chalcopyrite and pyrite.

Small amounts of argentite (Ag_2S, "silver glance"), acanthite (Ag_2S), and enargite (Cu_3AsS_4), are also to be classed with the secondary sulphides.

Oxidized ores.—Oxidized ores found in the Silver Plume-Georgetown area lie in a comparatively limited zone, extending from the surface down. Forty feet is a good average depth of complete oxidation. Occasionally small pockets of oxidized ore have been found far below the points above noted, even reaching depths of 1,000 feet or more below the surface along channels occupied by descending surface waters. The ores in the oxidized zone—the "sulphurets" of the miners—at times are granular, black, easily friable masses, while again they have the appearance of brown clay, often stained reddish, yellowish, or greenish. No analysis of these oxide ores has as yet been made, but they probably consist in part of lead carbonates or oxides, black silver sulphide ("silver black" of the miners), silver chloride, black oxide of copper, etc.

[a] Owned by Mr. Randall, of Georgetown, D. C.

Azurite and malachite are often abundant as coatings on minerals near the surface. Specks of these copper carbonates have also been found in the sulphide zone at considerable depths.[a] Occasional coatings and stalactites of copper sulphate and iron sulphate on chalcopyrite and pyrite ores show the method of alteration of these ores.

Below the oxidized surface zone come the sulphides, galena, zinc blende, pyrite, chalcopyrite, etc. Sometimes, as in parts of the Mendota vein, there is a sharp dividing line between the oxide ores and the sulphide ores; again the transition is very gradual.

At the gold mines of Empire the surface material usually consists of free-milling gold ores with very little, if any, sulphides. The surface vein filling is chiefly gold-bearing, "honeycomb," cellular quartz, containing cavities left by dissolution of the pyrite crystals. The zone often extends 60 or 70 feet below the surface, but only averages between $2.50 and $4 per ton. Below the free-milling surface ores of the Empire veins are pyrite and chalcopyrite ores, often of much higher grade.

While in the Empire gold district the oxidized ores are poorer than the sulphides below, the reverse is true of the silver districts around Silver Plume and Georgetown, where the oxidized ores are usually much richer than the sulphides of lower depths.

FAINT ZONAL DISTRIBUTION OF THE ORES.

There are evidences in some of the mines of a zonal distribution in the minerals of the sulphide zone, but nothing regular and persistent has been established.

In the Mendota mine low-grade zinc-galena ores of practically uniform nature extend from the bottom of the narrow oxide belt, 15 or 20 feet below the surface, to depths of over 1,000 feet. In the Colorado Central mine shoots or bunches of very high-grade lead and zinc sulphide ores bearing polybasite, tetrahedrite, and ruby silver may be found occurring at any depths in the low-grade galena and sphalerite ores down to 1,050 feet below the surface.

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[a] Colorado Central, 1,000-foot level.

THE NEGLECTED MINE AND NEARBY PROPERTIES, DURANGO QUADRANGLE, COLORADO.

By William H. Emmons.

LOCATION.

The Neglected mine is situated on the east slope of the La Plata Mountains, near the head of Junction Creek. It is in the small area of mineralization locally known as the "Oro Fino district," which lies in the western part of the Durango quadrangle. Prospecting for gold and silver has been carried on in this district for a number of years, but until recently operations have been confined mainly to development and assessment work.

Mr. C. W. Purington made a visit to this region in 1896 incidental to a study of the economic geology of the La Plata quadrangle, but later developments of some of the properties—especially at the Neglected and Durango Girl mines—appeared to be of sufficient importance to warrant reexamination in connection with the economic section of the text for the Durango folio, which is now in course of preparation by Mr. Whitman Cross.

The mining district is only about 15 miles from Durango, where the American Smelting and Refining Company operates a thoroughly modern smelter. It is not, however, so accessible as at first appears, since the rise to most of the mines is more than 3,000 feet, and roads in this rugged country are difficult to construct and expensive to maintain. Transportation to and from the present producing mines is for the greater portion of the distance by mule trains, although wagon roads, built for the hauling of machinery, are still in a more or less serviceable condition.

GENERAL GEOLOGY.

Character of the rocks.—The mines are located in an area of sedimentary rocks intruded by sheets and dikes of green porphyry, which in turn are cut by dark basic dikes. The sedimentary rocks consist of red calcareous clay shales, red sandstones, and conglomerates. The strata grade into each other horizontally and vertically, no single member persisting for any considerable distance. These rocks belong to the series generally known as the "Red Beds," and to the lower division of that series, the Cutler formation, which is very probably of Permian age. The intruding bodies are diorite- or monzonite-porphyries—light grayish-green rocks with white feldspars and dark hornblende phenocrysts. The porphyry sheets are usually about 50 feet thick, though they are often thinner. While they generally follow the bedding planes of the rocks which they intrude, frequently they are crosscutting and often irregular. The porphyry dikes are generally about 25 feet thick and have the same lithologic appearance as the sheets, from which they can not be distinguished except upon structural evidence. The basic dikes, which cut the green porphyries, are very dark and of a denser texture. These are only a few feet wide.

The age of the green porphyries is not definitely known. They are later than the "Red Beds," which they intrude, and from their similarity to intrusions of like character in neighboring districts they are assumed to be Tertiary.

Fissures.—Both the sedimentary and igneous rocks are jointed and fissured in several directions. There is a well-defined set of fissures running a few degrees south of east. This set of fissures is notable in the Durango Girl and Neglected mines, and is mentioned by Mr. Purington as occurring also in the southern part of the La Plata Mountains. Mr. Purington believes that the east-west fissures are of earlier age than the other fissures and that they are also older than some of the intrusive rocks.

Metamorphism—The sandstones, which are usually red and friable, are considerably metamorphosed in the vicinity of the ore deposits, where they have been indurated by the deposition of silica, and their color has been changed to light gray. It appears that the iron oxide, to which their usual red color is due, was either removed or altered. The shales, too, are more or less silicified, and their color is similarly changed, so that it is sometimes difficult to distinguish shale from sandstone. The fractures of the sediments where they are brecciated are sharp and clear cut, suggesting that their induration partly preceded the movement which crushed them. Since their induration appears to be due to the action of circulating water rather than to contact metamorphism induced by the heat of the porphyry, it would seem that there was some fracturing before and some after the metamorphism of the sediments. The fracturing and the metamorphism were probably concomitant.

ORE DEPOSITS.

Forms of the ore deposits.—The ore deposits fall into two groups: (1) those which occur as a filling between two walls of different rock, and (2) those which are situated along fractured zones at or near the contact between the sedimentary rocks and the porphyry, where impregnation and partial replacement has occurred. The best example of the first class is the Cumberland mine, just northwest of Cumberland Mountain, where, according to Mr. Purington, there is a well-defined vein several feet wide, consisting mainly of white quartz. The deposits of the Durango Girl and Neglected mine belong chiefly to the second class. There are gradations between these two classes of deposits, and sharp differentiation is not always possible. Even in the two mines last mentioned small fissures occur in the shattered zone, and these are filled with white siliceous minerals, mainly quartz, in which the precious minerals may occur.

Minerals of the ore deposits.—The metalliferous minerals of the La Plata district are the tellurides of gold and silver (sylvanite, petzite, and probably calaverite), native gold, native quicksilver, amalgam, freibergite, tennantite, stephanite (and other sulphantimonides and sulpharsenides of silver), pyrite, marcasite, chalcopyrite, galena, zinc blende, realgar, hematite, and magnetite.[a] Dr. W. F. Hillebrand, who examined the ores from the Durango Girl mine, found also a mercury sulphide, probably cinnabar. Though there is a considerable variety of gangue minerals in the deposits of the western part of the La Plata Mountains, in the properties examined in the Oro Fino district the gangue appears to be composed chiefly of quartz, kaolinite, hydrous silica, and sericite.

General character of the ore deposits.—All of the workings in the Oro Fino district are, so far as known, in or near the green porphyry intrusives. In some instances dark basic dikes cut the porphyries near the ore deposits, but in many cases these are absent, or at least are not exposed. The structural features which, from an economic standpoint, are the most important appear to be the fracture zones, which in the cases observed run nearly east and west. It is along these that the ore bodies lie. The ore may be developed in the porphyry, at its contact, or in the sedimentary rocks near the porphyry. Often it appears to be a replacement of the porphyry, which, in the vicinity of the fractured zone, is altered and decomposed. Both porphyry and sediments are sometimes impregnated with pyrite for a short distance away from the broken zone, and through them are little stringers of white quartz, which carry flakes and specks of telluride.

In cases where the sedimentary rocks are impregnated there does

[a] This list is a revision of that given by Mr. C. W. Purington in folio 60, page 13.

not appear to be any constant difference between the development of the ore in the sandstone and in the shale. In the Neglected mine the shale is considered the most productive horizon, while in the Durango Girl the richer ores so far have occurred in the quartzite below the shale. It appears that the movement which shattered the sandstone also shattered at least the lower portion of the bed of shale.

Alteration of the ores.—The surface portions of the ore are partly oxidized or altered. Free gold occurs in small quantities associated with sylvanite, and the pyrite has altered into limonite. Ores taken near the surface in the Ruby claim, which is in the gulch south of Cumberland Mountain, show a considerable quantity of native quicksilver, which occurs as small globules in a matrix of quartz and sylvanite; and small flakes of a yellow mineral, believed to be native gold, also occur in the same hand specimen. Satisfactory identification of the form of the gold is difficult in such an association, since the usual treatment designed to separate the metals from the gangue would amalgamate them. This intimate association of native gold and native quicksilver not amalgamated is unusual. It is probable that both are the alteration products of the original ore. The altered rock is also stained with malachite.

THE NEGLECTED MINE.

History.—The Neglected mine is situated near the head of Gaines Gulch on the west slope of Monument Hill at an elevation of 10,300 feet above tide. The property has been known as a prospect for ten or fifteen years, but was not extensively exploited until the early part of 1902, when an ore body was struck from which, in the following year, 1,070 tons of ore were shipped, and the returns from which amounted to $117,041.28 in gold and $1,682.30 in silver. The mine has been operated most of the time since then, and recently a mill has been installed for working low-grade ores, which can not be profitably shipped.

Equipment.—The mine is worked through a vertical shaft from which levels running east and west have been opened at depths of 85, 125, and 175 feet. The drifts at these levels aggregate nearly 2,000 feet. The shaft is supplied with a friction hoist, and a duplex pump running a 2-inch stream about half of the time keeps the mine dry.

The ore passes from the shaft house over a surface tramway to the crusher, which prepares it for a Chilian mill. This reduces it to fine size. From the mill it passes over amalgamating plates and over Frue vanners and canvas tables.

Geology.—The mine is located in the lower "Red Beds," the Cutler formation, which, in the vicinity of the workings of the mine, is made up of sandstones and calcareous shales. These sediments dip to the east at a low angle and are cut by a dike of monzonite-porphyry which trends nearly east and west. An intrusive sheet of monzonite-porphyry—a grayish-green rock which contains light-gray feldspar phenocrysts and which lithologically resembles the dike—appears to cross the gulch near the lower workings of the mine. Owing to limited exposures above ground, relations are not quite clear, but it is very probable that this sheet is in part the porphyry which is encountered near the lowest level. There is a shattered or fractured zone which trends a few degrees south of east, crossing both the porphyry and the sediments. Near this zone the rocks are much altered. The feldspars of the porphyry have completely decayed and their spaces are filled with white mud, chiefly kaolinite, while the groundmass of the porphyry has been silicified. The porphyry and also the sedimentary rocks contain a considerable quantity of pyrite which appears to be secondary.

Ores.—The principal ores of the mine are tellurides of gold and silver, and of these sylvanite is much the most important. Native gold, pyrite, and amalgam are present. At the close of a mill run the retorts yielded a considerable increase of quicksilver over that introduced on the amalgamation plates.

The ore deposits.—The ore deposits are quite irregular in form, but in a broad way they follow the vertical fracture zone which crosses the property east and west. The ore occurs as small rich veins and as stringers of white and gray quartz. The veins and stringers occur in the porphyry and at its contact with the sediments, and to a certain extent in the sediments also.

The plane of the shaft and the levels is at or near the contact of the porphyry dike and the sediments. The sediments here are sandstones and silicified shales. Experience in the development of the mine has shown that the contact between the sediments and the porphyry is the most favorable place to look for the ore, and so far the shale has proved the more favorable horizon. Apparently on account of their induration the shales and sandstones were at the time of their deformation equally easily fractured, and the water which deposited the metals penetrated both with equal facility. The most profitable horizon has been the zone between the 125-foot and the 175-foot levels. There has also been replacement and impregnation of the country rock away from the stringers or pay streaks, and here the values, considerably lower, are said to run largely in the pyrite. This is the milling ore.

Treatment.—The rich pay streaks are separated from the surrounding rock and the ore is sacked and sorted in the mine. This richer ore is taken to the smelter by pack train. The remaining low-grade ore goes to the mill, where it is amalgamated and concentrated. About 28 tons are concentrated into one, and the concentrates are carried to the smelter.

THE DURANGO GIRL MINE.

Location and production.—The Durango Girl mine is situated on the east slope of Lewis Mountain, in Walls Gulch, which is tributary to Junction Creek. Its altitude is 9,900 feet above sea level. The mine was located in 1893 and has been worked in a small way ever since. The ores are chiefly tellurides and the sorted shipping product is very rich. In 1903 and in the first half of 1904 its production was 36.27 tons, which netted something over $400 per ton. The ore is sacked at the mine and carried by pack mules and by wagon to Durango.

Geology.—The geologic relations are almost the same as at the Neglected mine. The lower "Red Beds," the Cutler formation, dip sharply eastward and are intruded by sheets of monzonite-porphyry and cut by a dike of the same rock. A fracture zone or fissure cuts the sediments and the porphyry, having nearly the same general direction as that in the Neglected mine. The mine is worked by a tunnel which follows this fissure, and much of the ground above the tunnel has been stoped out. Two dikes of a dark, fine-grained basic rock, trending nearly east and west, cut the porphyry and the sediments. These dikes have nearly the same direction as the vein.

The ore deposits.—The ore deposits occur along the vertical fracture zone which passes through the sediments and the green porphyry. The ores appear to be in part a replacement or alteration product of the porphyry, which, since its intrusion, has been crushed and impregnated. The sediments near the porphyry have likewise been mineralized. Small pay streaks or stringers of very rich ore occur in this altered zone. Some of these appear to be composed mainly of white hydrous silica which contains flakes and specks of sylvanite. These are light gray in color. Other and richer streaks are composed of clear, colorless quartz, talc, kaolinite, tellurides, and sulphides. These metallic constituents sometimes make up as much as one-fourth of the volume of the pay streaks. A mechanical separation of a sample of this rock was made in the Survey laboratory and the metallic constituents were examined by Doctor Hillebrand. Sylvanite, free gold, tetrahedrite, and a mercury sulphide were found to be present. Some of the richer ores occur also in the sedimentary rocks; a quartzite member which occurs below a bed of shale has, so far, proved the more productive horizon.

OTHER MINES AND PROSPECTS.

The Jenny Lind claim is also in Walls Gulch and its ore deposits are said to be similar in character to those of the Durango Girl, which lies below. The Ruby claim, located south of Cumberland Peak on a small tributary to Junction Creek, is interesting on account of the occurrence of a considerable amount of native mercury in the ore. In Leavenworth Gulch the Porcupine Company is developing a group of twelve claims, and the Londonderry Company, which also owns a large group, has a force of men at work in the same neighborhood.

In Fassbinder, in Stamboul, and in Mineral Wonder gulches, all at the head of Junction Creek, are a number of prospects which have been worked intermittently for many years. Upon some of these a considerable amount of development work has been done. These properties were not examined during the present field season. The relations of the surrounding rocks are very similar to those at the Neglected and Durango Girl mines.

SUMMARY.

The ore deposits in the western part of the Durango quadrangle are in an area of red sedimentary rocks, which have been intruded by dikes and sheets of grayish-green porphyry. Later basic dikes cut these sediments and also the porphyry bodies. Along certain nearly vertical planes the rocks have been fissured and fractured. Some of the more prominent fissures trend a few degrees south of east. These fissures have been and are channels for circulating waters. Along these fissures the porphyry and the sediments are impregnated with metallic minerals and contain small veins and stringers very rich in sylvanite. The occurrence of mercury sulphide and of native mercury is of peculiar interest. Where the ores have been deposited the circulating waters have metamorphosed the red sandstones and shales, changing them to light-gray or white quartzites.

NOTES ON THE GOLD VEINS NEAR GREAT FALLS, MARYLAND.

By Walter Harvey Weed.

The gold-bearing quartz veins near Washington, D. C., have been known for many years, and large sums of money have from time to time been expended in their development. A full account of the district and its geologic features, by Mr. S. F. Emmons, was published some years ago.[a] In the last two years considerable new work has been done at the Maryland mine and extensive prospecting work on the adjoining Anderson property. As the results are interesting, both scientifically and economically, a few notes made by the writer are presented herewith.

The Maryland mine.—This property is developed by a shaft 150 feet deep, with levels at depths of 100 and 150 feet. On the 100-foot level the vein is opened up for 100 feet north and 100 feet south of the shaft. The vein is from 7 to 12 feet wide and consists of massive, coarsely crystalline, vitreous quartz, incased in well-defined walls of mica-schist. The course is nearly north-south and the dip 85° to the west. The quartz incloses wedges and slivers of the schist, but these masses of schist are mostly attached to the walls at some point, though apparently isolated masses were seen.

Both country rock and vein quartz are traversed by well-defined joints, which form an angle of 90° with the plane of the vein. These fractures, however, in the instances seen, are not directly continuous from country rock into vein, as there is a little jog where they pass into the quartz. This fracturing has produced slight shifting of the veins, and combined with the sheeting of the vein itself gives a netted or diamond-meshed structure. The course of the veins does not correspond exactly to the foliation of the schist, but cuts across it at a slight angle. The quartz shows distinct banding, with lines marked by micaceous material and pyrite. Pyrite occurs abundantly in isolated cubes in the quartz, frequently associated with galena. Pyrite also occurs in small crystals in the included masses of schist and in the schist walls, but is pale in color and differs in appearance from the quartz. The richest ore occurs in masses varying from an inch to several inches in diameter and is formed of galena with coarse free

[a] Notes on gold deposits of Montgomery County, Md.: Am. Inst. Min. Eng., vol. 27, 1890, pp. 391–411.

gold. Sheeting of the vein after deposition of these minerals has produced a gilding of certain surfaces or a clouding due to galena dust. The pyrite crystals have also been broken by an earlier period of fracturing, and the fragments have been recemented by quartz. The quartz, though massive, shows plainly the outlines of hexagonal crystals and is certainly, in part at least, of comb structure. The schist fragments near the gold-bearing nests are honeycombed in part and the cavities drusy, as if the quartz and mica were being dissolved. So far as can be determined with the hand glass, the ferromagnesian minerals are being removed or leached out by alkaline waters, and quartz deposited in their place, together with pyrite, since the pyrite cubes projecting into these cavities are not affected. The secondary fractures traversing the quartz pass at times directly through the rich galena and gold masses, but there is no visible connection between the fractures and the nests of rich ore. At the same time there is an evident association of the gold with fractures in the quartz, though not as a filling between growing crystals.

Samples of the solid pyrite from the 100-foot level, showing no visible gold, assayed by E. T. Allen in the Survey laboratory, yielded 4.25 ounces gold and 0.36 ounces silver per ton. In the operation of the mill a considerable tonnage of the pyritic ore was run over the concentrators. The resulting product, consisting of almost pure pyrite, yielded upon assay, by A. C. Rombauer, of Butte, Mont., 0.74 ounces (or $14.80) gold and 1.5 ounces per ton of silver. In December 504 tons of ore from the pay shoot, run through the mill, yielded $5,144.

The Anderson property.—West of the Maryland mine several veins have been prospected in the past year on what is known as the Anderson property, where seven veins have been opened. The Potomac vein crosses the Aqueduct road about 200 yards east of the canal and is at this point exposed by two adits. The north adit follows the vein for 135 feet, the course varying from N. 5° E. at the mouth to N. 18° E. near the face. This vein has a dip of 75° to 80° to the west, and for this distance will average nearly 2 feet in width. It is always distinct and well defined, but thins and thickens from point to point. The vein consists of crushed and decomposed ferruginous schist, is usually defined by a clay selvage, but varies in appearance and character. Opposite a winze sunk on the vein at a point 100 feet from the entrance to the adit, the vein shows but 5 inches of crushed, dull, olive-drab schist. The winze is about 12 feet deep, and at the bottom the vein is opened for about 15 feet in length. At this point, almost directly opposite the 5-inch place just noted, the vein is 3 to 5 feet wide.

The exposures in the Potomac tunnel show, better than anywhere else in the property, that the veins cut obliquely across the schists in dip and strike. This is seen 40 feet in from the tunnel mouth, where the schists dip east at 75° to 80°, while the vein dips west at about the same angle. Along the strike, spurs or stringers are seen to run out from the vein into the schist on the east side of the vein, following the foliation. The vein filling is silicified and is interleaved with films of quartz, in addition to which there are streaks and lenses of rather massive quartz. Careful panning of samples from the vein, which is here all oxidized, show much coarse gold. The quartz is seldom the richest ore, and the best material usually comes from its contact with the schists. The association of the coarse gold with cellular and rusty limonite masses indicates its derivation from pyrite bunches. No pyrite is seen in the tunnel proper, but it appears in the bottom of the winze.

The veins on this property cross the slopes or gently inclined table-land, which is indented by the branches of a small brook. The largest vein shows a great outcrop of quartz, forming a reef that extends above the gentle slopes between the wagon road and the stream. This has been crosscut by open cut and tunnel and shows that the quartz does not extend downward as a solid mass, but in streaks and fingers, with altered schists between. Northward, across the brook, the same quartz reef is exposed in an old cut, now overgrown by trees 10 to 15 years old.

The Anderson vein lies a few yards east of the one last mentioned. It has been stripped for 250 feet north of the brook, and is exposed by a cut 15 feet deep. Its width is more than 10 feet. It shows some quartz and some auriferous schist.

The Jenkins vein is about 300 feet east of the Anderson, an unopened, unexplored vein lying between. The Jenkins vein is developed by a vertical shaft 40 feet deep, with a 10-foot crosscut at the bottom, leading to a 20-foot level driven on the vein. The vein is well defined, has a smooth wall, with crushed schist between this wall and the country rock. The quartz streak varies from 12 to 18 inches in thickness, and the richer samples come from the walls of this streak. Much pyrite is seen on the 40-foot level. The dip is east.

The Wabash vein lies east of the Jenkins. It is developed by a shaft 25 feet deep, with 15 feet of drifting on the vein. No quartz appears on this vein, but it carries 15 inches of gold-bearing schist.

The Hay vein to the north is exposed by a shaft 45 feet deep and shows 8 feet of sheared and schistose quartz. This evidence seems to show that the veins have been altered by regional metamorphism.

The Bonanza vein shows a well-defined lode of schist ore and quartz exposed for a width of 6 feet by a shaft 12 feet deep.

The Bell vein is opened on the ground south of the Government road. A vertical shaft 65 feet in depth sunk on the hanging wall of this vein opened two veins, about 36 feet of drifting being done on the one directly at the bottom of the shaft. The 18-foot cross-cut to the west disclosed a second vein, on which a few feet of drifting has been done.

All the work so far done on this property has been merely to ascertain the nature and extent of the veins. It is limited in depth by water, and therefore does not penetrate to the zone of unaltered sulphides below ground-water level. That the gold is partly free and partly in the pyrite is, however, certain from the developments at the Maryland mine, which is on a vein crossing this property. This is also in accord with the almost universal experience throughout the Piedmont belt. The veins are all nearly parallel, and their approximately north-south course and west dip conform closely to the schistosity of the inclosing rocks.

The rocks in which these veins occur are deeply altered by surface decomposition, and good exposures are rare. In the road cuttings and along the small stream courses the schists are seen to be thinly folded and to present little variety in character. In the river channel excellent rock exposures are found, but these lie west of the veins.

The veins are normal, consisting of sheared, thinly fissile, sericitic schist carrying much quartz in minute particles and in large and small lenses, the latter of white, vitreous, crystalline quartz. The ore above water level contains coarse free gold, mostly in the limonite left by the decomposition of pyrite crystals, but in part also in clay selvages, especially in the casing of the large quartz streaks. As a rule the coarse, honeycombed quartz and quartzitic schist is the richest ore. The veins occur in what might be called a mineralized zone a thousand feet or more in width. This zone lies directly north of and in line with a diabase dike traceable for many miles southward into Virginia.

It is evident that the veins lie along a pronounced and extensive line of fracturing. The character of the fissuring and the fact that some of the veins of this district are traceable for long distances indicate deep fracturing and probable continuity of vein for considerable depth. Whether payable values will be found to extend downward can not be foretold, although the development in the Maryland mine shows that high-grade sulphide ores do continue downward for some distance beneath ground-water level. The tests so far made upon the sulphide ores show that the pyrite carries some free gold, but that a large part of the value is locked up in the sulphide. Concentrates made by crushing up some of the pyritized schist in a mortar and panning by hand yielded $8 to $60 per ton in gold. Nothing has yet been developed below water level in the Anderson property, and it is therefore impossible to say whether the numerous ore shoots exposed on the veins of this property will prove as rich below the water level as that of the Maryland mine, or will become low-grade ore.

THE ORES OF GOLDFIELD, NEV.

By J. E. Spurr.

Development.—The new camp of Goldfield, in Nevada, was revisited by the writer in November of this year. This district lies 23½ miles south of Tonopah (about 28 miles by wagon road), and was located late in the spring of 1903. At the time of the writer's first visit, shortly after its location, the only work being done was by a few men on what is now known as Columbia Mountain. Up to that time no good strikes had been made. About January and February, 1904, however, rich finds began to be made in certain spots south of Columbia Mountain. Now there are probably upward of 6,000 inhabitants in the district. The town of Goldfield and a number of adjacent smaller camps have sprung up. It is estimated that $2,000,000 worth of ore had been shipped up to November, 1904; since then the amount has been largely increased.

Conditions.—Goldfield is reached by stage from Tonopah, to which point a railroad runs, connecting with the Carson and Colorado Railroad at Rhodes; a branch is now under construction to Goldfield. The camp has a water supply which is said to be sufficient, but in all other respects—fuel, climate, supplies, etc.—it partakes of the inevitable disadvantages of the desert.

General geological situation.—The district is bounded on the west in part by a lava-capped mesa,[a] whose erosion has laid bare the underlying gold-bearing rocks. The auriferous region is characterized by numerous low, irregular ridges standing out from the lower and more nearly level surface. These ridges owe their origin to hard reefs of quartz which form their crests, whose resistance to erosion has left them thus protruding above the general elevation; and in these quartz reefs the auriferous deposits are found.

Columbia Mountain.—Columbia Mountain is the most prominent of the ridges, and some notes on its geology were made public by the writer last year.[b] Near the south end of the ridge the rock is largely alaskite (an igneous rock consisting of quartz and feldspar),

[a] The capping lava is reported to be basalt. A brown sandy-looking rock underneath this, a specimen of which was sent to the Survey by Mr. Maynard Bixby, is a rhyolitic glass flow.

[b] Notes on the geology of the Goldfield district, Nevada: Bull. U. S. Geol. Survey No. 225, pp. 118-119.

which is sometimes of granitic structure, and sometimes very fine grained, even resembling quartzite. White mica or muscovite is sometimes present, and pure quartz veins or dikes of similar origin also occur. These alaskitic rocks are intrusive into a dark siliceous rock (jasperoid), which is probably the result of the silicification of an original limestone. We may believe this limestone to have been Paleozoic, and the alaskite is certainly pre-Tertiary.[a] On the north end of the mountain the rock is a very much altered rhyolite, in which are broad masses of white to purplish and reddish cherty quartz, extending irregularly in a northerly direction. This quartz is simply a highly silicified rhyolite. The silicified areas have ill-defined walls, and the highly mineralized portions which they inclose are very irregular.

Productive area.—The area of known ore bodies has, since last year, spread far out from Columbia Mountain, so that now it may be estimated at about 6 miles square. The most productive area is inclosed in a square, 2 or 2½ miles in either direction. The chief mines at the present time are the Jumbo, the Combination, the Florence, and the January, all grouped together about a mile south of the southeast end of Columbia Mountain. About 5 miles southeast of Columbia Mountain is the Diamondfield group, including the Vernal, the Quartzite, and the Black Butte. Shipments have also been made from this group. Other ore deposits have been developed in various parts of the field.

Nature of rocks.—The rocks in that part of the field examined during this last trip (the region of Columbia Mountain, Diamondfield, and the Jumbo group of mines), were found to be almost entirely volcanic, consisting of rhyolite, rhyolite tuffs, andesite, and basalt, all probably of Tertiary age. The alaskite and jasperoid of Columbia Mountain are hardly represented in the surrounding district.[b] The predominant rocks are abundant rhyolites and andesites, while basalt is rare. One andesite from near the Tonopah Club, examined microscopically, is a hornblende-andesite, resembling the earlier andesite at Tonopah. A patch of basalt from near the Florence is an augite basalt, like the basalt of Siebert Mountain at Tonopah. The rhyolite resembles the rhyolite of the Gold Mountain district, which lies about 4 miles south of Tonopah, on the road between Tonopah and Goldfield, and this Gold Mountain rhyolite again resembles closely some of the phases of the earlier (dacitic) rhyolite at Tonopah. The relative ages of the rocks at Goldfield have not been determined, but it may be that they are like similar rocks at Tonopah.

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[a] The writer regards its age as post-Jurassic.

[b] In a press bulletin, given out earlier, the rock constituting the ore at the Tonopah Club mine was characterized as probably jasperoid (silicified shaly limestone). The specimen collected, however, proves upon microscopic examination to be a somewhat disintegrated glassy volcanic rock.

Period of mineralization.—At Goldfield the ores occur in both rhyolite and andesite, showing that the mineralization occurred subsequent to the eruption of both lavas. At Gold Mountain the ores evidently were formed after the eruption of the rhyolite, and at Tonopah the eruption of the earlier (dacitic) rhyolite was followed by a period of mineralization which produced veins showing frequently a larger proportion of gold than the locally more important veins whose formation followed the eruption of the earlier andesite. There is, therefore, the possibility that the Goldfield deposits are identical in origin with the later series of veins at Tonopah. Indeed, there are at Tonopah, in one place at least, mineralized quartz reefs in rhyolite tuffs which have the same peculiar characteristics as those of the Goldfield reefs, and these Tonopah deposits have afforded moderate assays showing gold and no silver.

Nature and origin of the ore deposits.—The veins at Goldfield are not persistent nor well defined. The outcrops of the quartz bodies are irregular, straggling, branching, and apt to disappear suddenly (fig. 9). Neither were any definite systems observed, though further study might detect them. The outcrops may even be nearly circular or crescentic, and frequently they are roughly lenticular and intermittent. The quartz itself is gray and jaspery, and is due almost entirely to the silicification of the volcanic rock in which it occurs. Practically no ordinary vein quartz was observed.

All indications show that this silicification (and the accompanying mineralization) is the work of hot springs, and that these irregular reefs represent the horizontal sections of columns of rocks traversed by rising columns of hot water. Had the rocks been strongly fractured we should have had veins like those of the early andesite at Tonopah, which are also due to hot-spring action; but at Goldfield the lack of such a fracture system resulted in this curious and rather unusual type of deposit. It follows that the quartz bodies will probably, as a rule, extend deeper vertically than horizontally, and so have roughly the nature of columns or pipes.

Pay shoots.—The greater part of one of these jaspery quartz reefs, although showing disseminated pyrite, contains little or no values in gold. Microscopic investigation has shown that in such quartz the pyrite is often probably mainly indigenous—that is, that the iron sulphide has been formed by the action of the sulphur contained in the hot-spring waters upon the iron silicates contained in the hornblende and biotite. This explains the absence of gold, the pyrite having the same origin as the barren pyrite near the ore bodies in the country rock at Tonopah. Within some of these barren reefs of silicified volcanic rock at Goldfield, however, prospecting has led to the discovery of portions containing gold, sometimes in large quantities. Such portions are apt to be lenticular or irregular, like the main quartz reefs, and they are not easily distinguishable from the

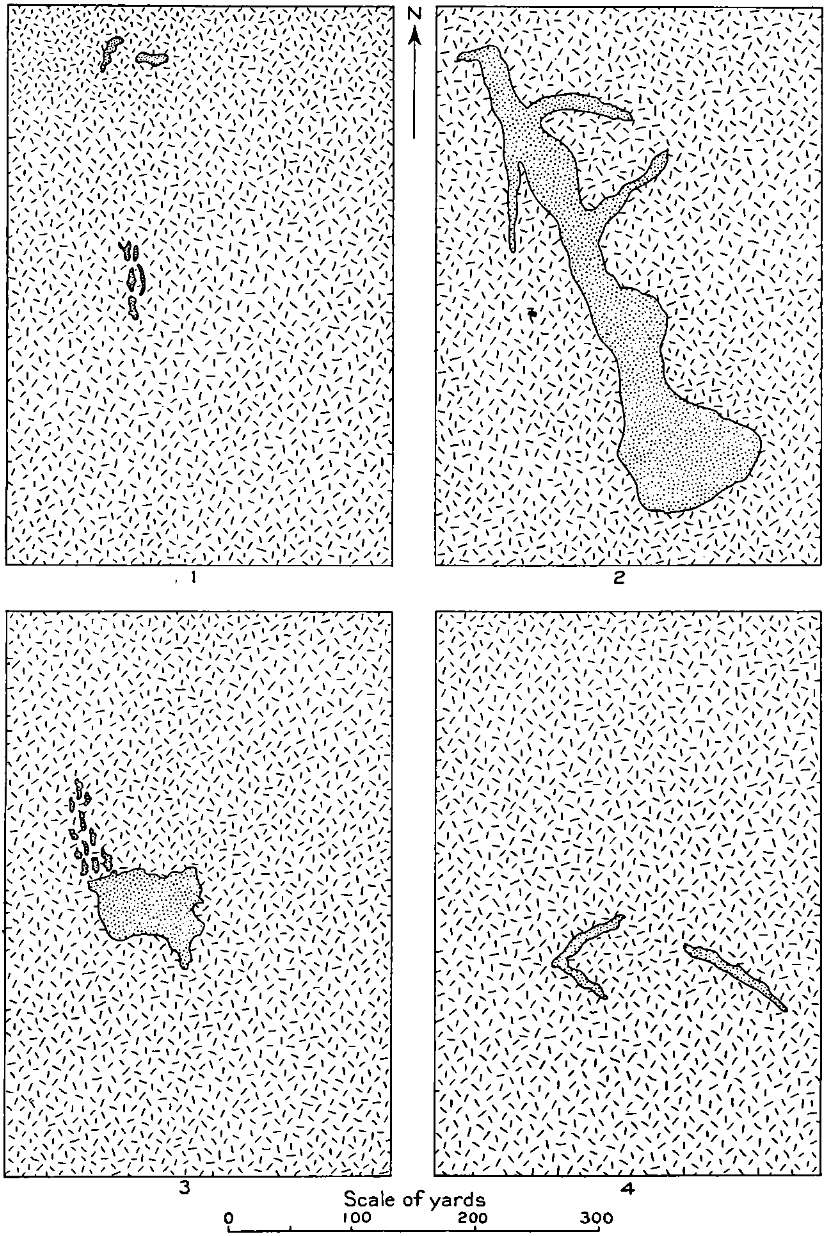

FIG. 9.—Types of quartz bodies at Goldfield. Horizontal sections, sketched from outcrops. Country rock is andesite or rhyolite, or both.

barren quartz except by panning or assaying; but these shoots are the real ore deposits, and the mass of the reefs constitutes merely a siliceous jacket or casing, such as is known to surround ore bodies in some other parts of the world. While the siliceous casing may be 25 or 30 feet wide the auriferous portion may be only 1 or 2 feet, and the form and extent of this portion become evident only after the ore has been extracted. It is then seen to have a definite channel-like shape, often more regular than that of the whole outcropping reef, though it has usually a limited extent in the direction of its greatest elongation (fig. 10). It seems that these pay shoots represent the main channels of hot-water circulation, while the siliceous casings are the result of the water soaking through the rock adjacent.

Value of ores.—The ores are often of very high grade. As an extreme example may be noted a shipment of 14¼ tons from the Sand-

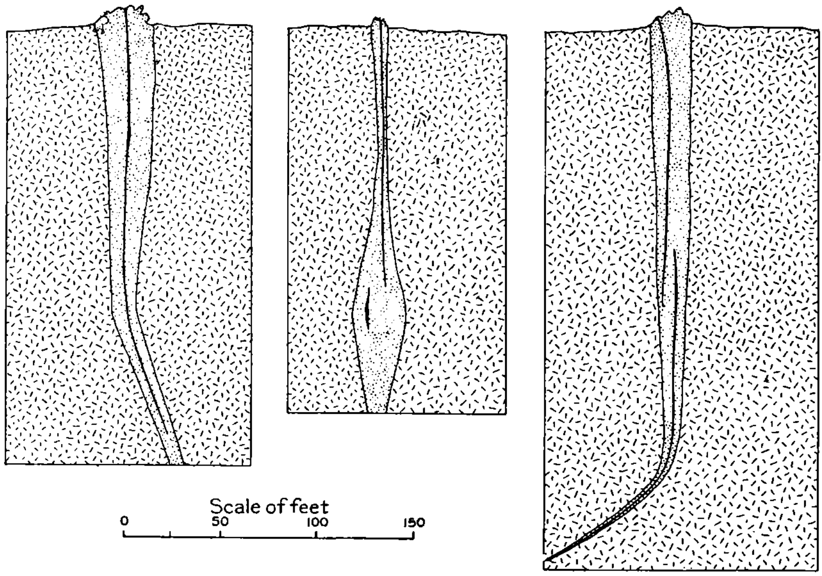

FIG. 10.—Diagrammatic vertical cross sections of quartz bodies, based upon actual development of mines in Goldfield. Dotted portion is quartz mass; black streaks are ore shoots.

storm (Kendall claim), which when worked in a stamp mill yielded $45,783 net, while the tailings still contained about $1,000 to the ton. From the McKane-Bowes lease on the Jumbo there was taken out in five months, from a space 100 feet long and 200 feet deep on the shoot, $600,000. One small shipment from this lease—917 pounds of ore—gave gross returns of $4,766. The whole production of the camp has been from ore which may be roughly estimated as averaging $200 to $300 per ton or more. The values are generally all in gold;

silver is usually practically absent, though the shipping ore from the Combination mine contains from 1 to 3 ounces.[a]

Deposition of rich ore during oxidation.—The origin of this rich ore is important to consider in order to judge the future chances of the district. Most of that which has been extracted up to the present time has been oxidized ore. The ores are mixed sulphides (usually in large part pyrite) and oxides up to near the surface. The oxidized material which follows cracks and seams is usually found to be several times (sometimes several hundred times) as rich as the unoxidized portion. The irregular spongy nature of the free-gold particles in such oxidized material completes the proof that this is gold that has been dissolved and redeposited in concentrated form during the process of oxidation. Iron sulphate derived from oxidation of the pyrites is the probable agent. A peculiar yellow coating, pointed out to the writer as the best sign of values in the oxidized ores, was shown by Doctor Hillebrand to be a basic ferric-alkali sulphate, containing both sodium and potassium—perhaps jarosite. Other sulphates, such as alum and gypsum, are abundant. These oxidized ores are prepared for shipment by screening, the fines being shipped and the coarse quartz rejected. This is a rather crude method of treatment. Some specimens of ore from the waste or low-grade dumps have been found by the writer to show under the microscope a large amount of free gold.

Rich sulphide and telluride ore.—As the ground-water level at Goldfield is unusually high for this desert country, water having been encountered in several shafts at from 150 to 200 feet, it is plain that this oxidized ore is only a temporary supply. In the Combination and the Florence mines, however, sulphide ores of very high grade have been encountered below the oxidized zone. In these mines a dark-gray copper-bearing mineral is most intimately connected with the gold, being very rich. A specimen from the Combination, analyzed by Doctor Hillebrand, proves to be a sulpho-salt of copper, antimony, and arsenic, which, so far as qualitative composition goes, may be tetrahedrite. Tellurium is also present in this ore; and the same element has been reported elsewhere in the district. Therefore the sulphide ores may also be very rich. Moreover, while the difference between the oxidized and unoxidized portions of the ores within the oxidized zone is in general so great, certain shoots occur in the oxidized zone, as in the January and the Jumbo, where the unoxi-

[a] Assays from the Blue Bull mine at Goldfield made by Mr. A. Hamilton show much more silver (up to 73 ounces). In five assays the proportion of gold to silver by weight was 1 : 50, 1 : 52, 1 : 51, 1 : 137, and 1 : 382. All these samples were from depths of 35 to 40 feet except the last, which was from the outcrop. In a sixth specimen the proportion was reversed, being silver to gold, 1 : 37, by weight. (Courtesy of H. C. Morris.)

dized quartz is of extremely high grade. Such ore appears to contain mostly pyrite as metallic mineral, but in view of the fact that tellurium is known to be present in the district, it is probable that gold telluride is present. Doctor Hillebrand has determined tellurium and gold (probably gold telluride) as well as a copper mineral in a specimen of ore of this class from the January mine. These are probably residual minerals similar to those characteristic of the unoxidized zone, as microscopic work by the writer indicates. Most of the hard quartz in the pay shoots of the different mines shows, when thus examined, pyrite, tetrahedrite (?), and free gold, the last two closely associated and often intergrown. The tellurides have not yet been identified microscopically, probably because of the difficulty of distinguishing them from pyrite.

It appears, then, that the rich oxidized ores owe their richness, not primarily to concentration during oxidation (though this process has certainly been very important), but to the existence of shoots of rich antecedent (sulphide) ore.

Probability of rich ore in depth.—Concerning the origin of these rich sulphide ores, it is probable that some, so far as can be yet seen, are purely primary, while evidence points out other cases as having been formed subsequent to the main silicification of the reef, as in the Combination mine. Here the rich auriferous sulphides have formed in a broken zone (breccia-zone) in the silicified barren reef, and occur as seams, and often as coatings on the pebbles in the breccia. The question arises, however, as to whether this subsequent mineralization was the result of descending or ascending waters. Concerning this the evidence is not conclusive; but there is no sufficient evidence that these rich ores have been concentrated from the lean antecedent quartz mass, and the presence of elements like arsenic, antimony, and tellurium in the subsequent sulphide ore suggests a deep-seated origin. Moreover, microscopic examination of such rich ores shows they have as gangue cherty silica like that of the first period of silicification, and the associated evidence favors the idea that the conditions of this subsequent deposition were very much like those of the first.

Besides the elements mentioned above, bismuth occurs in the ore. In the January mine it occurs in the oxidized ores in the form of silvery scales, which is, as described by Doctor Hillebrand, bismuth; perhaps the oxide bismite. In the Combination long needle-like crystals have been found, which, according to the manager, Mr. Collins, give the chemical tests for bismuth sulphide (bismuthinite). In the January mine the silvery mineral above noted is sometimes arranged in long rod-like forms, and these are very likely pseudomorphs after the sulphide. This silvery mineral is usually, but not always, an indication of rich ore in the January. According to Mr. Hamilton, several of the Blue Bull samples[a] show bismuth. Barite is a common mineral in all these deposits, but is not abundant.

The indications are, therefore, not unfavorable to the continuance of ores of high grade, or at least of good grade, down to considerable depths. There is, however, as already demonstrated by exploitation, no continuous regularity to the ore shoots, whether sulphide or oxidized. They are curving, irregular, and often lenticular, but it may happen that below a shoot which has come to an end another shoot may be found occupying a slightly different relative position, or even overlapping the first.

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[a] Page 137, footnote.

DEVELOPMENTS AT TONOPAH, NEV., DURING 1904.

By J. E. Spurr.

ECONOMIC CONDITIONS.

A preliminary report on the geology and ore deposits of Tonopah by the writer was published last year as Bulletin 219 of the Geological Survey, and subsequently, to meet the great demand, as a part of Bulletin 225. During the past autumn the writer spent several weeks at Tonopah taking note of developments, and he has very recently finished his final report on the district.[a]

The information contained in the first report was promptly appreciated by those interested in mining in Tonopah, and since that time the prospecting of the district has been carried on on substantially the lines therein laid down. Formations and portions of the district which were pointed out as unfavorable or hopeless for mining enterprise have been almost absolutely neglected, and development has been vigorously prosecuted only in those portions which were pointed out as most favorable. In view of the influence thus exerted the writer believes that the mining public will welcome a slight summary of the observations made on the underground work done during the last year and the conclusions derived therefrom.

To leave for a moment the question of the geology of the district, which is the chief factor in the study of its destiny as a mining camp, we may note that the general conditions for mining and profitable production of ores are decidedly better than a year ago. The greatest advance has been in the building of a railroad to Tonopah connecting with the Carson and Colorado Railroad at Rhodes, near Sodaville. This has lessened the cost of transportation, so that supplies have become cheaper and ores can be profitably marketed which are of lower grade than what was "shipping" ore during the period when a 60-mile haul in ore wagons was necessary. This railroad, and also the connecting Carson and Colorado, have, however, only a single narrow-gage track as far as the junction of the latter with the Virginia and Truckee Railroad at Mound House, near Virginia City.

[a] Spurr, J. E., Geology of the Tonopah mining district: Prof. Paper U. S. Geol. Survey No. 42, 1905 (in press).

Therefore these roads have turned out to be inadequate for the transportation of supplies to Tonopah and the more recently discovered districts and for the transportation of the ore which has been produced. The rates of railroad transportation, however, are so high that the cost of supplies has not been reduced and the profits upon the ores shipped have not increased so much as was expected.

The supply of water for the town seems to be somewhat more abundant than last year, though there is still much to be desired. Part of the supply still comes from the wells of the Crystal Water Company, 4 miles north of the town, while another portion is derived from the Rescue shaft, which is practically within the town itself. Underground water is irregularly distributed in this district, occurring only in certain zones, so that comparatively few shafts have encountered water, while others, even some considerably over 1,000 feet in depth, are perfectly dry.

Until recently there have been practically only three producing mines in the Tonopah district, although a number of others have shipped small quantities of ore. These producers have been the consolidated Mizpah and Valley View mines (Tonopah Mining Company), the Montana Tonopah, near by, and the Belmont Company, whose properties are operated through the Desert Queen shaft. Recently, however, another mine, which ranks with those above mentioned, has been discovered and developed—the Tonopah Extension—and shipments of considerable amounts of ore have been begun.

The effect of the discovery of Tonopah upon the prosperity of the State is illustrated only to a partial extent in the development and prosperity of the Tonopah district. Of probably greater importance is the stimulus given to mining activity throughout this hitherto almost forgotten mining country. All over the State old mines that had become dormant have been taken up and are being developed, frequently at a profit. Besides this, an army of prospectors has been searching the desert for new discoveries. The most notable success due to this prospecting thus far is the discovery of the new camp of Goldfield, which lies about 23½ miles in a straight line south of Tonopah. This is an absolutely new discovery, which was made in 1903, but which first assumed importance in the early part of 1904, when rich discoveries of gold ore were made. At the time of the present writing this camp equals or exceeds in population, and far exceeds in activity, the parent camp of Tonopah. Since, however, all the traffic for Goldfield must pass through the railroad terminus at Tonopah it contributes largely to the sustained prosperity of the latter town. From Goldfield prospectors and mining men, with their interest and courage increased a hundredfold by the discovery of this second rich camp in the desert, have pushed southward along the volcanic belt, have taken up old claims, and have made new discoveries. The most widely heralded of these new finds is that at Bullfrog, about 60 miles southeast of Goldfield, in the Amargosa Desert. This has not yet been visited by the writer. Ores are also reported in the Kawich Range, about 50 miles east of Tonopah and Goldfield.

PROGRESS OF GEOLOGIC KNOWLEDGE.

The prediction made in last year's report that new veins belonging to the productive period of the earlier andesite would probably be discovered underneath the later overlying lavas has been fulfilled during the past year by the discovery of several such veins. In the Montana-Tonopah, north of the first large vein discovered (the Montana vein), another large east-west vein has been discovered and developed. This vein contains large quantities of rich sulphide ore, and has been called the "Macdonald vein." West of the Montana-Tonopah mine the Tonopah Extension shaft has cut a similar rich and large vein in the earlier andesite, in a portion of the district which, while on the borders of the formerly known productive region, had not been shown to contain any valuable ores. This vein, encountered beneath the overlying later andesite, is as strong as any of the other first-class veins yet developed, and may, indeed, be the extension of some of the earlier-known lodes. Besides these important discoveries, fragments of similar veins broken by intrusion or faulting, so as not to have at present as great economic value as the unbroken veins, and similar veins of smaller size have been encountered in other mines, such as the North Star, the Midway, and the Tonopah and California.

COMPOSITION OF ORES.

A preliminary account of the early andesite ores was given in the last report, in which it was shown that the primary ore was essentially a rich silver sulphide, black in color and often antimonial. Since that time Dr. W. F. Hillebrand, of the Geological Survey, has made a prolonged chemical investigation of the ores, which is of great interest, as it touches their origin and their commercial treatment. The primary sulphide ore taken from the Montana Tonopah (Montana vein) has the following composition:

Analysis of sulphide ore from Montana vein, Montana Tonopah mine.

Siliceous matter	15.18
Gold	.72
Silver	25.92
Lead	6.21
Copper	1.32
Iron	9.87
Manganese	1.36
Zinc	5.84
Selenium	2.56
Tellurium	None.
Arsenic	.19
Antimony	.92
Magnesia	1.49
Lime	3.70
Carbon dioxide	6.34
Sulphur	Not determined.

Typical rich ore from the oxidized zone of the Valley View vein yielded the following results:

Analysis of oxidized ore from the Valley View vein.

Siliceous matter	16.53
Gold	.62
Silver (38.10 as sulphides; 24.44 as chloride, selenide, and alloy)	62.54
Lead	.32
Copper (mostly oxidized)	.09
Iron	1.39
Manganese	.07
Zinc	.10
Selenium	.78
Tellurium	None.
Arsenic	.03
Antimony	.15
Sulphur	Not determined.

Doctor Hillebrand's analyses show that the carbonate, which forms a small part of the gangue in the primary ores, is complex, consisting of carbonates of lime, magnesia, iron, and manganese. Aside from this, the analysis of the primary sulphide ore indicates the presence of a large amount of the silver sulphide, argentite, which occurs also as a secondary sulphide, as previously reported. Other sulphides of silver are also indicated, certainly polybasite, and very probably stephanite. Smaller amounts of galena, blende, pyrite, and chalcopyrite are evidently present. Of very great interest is the presence of a considerable amount of selenium, with no trace of its usually closely associated element tellurium. This occurs, in part at least, as a silver selenide. The chemical form of the gold is as yet uncertain, but the presence of a selenide of gold is not impossible, although this mineral has not yet been described as occurring in nature.

The analysis of the so-called oxidized ore shows considerable changes from the primary condition, but the argentite seems to have largely remained unaltered, while the polybasite and stephanite, and also much of the silver selenide, have probably been attacked by oxidizing agents. It is thus seen that the so-called oxidized ore of the Tonopah district is really a modified ore, consisting of an intimate mixture of sulphides and selenides, together with secondary sulphides, chlorides, and oxides.

VEINS OF A LATER PERIOD THAN THE EARLIER ANDESITIC VEINS.

In last year's report[a] it was noted that while the most productive veins were connected with the earlier andesite eruption, yet the subsequent volcanic eruptions also were frequently accompanied by silicification and vein formation, although these veins are of minor economic importance. It was clear even at that time that the most abundant mineralization and silicification, besides that connected with the earlier andesite, had occurred subsequent to the intrusion and extrusion of a more siliceous rock of later age. This rock was referred to at that time as the "early" rhyolite, and was indicated on the accompanying map as rhyolite breccia. In the final report this formation is somewhat more accurately classified as rhyolite-dacite, and is specifically referred to as the Tonopah rhyolite-dacite. In intrusive bodies of this rhyolite-dacite, especially near the contacts, and lying within either the intrusive or the intruded rock, but preferably in the former, bodies of quartz, more or less mineralized, are very common. At the time of writing last year's report the chief examples known were the veins of the Mizpah Extension, one vein in the Desert Queen shaft, and the mineralization found in the workings in the King Tonopah and the Belle of Tonopah shaft. During the past year, however, most of the working mines in the central part of the district have developed large bodies of this rhyolite-dacite and have encountered in this connection many of the characteristic quartz veins of this period.

These veins may be large and may carry values. They are easily confounded with the veins of the earlier andesite, just as the silicified Tonopah rhyolite-dacite, in which they usually occur, may be confounded with certain highly silicified phases of the earlier andesite. Such veins have been encountered in the Belle of Tonopah, King Tonopah, Mizpah Extension, Desert Queen, North Star, Montana, Tonopah, Mizpah, Midway, MacNamara, West End, Tonopah

[a] Bull. U. S. Geol. Survey No. 225, p. 98.

Extension, and Ohio Tonopah. On account of their resemblance to the earlier andesite veins they have been the object of a good deal of exploration and development work, which, on the average, has been decidedly unprofitable.

CHARACTERISTICS OF RHYOLITE-DACITE VEINS.

The veins of this period are characterized everywhere by irregularity and by a lack of definition and persistence, though their size may locally be great. As a rule they are elongated and have the appearance of regular veins, but can not be followed as far on either the strike or dip as can the regular veins. They may disappear by scattering and passing into a silicified wall rock, or they may be cut off along a cross fracture. The quartz is, as a rule, dense and jaspery and either white, gray, or black in color, and is therefore usually different in appearance from the white quartz of the earlier andesite veins. The veins are commonly barren or contain only very small quantities of gold and silver, except locally, where rich bunches of ore may occur, though of limited and irregular extent. In the Ohio Tonopah barite occurs as a gangue mineral with the rhyolite-dacite veins. This mineral has not yet been found in connection with the earlier andesite mineralization. In the Desert Queen and the North Star, where quartz of the rhyolite-dacite period has been opened by drifting, a green stain forms on the walls, which is a basic copper sulphate. This phenomenon has not yet been noted in connection with the earlier andesite mineralization. Characteristic of the rhyolite-dacite veins, to which, however, there are numerous exceptions, is the greater ratio of gold to silver in them as compared to that in the earlier andesite veins. In the latter class of veins the gold averages about two-fifths of the value, the silver three-fifths, while in the former class the gold is apt to exceed this amount and sometimes to occur with practically no silver, although the proportion is very changeable. Often, again, the proportion of gold and silver is the same as in the earlier andesite veins.

A favorite place for these veins is on the upper contact of a rhyolite-dacite sheet with overlying decomposed andesite. Such, for example, is the situation in the Mizpah Extension, the MacNamara, Tonopah Extension, and West End, and to a less degree in the Ohio Tonopah. This fact is explained by the conception that ascending hot waters circulating through the fractured rhyolite-dacite rose until at the contact with the overlying soft, decomposed andesite they found a partially impervious barrier, along whose lower contact they circulated and deposited the materials which they held in solution.

EFFECT OF WATERS PRODUCING THE TONOPAH RHYOLITE-DACITE VEINS ON EARLIER FORMED VEINS.

Although as a rule a decomposed andesite seems to have presented a formidable barrier to the circulating waters accompanying the Tonopah rhyolite-dacite, in some places the waters must have traversed the andesite. Indeed, it is along the brittle andesite veins and silicified adjacent andesite that fractures and fissures must have been most easily formed at this period. In the case of the Tonopah Extension, the earlier andesite vein has been reopened, and along the hanging wall a new vein of barren jaspery quartz formed. This is probably due to waters of the rhyolite-dacite period of mineralization. In this case the new quartz is relatively barren as compared with the old. It is evident, however, that the effect of such solutions must have been to dissolve a great deal of the gold and silver contained in the earlier veins, and naturally to reprecipitate it elsewhere. Thus the ores might be reprecipitated in a concentrated form. This very likely has been the case in the Montana Tonopah, where the original vein has been reopened, and in the fissure thus formed minerals similar to those in the older vein, but richer in gold and silver, have been precipitated in crustified form. It is reasonable to assume that this may have been the work of the waters of the rhyolite-dacite period, of the same kind and character as those to which the barren quartz hanging-wall portion of the vein in the Tonopah Extension is due.

Again, it is natural that such waters may have dissolved some of the metallic contents of the older veins, and instead of precipitating them within these veins may have carried them out and deposited them elsewhere, as, for example, in the veins of the rhyolite-dacite, forming bunches of high-grade ore in these usually barren veins. This may be the explanation of the comparatively small amount of rich ore found in some of the rhyolite-dacite veins, as, for instance, in the Desert Queen and the MacNamara. These are practically the only veins of this period in the district that contain high-grade ore, and both these veins lie near rich earlier andesite veins. Veins in the rhyolite-dacite that lie farther away from the earlier andesite veins are frequently large, but are typically of low grade or barren.

These veins are plainly the results of ascending hot waters, and represent the effects of the Tonopah rhyolite-dacite eruptions, having the same relation to these eruptions that the earlier andesite veins did to the eruptions of the earlier andesite. The characteristic lack of definition and persistence in these veins as compared with the veins in the earlier andesite shows that at the time they were formed no definite fracture zones were available as channels, so that the ascending waters had to force themselves up along irregular courses. This mineralization is probably the same in time, nature, and origin as that at Gold Mountain, which is 4 miles south of Tonopah,[a] and may very likely be the same as that in the newly discovered camp of Goldfield, which lies about 23½ miles south of Tonopah.

PROGRESS OF KNOWLEDGE OF UNDERGROUND FORMATIONS.

It was explained last year that the geology at Tonopah was so complex that no accurate detailed knowledge sufficient to guide mining operations with certainty could be obtained far from the regions which have been explored underground by mine workings, and it was pointed out that with the increase in number of such workings the chances for successful mining in the immediately contiguous regions could be progressively more closely estimated. It has indeed turned out to be true that the developments of the past year have had this effect in adding to our knowledge of underground geology and in increasing our basis for future estimates. The actually productive area has been slightly but not greatly enlarged, and within this area, as previously mentioned, most of the mine workings have encountered serious drawbacks to successful mining in the shape of large and irregular bodies of the later and intrusive Tonopah rhyolite-dacite. These bodies do not come to the surface over most of the area, and their presence could not have been accurately foretold, although the probability that such intrusions would be encountered anywhere and everywhere was pointed out by the writer in his previous report. The complexity of the intrusions was not exaggerated in the ideal cross section previously published.[b]

Besides the intrusions of later eruptives, cutting off the earlier-formed andesitic veins, the complicated faulting, characteristic of the district, which, in the early history of its development, made the Fraction vein practically impossible to follow and to exploit economically, has been found to manifest its effects in the other veins, entailing more or less serious hindrance to mining operations. The Mizpah vein is not only broken in detail by minor faults, but is cut off to the east, the west, and at the bottom by faults of greater magnitude. Within the important and rich veins of the Montana Tonopah complicated faulting has operated so as to displace the ore bodies in a very puzzling way. These faults have different systems and their effect is too complicated for explanation within a short space, but they are explained more at length in the final report. The Tonopah Extension vein, up to the time of examination by the writer, had continued to be unusually free from faulting.

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[a] Bull. U. S. Geol. Survey No. 213, p. 87.
[b] Bull. U. S. Geol. Survey No. 225, p. 108.

Outside of the known productive area exploration has been continued in those formations and in those portions of the district which were found by the writer to be more favorable than the rest. The chief work has been done east and west of the productive region, but it can not be said that so far the results are highly gratifying. To the east the Halifax shaft has been pushed down to a depth of 800 feet and is in the later andesite from top to bottom. Work has been continued on the Rescue shaft, which is in a white rhyolite volcanic neck. Work in which a larger amount of hope could perhaps have been reasonably placed has been carried on in the area west of the productive region. In this area, as already noted, the Tonopah Extension has been successful, while the other workings have developed nothing of importance. The Ohio Tonopah shaft, 770 feet deep, encountered a large body of the Tonopah rhyolite-dacite, and in this most of the drifting was done. The Golden Anchor shaft, situated in as favorable a position as could be chosen in this neighborhood, has reached a depth of 640 feet without definite developments. This shaft is mostly in the later andesite, with some rhyolite-dacite near the lower portion. Farther west, near the western limit of the area shown on the published geologic map, the new Pittsburg shaft was, at the time of the writer's visit, in November, 1904, 570 feet deep in soft volcanic breccia belonging to a period later than the ore-bearing formations. North of this point, but also on the edge of the area mapped, the Little Tonopah shaft was at that time 585 feet deep, and its bottom was still in the later andesite.

SUMMARY.

The Tonopah veins are similar in nature, composition, and origin to those found in some of the richest mining districts, such as the Comstock of Nevada and the Pachuca district of Mexico. Indeed, it is probable that all of these districts and many others lie within a single petrographic and metallographic province characterized by similar rocks and similar veins formed at similar periods. In the Tonopah district the rich ores occur in the veins in the shape of irregular shoots or masses (bonanzas), comparable in size and richness to the famous bonanzas of the districts mentioned. The geological conditions also indicate that such bonanzas were formed down to considerable depths. These are the striking advantages of the district, which have justified considerable expenditure of money in exploration.

The disadvantage of cost of production is common to all mines in the desert region, and if this were the only drawback the production of the district might reasonably be expected to become enormous. A greater disadvantage, however, as previously pointed out, consists in the disturbances to which the veins have been subjected since their formation. These disturbances consist of both repeated and copious intrusions of later volcanic rocks and of faulting which accompanied the intrusions, forming a condition illustrated in the ideal cross section published last year.[a]

By these disturbances the veins have been broken in detail, and sometimes even displaced to such an extent that search for their continuation is practically hopeless. In mining, the expense of following the vein is increased by slight disturbances, and where the vein is greatly displaced a large amount of money must be spent in exploration, however intelligently this may be directed. When veins belonging to one of the later periods, especially that following the Tonopah rhyolite-dacite intrusion, are encountered, it may be difficult for the mining man to identify their character or class, and much expense is incurred in drifting along these in search of ore bodies, which, if encountered, are usually not sufficient to pay for the whole work done.

Moreover, the exploratory shafts which have been sunk, particularly during the last year, in the region around the productive area, indicate that the earlier andesite, with its productive veins, if, indeed, it can be found in any large amount in these regions, lies under an average great thickness of the subsequent barren formations. Where these veins are very close to the surface, as in the present chief productive area, the difficulties of mining, as pointed out, are still so great as to make large profits often a matter of considerable doubt; and where similar mining and exploration must be carried on at an increasingly greater depth it becomes more and more doubtful whether the results will warrant the necessary outlay.

For these reasons, in considering the balance struck between the highly advantageous character of the ore and the origin and nature of the veins, and the disadvantageous circumstances introduced by late disturbances, it impresses the writer that the balance is at present rather on the disadvantageous side.

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[a] Bull. U. S. Geol. Survey No. 225, p. 108.

PROGRESS REPORT ON PARK CITY MINING DISTRICT, UTAH.

By J. M. Boutwell.

STATEMENT OF PROGRESS.

At the date of writing the last progress report on the survey of this district,[a] January, 1904, the detailed study of the ore bodies was being made. When this underground work had been nearly finished it was discontinued temporarily to complete other work, but office study was continued through the winter and spring of 1903-4. The most important result then accomplished was a thorough study, microscopically, of the igneous rocks of the district by Mr. L. H. Woolsey. The field work was again taken up in the season of 1904 and finished in December of that year. This included the detailed mapping of the surface geology in the areas shown on the Park City special map and on the larger scale special map, the detailed examination of the geology of all accessible underground workings, with special study of the ore deposits and the investigation of particular geologic problems. At the conclusion of this work reconnaissance work on problems of geologic correlation was carried on in the Wasatch range, in the neighboring mining camps in the Cottonwood region, west of Park City, and in the areas north and south of this general locality. The work in this district affords the basis for a detailed statement on the occurrence and origin of the ore deposits, proof of the character and amount of faulting and intrusion which directly affect the occurrence and continuance of ore bodies, suggestions as to best areas for prospecting, and evidence on the permanence of old and discovery of new ore bodies, and thus on the future of the camp. Significant facts, mainly of a paleontologic and stratigraphic nature, have also been found which throw new light upon the geologic history of the region. After careful study of the evi-

[a] Boutwell, J. M., Progress report on the Park City mining district, Utah: Bull. U. S. Geol. Survey No. 225, pp. 141–150.

dence secured, the results will be prepared for publication with the greatest rapidity consistent with thorough and reliable work.

RECENT SUCCESSFUL PROSPECTING.

Since the publication of the last statement on this district, the extensive exploration there described, which had then been persistently carried on for more than a year without adequate results, has at last been rewarded by valuable discoveries. The object of this sketch is to give an account of the general results of this successful prospecting and of the principal recent mining developments. In the earlier statement it was pointed out that as a result of the extensive exploration "some slightly mineralized ground has been opened, a small amount of ore has been discovered, and in the ground which was more wisely located the indications are good."[a] During the last year these indications have materialized, and, although nothing comparable with the Quincy strike is yet announced, new ore bodies have been found, and three of the new properties have begun shipments.

At the Kearns-Keith mine extensive beds of sulphide ore with some carbonate have been discovered in the foot of the main vein. In the course of cleaning out old workings and connecting the mines forming the present consolidation, including Crescent, Apex, and Hanauer workings, considerable ore has been taken out and the main vein has been opened in new ground—notably, to the southwest. The new concentration mill, a copy of one unit of the Silver King mill, has been in daily operation on the ores from this property and makes regular shipments.

In American Flag ground a strong ore-bearing fissure has been opened to a depth of more than 1,000 feet, and at a number of levels for several hundred feet along its strike. Although no attempt at stoping for regular shipments has yet been made, several carloads of ore taken out in the course of development have been shipped. These yielded excellent returns, indicating that the ore carries good values in silver, gold, and lead, and some copper.

In the New York one result of considerable exploration has been the discovery on the 400-foot level of a fissure, which, on being opened down to the 600-foot level and below, has yielded several shipments of high-grade silver-lead ore with accessory gold. In the Naildriver prospecting has ceased and a reduced force has been taking out ore struck several years ago. The Scottish Chief has made additional shipments of rich ore and continued active exploration. Some ore has been extracted from the Comstock and Cali-

[a] Progress report on Park City mining district, Utah: Bull. U. S. Geol. Survey No. 225, p. 150.

fornia, which was treated in the mills at those properties. The old Glencoe property has been reopened and the mill and mine are being put into shape for regular work. In some of the other smaller properties, in which work has been begun in only comparatively recent times, development is still actively in progress. After encountering unusual difficulties from water, the management of the West Quincy property has effected an agreement whereby its ground will be opened and worked at a depth through the Little Bell.

In some of the great properties encouraging results have also attended prospecting. In the Daly West, a strong ore-bearing fissure, the back vein, which has afforded considerable ore in the adjoining Daly-Judge property, has been found, and its ore is being actively stoped. The great Daly–Daly West vein, the main single fissure of this property, has been opened to the 1,550-foot level and found to carry a large body of milling ore. Arrangements have been perfected with the Ontario and Daly companies for extending the 1,500-foot level Ontario and 1,700-foot Daly into the Daly West and prospecting its ground at this depth (2,100, Daly West). With a view to treating the increasing amount of milling ore yielded by this mine, the capacity of its concentrating mill has been considerably enlarged and a tailings plant erected and equipped with the Sherman classifiers and slime-settling tanks, Wilfley tables (ordinary), and Wilfley slime tables.

In the Daly-Judge, exploration of virgin ground at a depth on the west has already resulted in cutting some very high-grade ore. As a result of prospecting in promising ground of the Daly, through the Mazeppa shaft, those upper workings have been closed and the old Federal tunnel is being driven ahead to prove this ground at a depth. The other properties, large and small, have maintained their regular operations.

These newly discovered ore bodies, with a single exception, occur as veins in northeast-southwest fissures. The exception is the replacement ore in the Kearns-Keith, which lies in beds in the foot wall of the main fissure and takes the place of portions of limestone strata. In the Silver King and Daly West mines no new bodies of high-grade "bedded" ore have been recently found comparable to those which afforded the large shipments of crude ore. Considerable areas of the ore-bearing limestones remain unexplored, however, in each of these mines, and they are now being extensively and thoroughly prospected. The boom in 1902 resulted in an unprecedented number of new locations, the incorporation of several large companies, and a vast amount of prospecting. During 1903 the mining industry gradually resumed its normal condition, and newly formed companies settled down to persistent, serious development work. The last year, 1904, has witnessed the successful outcome of this extensive exploration in the discovery of ore and the addition of three shipping properties. This tends in a measure to offset a decrease in the annual output from the camp. Furthermore, the discovery of new ore bodies in large mines, promising developments in other properties, amicable arrangements between neighboring companies for prospecting through adjoining ground, and various surface improvements mark important progress in the mining industry in this district during 1904.

GOLD PLACERS OF THE COAST OF WASHINGTON.[a]

By Ralph Arnold.

Introduction.—It has been known for a number of years that the beach sands of certain portions of the Pacific coast of Washington contained gold, but no effort was made to mine any of them until 1894, when a report spread that pay sand was to be found almost anywhere from Cape Flattery, at the entrance to the Strait of Juan de Fuca, to Grays Harbor, 50 miles north of the mouth of Columbia

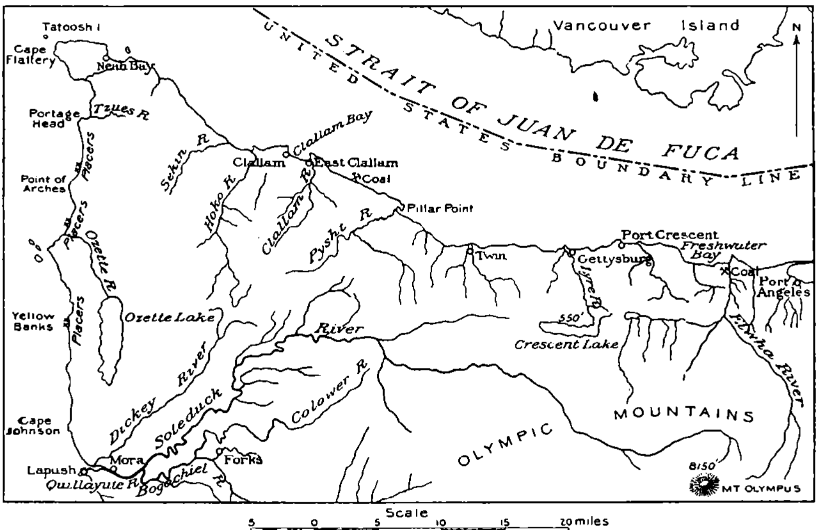

Fig. 11.—Sketch map showing location of gold placers and coal deposits in Clallam County, Wash.

River. As a result of this report a "rush" was made to this portion of the coast, and most of the sand beaches for 60 or 70 miles south of Cape Flattery were staked and prospected. Pay sand, however, was found at but few places, and at the present time only three claims are being worked. The northernmost is located on Shishi Beach, between Portage Head and Point of the Arches, about 10 miles south of Cape

[a] For a brief description and general geologic outline of this portion of the Olympic Peninsula see pp. 413–417.

Flattery; the second is about 5 miles south of the Shishi Beach claim, or 2 miles north of the mouth of Ozette River; while the southernmost claim is at Yellow Banks, 6 miles south of the mouth of the Ozette. It is thus evident that so far as is now known the pay sand is confined to a strip of the coast about 13 miles long, which extends from 10 miles below Cape Flattery to 6 miles below the mouth of Ozette River. With the exception of certain portions of the year, when landings are possible through the surf at Shishi Beach, trails furnish the only means of access to the placer region. The usual route of travel is the trail which skirts the coast from Neah Bay village, 5 miles east of Cape Flattery, to La Push, 35 miles south, at the mouth of Quillayute River.

A very conservative estimate of the output of these beach claims since their discovery is that furnished by Mr. W. W. Loveless, a miner who has lived in the region since 1894 and who is authority for the statement that at least $15,000 has been taken from the Shishi Beach-Ozette River district up to the present time.

Shishi Beach placers.—Shishi Beach, which extends about 2 miles northward from Point of the Arches, has furnished the most profitable claims of any along the Cape Flattery-Grays Harbor portion of the Washington coast. Nearly all of the richer claims have been pretty well worked out, and at present only one claim is being mined. This one is located a mile north of Point of the Arches.

The coast at this locality is skirted by a low bluff of gray shale and fine gray sandstone. The top of the bluff and the surface of the rolling terrace behind it is covered by a layer of varying thickness of yellowish sands and gravels of Pleistocene age. The beach at the base of the low bluff is covered with pebbles and cobbles of varying size, which are largely derived from the Pleistocene deposits by the encroachment of the sea upon the terrace, while the lower portion of the beach is covered by finer gravels and sands. The beach deposits at the present workings are from 1 to 3 feet in thickness and rest upon the eroded surface of the sandstone and shale. The pay sand forms a thin layer on bed rock near the base of the bluff and is profitably worked for some feet away from the latter. It penetrates the crevices of the underlying sandstone and shale for 2 or 3 inches, and on this account a layer of the bed rock is generally removed and sluiced with the sand.

The gold is derived from the Pleistocene sands and gravels, and occurs in paying quantities only where the conditions of concentration by wave action are favorable. Colors are obtainable in all of the small streams which flow across or cut through the Pleistocene terrace in this vicinity, but the writer was informed that the pay sand is confined to the beach deposits. As no veins of quartz occur in the bed rock at this locality, and as the Pleistocene sand at this and the other placer workings of the region yields colors by panning, it is evident that the Pleistocene deposits are the local source of the pay dirt.

The gold is always associated with magnetite ("black sand") and garnet ("ruby") sand, and in some places with considerable quantities of pyrite in small grains. Although the gold is always associated with "ruby" sand, it often happens that where the latter is most abundant the gold may be lacking, except in very small quantities. Small amounts of platinum and iridosmine (an alloy of iridium, osmium, platinum, rhodium, and ruthenium) occur with the gold and are probably derived from the same source as the latter. Whether the platinum and iridosmine are found in paying quantities was not learned by the writer.

The gold is found in worn flakes varying in size from particles fine enough to float to pieces worth 15 or 20 cents. The largest piece found on this beach was worth a dollar. The gold is quite uniform in composition, assaying from 18.12 to 19.20 carats.

Mining is carried on by the usual sluice-box method, the water being taken from a near-by stream and conveyed to the workings in a wooden flume. The gold is removed from the riffle concentrates by panning. Although no definite estimate could be obtained, it is probable that the claims along here yield from $2 to $5 per day per man by the methods now in vogue. More elaborate methods would doubtless greatly increase this output.

Ozette placers.—The physiographic and geologic conditions for 2 miles north of the mouth of Ozette River are similar to those north of Point of the Arches, and pay sand occurs here in the same way as it does at the latter locality. The claims along this stretch of the coast have not been very thoroughly prospected owing to lack of available water, but from the tests made the gold and associated minerals are similar to those found farther north and occur in paying quantities. On account of the scarcity of water at this locality rockers have been used exclusively in the prospecting and mining operations. Water will have to be brought from Ozette River or some of its tributaries before the claims in this district can be very profitably worked.

Yellow Banks placers.—Six miles south of the mouth of Ozette River is a locality known as Yellow Banks. The place derives its name from the characteristic yellowish brown or "rusty" bluffs which skirt the coast in this vicinity, and which at one place attain a height of over 125 feet. These bluffs consist of roughly horizontally bedded Pleistocene sands and gravels, which continue below the surface of the beach, no bed rock being visible either on the beach or in the bluff.

Placer mining has been profitably carried on in the beach sands and gravels at the base of these bluffs, the pay sand being the "concentrate" from the material which is continually dropping from the face of the cliff. Water being abundant at this place, the sluice-box method is used entirely. The association of gold, platinum, iridosmine, garnets, magnetite, etc., is the same at this locality as at those previously described. No estimate of the output of this district or of the pay quality of the placers could be obtained, as at the time of the writer's visit the workings were temporarily deserted.

Résumé.—Placer gold mining has been carried on since 1894 in the beach sands at different points along the west Washington coast from about 10 to 23 miles south of Cape Flattery. During this period at least $15,000, and possibly much more, has been taken from the district. The gold is derived from the Pleistocene sands and gravels, which cap the bluffs along this portion of the coast, being concentrated on or near the bed rock at the base of the bluffs by the action of the waves. The gold is accompanied by small amounts of platinum and iridosmine, the three being associated with magnetite and "ruby" (garnet) sand and small quantities of pyrite. Mining is carried on principally by the sluice-box method, although where the water supply is limited, as at the locality 2 miles north of the mouth of the Ozette, rockers are used.

GEOLOGICAL SURVEY PUBLICATIONS ON GOLD AND SILVER.

The following list includes the more important publications by the United States Geological Survey on precious metals and mining districts. Certain mining camps, while principally copper producers, also produce smaller amounts of gold and silver. Publications on such districts will be found in the bibliographies for copper on pages 249 and 250, and for lead and zinc on page 316. For a list of the geologic folios in which gold and silver deposits are mapped and described, reference should be made to the table on pages 14 and 17 of the present bulletin:

BAIN, H. F. Reported gold deposits of the Wichita Mountains (Okla.). In Bulletin No. 225, pp. 120–122. 1904.

BECKER, G. F. Geology of the Comstock lode and the Washoe district; with atlas. Monograph III. 422 pp. 1882.

——— Gold fields of the southern Appalachians. In Sixteenth Ann. Rept., pt. 3, 251–331. 1895.

——— Witwatersrand banket, with notes on other gold-bearing pudding stones. In Eighteenth Ann. Rept., pt. 5, pp. 153–184. 1897.

——— Brief memorandum on the geology of the Philippine Islands. In Twentieth Ann. Rept., pt. 2, pp. 3–7. 1900.

BOUTWELL, J. M. Progress report on Park City mining district, Utah. In Bulletin No. 213, pp. 31–40. 1903.

——— Progress report on the Park City mining district. In Bulletin No. 225, pp. 141–150. 1904.

CROSS, WHITMAN. General geology of the Cripple Creek district, Colorado. In Sixteenth Ann. Rept., pt. 2, pp. 13–109. 1895.

——— Geology of Silver Cliff and the Rosita Hills, Colorado. In Seventeenth Ann. Rept., pt. 2, pp. 269–403. 1896.

CROSS, WHITMAN, and SPENCER, A. C. Geology of the Rico Mountains, Colorado. In Twenty-first Ann. Rept., pt. 2, pp. 15–165. 1900.

CURTIS, J. S. Silver-lead deposits of Eureka, Nevada. Monograph VII. 200 pp. 1884.

DILLER, J. S. The Bohemia mining region of western Oregon, with notes on the Blue River mining region. In Twentieth Ann. Rept., pt. 3, pp. 7–36. 1900.

ECKEL, E. C. Gold and pyrite deposits of the Dahlonega district, Georgia. In Bulletin No. 213, pp. 57–63. 1903.

ELDRIDGE, G. H. Reconnaissance in the Sushitna Basin and adjacent territory in Alaska in 1898. In Twentieth Ann. Rept., pt. 7, pp. 1–29. 1900.

EMMONS, S. F. Geology and mining industry of Leadville, Colorado; with atlas. Monograph XII. 870 pp. 1886.

——— Progress of the precious-metal industry in the United States since 1880. In Mineral Resources U. S. for 1891, pp. 46–94. 1892.

EMMONS, S. F. Economic geology of the Mercur mining district, Utah. In Sixteenth Ann. Rept., pt. 2, pp. 349–369. 1895.

——— The mines of Custer County, Colorado. In Seventeenth Ann. Rept., pt. 2, pp. 411–472. 1896.

HAGUE, ARNOLD. Geology of the Eureka district, Nevada. Monograph XX. 419 pp. 1892.

HAHN, O. H. The smelting of argentiferous lead ores in the Far West. In Mineral Resources U. S. for 1882, pp. 324–345. 1883.

IRVINE, J. D. Ore deposits of the northern Black Hills. In Bulletin No. 225, pp. 123–140. 1904.

LINDGREN, WALDEMAR. The gold-silver mines of Ophir, California. In Fourteenth Ann. Rept., pt. 2, pp. 243–284. 1894.

——— The gold-quartz veins of Nevada City and Grass Valley districts, California. In Seventeenth Ann. Rept., pt. 2, pp. 1–262. 1896.

——— The mining districts of the Idaho Basin and the Boise Ridge, Idaho. In Eighteenth Ann. Rept., pt. 3, pp. 625–736. 1898.

——— The gold and silver veins of Silver City, De Lamar, and other mining districts in Idaho. In Twentieth Ann. Rept., pt. 3, pp. 75–256. 1900.

——— The gold belt of the Blue Mountains of Oregon. In Twenty-second Ann. Rept., pt. 2, pp. 551–776. 1902.

——— Neocene rivers of the Sierra Nevada. In Bulletin No. 213, pp. 64–65. 1903.

——— Mineral deposits of the Bitterroot Range and the Clearwater Mountains, Montana. In Bulletin No. 213, pp. 66–70. 1903.

LORD, E. Comstock mining and miners. Monograph IV. 451 pp. 1883.

NITZE, H. B. C. History of gold mining and metallurgy in the Southern States. In Twentieth Ann. Rept., pt. 6, pp. 111–123. 1899.

PENROSE, R. A. F., jr. Mining geology of the Cripple Creek district, Colorado. In Sixteenth Ann. Rept., pt. 2, pp 111–209. 1895.

PURINGTON, C. W. Preliminary report on the mining industries of the Telluride quadrangle, Colorado. In Eighteenth Ann. Rept., pt. 3, pp. 745–850. 1898.

RANSOME, F. L. Report on the economic geology of the Silverton quadrangle, Colorado. Bulletin No. 182. 265 pp. 1901.

——— The ore deposits of the Rico Mountains, Colorado. In Twenty-second Ann. Rept., pt. 2, pp. 229–398. 1902.

SMITH, G. O. Gold mining in central Washington. In Bulletin No. 213, pp. 76–80. 1903.

——— Quartz veins in Maine and Vermont. In Bulletin No. 225, pp. 81–88. 1904.

SPURR, J. E. Economic geology of the Mercur mining district, Utah. In Sixteenth Ann. Rept., pt. 2, pp. 343–455. 1895.

——— Geology of the Aspen mining district, Colorado; with atlas. Monograph XXXI. 260 pp. 1898.

——— The ore deposits of Monte Cristo, Washington. In Twenty-second Ann. Rept., pt. 2, pp. 777–866. 1902.

——— Ore deposits of Tonopah and neighboring districts, Nevada. In Bulletin No. 213, pp. 81–87. 1903.

——— Preliminary report on the ore deposits of Tonopah. In Bulletin No. 225, pp. 89–110. 1904.

——— Ore deposits of the Silver Peak quadrangle, Nevada. In Bulletin No. 225, pp. 111–117. 1904.

——— Notes on the geology of the Goldfields district, Nevada. In Bulletin No. 225, pp. 118–129. 1904.

TOWER, G. W., and SMITH, G. O. Geology and mining industry of the Tintic district, Utah. In Nineteenth Ann. Rept., pt. 3, pp. 601–767. 1899.

WEED, W. H. Geology of the Little Belt Mountains, Montana, with notes on the mineral deposits of the Neihart, Barker, Yogo, and other districts. In Twentieth Ann. Rept., pt. 3, pp. 271–461. 1900.

——— Gold mines of the Marysville district, Montana. In Bulletin No. 213, pp. 88–89. 1903.

WEED, W. H., and BARRELL, J. Geology and ore deposits of the Elkhorn mining district, Jefferson County, Montana. In Twenty-second Ann. Rept., pt. 2, pp. 399-550. 1902.

WEED, W. H., and PIRSSON, L. V. Geology of the Castle Mountain mining district, Montana. Bulletin No. 139. 164 pp. 1896.

——— ——— Geology and mining resources of the Judith Mountains of Montana. In Eighteenth Ann. Rept., pt. 3, pp. 446–616. 1898.

WILLIAMS, A. Popular fallacies regarding precious metal ore deposits. In Fourth Ann. Rept., pp. 253–271. 1884.

TIN.

THE OCCURRENCE AND DISTRIBUTION OF TIN.

By Frank L. Hess and L. C. Graton.

ORES OF TIN.

The principal ore of tin is the dioxide (SnO_2), cassiterite. When pure this mineral contains 78.6 per cent of metallic tin, but usually the percentage is less, by reason of the presence of impurities. In color it is usually brown, but it varies from white to black. The streak or color of the powder is white, grayish, or brownish. Cassiterite crystallizes in the tetragonal system and very frequently occurs in well-developed crystals, which are usually double pyramids. The hardness of the mineral is between 6 and 7, or nearly that of quartz. It has only imperfect cleavage, but is very brittle, and in consequence can be easily crushed. It is practically insoluble, and is very resistant to weathering agencies. One of the characteristics of cassiterite is its high specific gravity, it being about seven times as heavy as water (6.8 to 7.1). On account of this high specific gravity, grains of the mineral are transported by running water with considerable difficulty, and are deposited at the first opportunity, forming placer deposits of the so-called stream tin. Over 80 per cent of the present supply of tin comes from these placers.

Wood tin is cassiterite which has been formed in such a way as to possess a fibrous structure, suggesting the grain of wood.

Stannite, or tin pyrites, a complex sulphide of copper, iron, and tin, occurs but rarely as an ore.

PRODUCTION AND CONSUMPTION OF TIN.

For many years the increasing world's production of tin has been unable to keep pace with the demand, and the consequently increased price of this metal has served to stimulate prospecting and mining. Notwithstanding this, the production for 1904 was 103,134 tons,[a]

[a] The short ton of 2,000 pounds is used throughout this article.

against 105,160 tons in 1903. This production was distributed as follows:

Production of tin for 1904.[a]

	Tons.
Straits Settlements	65, 696
Banka and Billiton	16, 394
Bolivia	10, 304
Australia and Tasmania	5, 692
England	4, 796
Germany and Austria	112
Miscellaneous	140
Total	103, 134

These figures do not include an uncertain amount, placed at 10,000 to 20,000 tons, which is annually produced and consumed in China. Owing to various speculative influences the average price of tin in the New York market during 1904 was practically 28 cents per pound, a very slight decrease from the price in 1903. On comparing the world's production of the common metals it appears that the yearly output of zinc or copper is over 5 times that of tin, that of lead over 9 times, and that of pig iron about 450 times as great.

The United States consumed in 1904 about 43,120 tons of the metal, or over 40 per cent of the world's production for that year. Of that amount about 13 tons were actually produced by this country, coming from the Ross mine, at Gaffney, S. C. Ore containing about 25 tons of metal was mined in Alaska in 1904.

In view of the high price which tin commands and the great disparity between domestic supply and demand it is surprising that so little search for the metal should be made in this country. In order, if possible, to aid in the discovery either of new localities for tin ore in the United States or of larger deposits in localities already known, there is given in this paper a summary of those places in the United States where tin ore is known to have been found, with a brief description of the mode of occurrence and the accompanying minerals at the more important localities. For comparison and for fuller information on the subject, the same data have been given, wherever obtainable, for all the foreign localities which produce tin.

TIN IN THE UNITED STATES.

By L. C. GRATON.

Tin has been found in many places in both the eastern and western parts of the United States, and in consequence can not be considered a rare metal in this country. As indicated by the production stated above, however, it is by no means abundant.

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[a] Based on an estimate in Eng. and Min. Jour., vol. 79, No. 2, Jan. 12, 1905, p. 76.

Maine.—Tin occurs at Winslow in a number of narrow veins in mica-schist. The veins are composed largely of lepidolite and fluorite, holding cassiterite, beryl, and mispickel. This deposit was once worked, but with little success. Cassiterite has also been found in small amount at Paris and Hebron.

New Hampshire, Massachusetts, and Connecticut.—Cassiterite occurs at Lyme and at Jackson, N. H., in narrow veins carrying also quartz, mispickel, chalcopyrite, fluorite, and phosphate minerals. The mineral has been found at Goshen and Chesterfield, Mass., associated with albite and tourmaline. At Haddam, Conn., a few crystals have been found.

New York and New Jersey.—Tin has been reported from the highlands of New York and New Jersey as sparingly present in the magnetite deposits.

West Virginia.—In Mason and Cabell counties cassiterite has been found in quantities only of mineralogical importance.

Virginia.—Several finds of tin ore have been reported from Nelson County. The most important locality, however, is in Rockbridge County, near the headwaters of Irish Creek. Cassiterite was discovered there about 1883, and considerable attention has been drawn to the region at various times since. The best known property is the Cash mine, 7 miles east of Vesuvius station on the Norfolk and Western Railway. Narrow quartz veins cut a coarse-grained granite and carry bands of minerals, of which cassiterite, mispickel, pyrite, wolframite, and beryl are the most important. Fluorite and siderite have also been found. The granite adjoining the veins is largely converted into scaly muscovite mica and is impregnated with cassiterite. It is said that the ore will average 3 per cent cassiterite.

A small amount of development work was done some years ago and a large mill erected. Work was abandoned soon afterwards, probably more because of poor management than of proof that the deposit was not valuable. Some prospecting was done in the region during the summer of 1904.

North Carolina and South Carolina.—Dikes of pegmatite carrying cassiterite as an original constituent occur in a belt crossing Lincoln, Gaston, and Cleveland counties, in North Carolina, and extending into Cherokee County, S. C. Tin ore was found in place in 1886, and since that time more or less work has been done. The cassiterite occurs concentrated in certain parts of the dikes, but the distribution of these rich portions is irregular. Work is now being carried on with gratifying results at the Ross mine, near Gaffney, S. C., and at the Jones mine, north of Kings Mountain, N. C. It is probable that good ore bodies carrying over 2 per cent cassiterite will be found. Thirty-seven tons of ore of good grade have been shipped from the former property. A little cassiterite has been found at the Brewer gold mine, in Chesterfield County, S. C.

Georgia.—Tin ore has been found in Lumpkin County, northeast of Dahlonega, where schists are said to be interfoliated with granitic rock. A very small amount of tin has been found near Dahlonega in the process of gold washing.

Alabama.—At two localities in Alabama cassiterite has been found. In Coosa County a few pounds were found on the surface in association with a ledge of coarse-grained granite (pegmatite?) which cut the schists of the gold belt.

Near Ashland, in Clay County, work was done in the eighties at the Broad Arrow mines. Bands of gneiss are said to alternate with layers of schist, all resting on a feldspathic granite. The cassiterite occurred in the gneiss. A stamp mill was erected, but the venture proved unsuccessful.

Lake Superior and Missouri.—Reported discoveries of tin ore at the head of Lake Superior and in the Ozark region proved to be fraudulent.

South Dakota and Wyoming.—Probably the most widely known occurrence of tin in the United States is in the Black Hills. Tin in place was discovered in 1883 near Harney Peak, South Dakota, in the southern part of the Black Hills region, and shortly afterwards in the Nigger Hill region, Wyoming, in the northwestern part of the hills. Since that time the known area of distribution has been extended over much of the intervening territory.

Cassiterite appears to occur there in four ways:

1. As impregnation deposits from solutions or vapors in the pre-Cambrian pegmatite dikes, sometimes also partially replacing the mica-schist wall rock of the pegmatite. In this occurrence it is accompanied by spodumene, lepidolite, columbite, tantalite, tourmaline, arsenopyrite and other minerals.

2. In quartz veins cutting the pre-Cambrian core of the hills with spodumene and other accompanying minerals.

3. As an original constituent of some of the pegmatite, with practically no other uncommon minerals present.

4. In placers resulting from the breaking down of any or all of the foregoing deposits.

Judging from many estimates which have been made, it is probable that the veins average 1 to 2 per cent metallic tin.

A great deal of money has been expended in development, particularly in the vicinity of Harney Peak, but the output has been only a few small shipments. A little development work is now going on in the Nigger Hill region.

Montana.—In Jefferson County wood tin, associated with white topaz, has been found near Glancy. Stream tin has also been found at Prickly Pear Creek, French Bar, at the head of Tenmile Creek, in the " basin," in Basin Gulch, and in Peterson Creek.

Idaho.—Tin oxide is occasionally found in streams which have their source in the Bitterroot Range in Idaho. Jordan Creek is one of the localities known for many years. The mineral has also been found in the Coeur d'Alene district.

Colorado.—Tin ore has been reported from Jefferson County, near Golden.

Texas.—Cassiterite has been found near Barringer Hill, in Llano County, and about Herman and Willow creeks in Mason County.

A more important deposit has been described as occurring about 10 miles north of the city of El Paso. The granite core of the Franklin Mountains is here cut by a number of quartz veins carrying cassiterite and wolframite, and in places pyrite. The granite is much altered near the veins, and holds cassiterite and a little tourmaline. Some development work has been done, but the present conditions are not known.

California.—Tin has been found in small quantities, or has been reported from a number of widely separated localities in California.

In Hungary Creek, a tributary of the Klamath River, in Siskiyou County, the occurrence of float tin has been reported.

Small pieces of stream tin have been found near Weaverville, in Trinity County, and in the middle fork of Feather River, near Big Bar, in Plumas County.

A 5-foot vein carrying tin has been reported to occur near the Mokelumne River in Amador County.

In washing for gold on the White Lead gravel claim, in Tuolumne County, it is stated that native crystalline tin was found in final pannings from the boxes.

In the Temescal Mountains, in San Bernardino County, is the only important occurrence of tin ore in the State. Metamorphosed sediments are there cut by a large mass of coarse-grained granite. Small dikes of fine-grained siliceous granite cut the coarser rock. A porphyritic intrusive also invades the metamorphic rocks. A system of fissures containing quartz and tourmaline cuts these intrusive rocks. In but one of these veins, that which crosses Cajalco Hill, has cassiterite been found. It is distributed through portions of the vein or gathered in bunches or stringers. The irregular walls of the ore body and the character of the vein filling make it probable that the veins are due to replacement of the granite along originally narrow fissures. Copper and arsenopyrite have been found with the tin.

Tin was discovered at this locality in 1853. In the eighties considerable work was done, and a small amount of ore was mined and shipped. It is said that the rock sent to the mill contained in the neighborhood of 5 per cent cassiterite, but it is apparent that the enterprise was unprofitable. For many years the property has been idle, but it is now reported that work is soon to be resumed.

TIN IN FOREIGN COUNTRIES AND ALASKA.

By Frank L. Hess.

INTRODUCTION.

The portions of the world that produce tin in commercial quantities may be grouped into four regions—the Malayan, Australian, Bolivian, and European.

Of these, the Malayan and Australian regions are connected rather closely, as Australia belongs structurally to the same land mass as Asia, and the Malayan region forms a partial connecting link between the two.

The Malayan region, which includes, besides the Malay Peninsula, Burma, Yunnan, and the territory adjacent to the Lakawn Mountain axis, the islands of Banca and Billiton, and other islands of the East Indies, produces more than two-thirds of the tin output of the world. The Australian region includes all of Australia and Tasmania. The Bolivian region is the second largest producer of tin and the largest producer from veins, practically all its output being lode tin. The European region includes Great Britain and the continent of Europe.

Besides the tin produced in these four regions small amounts are mined in Japan and Africa, and scattered deposits have been found in the United States, Alaska, Siberia, and other places.

MALAYAN REGION.

The Malayan region, as stated, covers all that producing territory which, centering in the Malay Peninsula, extends northward into China and southward into the East Indies.

Malay States.—Running in a northwest-southeast direction through the Malay States is a backbone of granite mountains—the Lakawn Range—flanked by crystalline limestones, sandstones, and some chlorite- and talc-schists, which are generally considered Paleozoic. The range runs northward from the Malay States and unites with the mountain complex of southern China and eastern India. On the south, through the sinking of the land, it is now separated by comparatively shallow water from its southeasterly extension on the producing islands of Singkep, Banka, and Billiton. In the Malay Peninsula this range divides the country longitudinally into approximately equal parts. Behind Perak the mountains rise to a height of

8,000 feet, from which they gradually lower, northward, to half that height.

The granites become porphyritic in the main range, often containing much tourmaline in the tin regions, where they sometimes lose their mica content. The rocks are deeply weathered, and the valleys are filled with their detritus. Through this detritus cassiterite is scattered, forming the placers from which most of the tin of the region is obtained.

Of the sedimentary rocks, the limestone is the most abundant and important, and in it deep holes, formed by weathering, sometimes contain rich accumulations of stream tin.

Quartzose and feldspathic dikes, carrying cassiterite, cut the granite at many places. Cassiterite occurs in the granite as impregnations, veins, and stockworks. The veins are found also in the limestone and sandstone.

On the east side of the range veins occurring in slate are being worked. They vary greatly in thickness, generally have indistinct walls, and the cassiterite impregnates the country rock. This deposit is four days by boat up a river from Kuantan, a small town on the east coast, 225 miles by steamer from Singapore.

The minerals accompanying cassiterite in the various veins are tourmaline, topaz, fluorite, wolframite, iron pyrites, chalcopyrite, arsenopyrite, bornite, scheelite, sapphire, magnetite, and rhodochrosite, besides the usual minerals of the inclosing rocks. Small amounts of thorium and cerium minerals have also been found in some places. All of these minerals, except those destroyed by weathering, as the sulphides, are also found in the placers.

The largest placers of the Malay States are on the western side, but fields are also worked on the eastern side. They have been worked for hundreds of years and are now producing over 60 per cent of the tin that finds its way into the general commerce of the world. The Kinta district, in the State of Perak, contains the richest and most extensive placers of the region. The placers extend from the hillsides out into the plain, being residual upon the hill slopes and largely alluvial below. The hillside placers are often richer and contain larger pieces of tin ore, but are shallower. The richest ground is just at the foot of the hills. The cassiterite may be distributed throughout the gravel, but is generally in the lower part and is covered by an overburden of barren alluvium from 10 to 40 feet or more in thickness. The pay gravel may be of any thickness up to over 140 feet, which it reaches at one place in Perak.

Nearly all work is done by Chinese laborers, and many of the placers are controlled by them. The overburden is removed by contract. The earth, both barren and rich, is carried out by men and washed by a crude method of sluicing. Modern methods are being introduced, however, and hydraulic plants for sluicing, puddlers for clayey ground, and steam crushers for coarse ore are being installed.

Water interferes considerably in the lower workings, and in many of them centrifugal pumps run by steam are used, while in others Chinese pumps run by man power are still in use.

Much of the ore was formerly smelted with charcoal in small shaft furnaces, but now nearly all of it is smelted at Singapore in reverberatory furnaces.

The production of tin in the Malay Peninsula for 1904 was 65,696 tons, or nearly 64 per cent of the total production of the world exclusive of China.

Region north of the Malay States.—Tin deposits are also worked along the Lakawn Range in many places in Tenasserim and Burma, and have been worked for centuries on the eastern side of the range by the Karen-ni or Red Karen tribes.

Yunnan.—China is said to have an output of from 10,000 to 20,000 tons of tin per year, from the province of Yunnan, but this estimate is probably too high. It is seldom that any of this tin finds its way into the markets of the world, being generally consumed in China. The deposits occur at Tomuko, Tsementong, Malaken, and Kotin, those at the last-named place being the most important.

Some of the tin ore occurs in veins in Triassic limestone and in residual deposits from the weathering of the rocks. At Malaken the tin in " red clay " veins is giving way to copper.

French Indo-China and Siam, on the eastern side of the Lakawn Range, produce tin at a number of places, but the output is unimportant at the present time.

Junk Ceylon, the *Mergui Archipelago*, and other islands off the west coast of the Malay Peninsula have some unimportant deposits of tin. The geology and occurrence in these places are similar to those of the Malay States. The output is unknown, but is small.

Singkep, a small island (about 193 square miles) lying about halfway between Banka and Singapore, contains tin placers which have been productive for more than a century. The geology is very similar to that of Banka and Billiton. In 1901 it produced 793 tons of tin. No figures showing the production since that time are available.

Banka.—The island of Banka lies about 200 miles southeast of the end of the Malay Peninsula and with Billiton forms the extension of the tin-bearing Lakawn Range. The island contains several large masses of granite, cut by finer-grained granite, granitic porphyry, and syenite. On the north and south are Silurian slates and sandstones, the latter changed to quartzite near the granites.

The tin ore seems to occur in the granites, generally as impregnations, sometimes as lodes or veins. Narrow veins and pockets of ore occur in the overlying slates and sandstones along the cleavage planes. It is from the deposits in the sedimentary rocks that the larger part of the alluvial accumulations are believed to have come.

The alluvial deposits have about 3 feet of bearing gravel, with an overburden of 25 to 35 feet of barren ground. The percentage of tin, taking the whole deposit, seems to be much under 0.5.

The water supply allows washing about eight months of the year in the lowlands and about five months in the higher districts.

The production in 1903 was 16,878 tons.

Billiton.—This is an island lying about 50 miles east of Banka, on which the conditions are said to be very similar to those at Banka. The granites are thrust through quartzite, hornblende-schists, clay slates, quartzitic sandstones, and close-grained black siliceous schists of Silurian and Devonian age.

The tin placers have been very systematically worked. Prospecting is done by boring, and the land is leased to Chinese on a basis of the tin content.

The production of Billiton for 1903 was 4,088 tons of tin. The production has been diminishing since 1900, for which year it was 6,227 tons.

Sumatra lies southwest of the Lakawn Mountain axis, and is but a small producer of tin, although some veins and placers have been found there.

Other localities.—Tin also occurs on Carimon Island, a small island in the Strait of Malacca, between Singapore and Sumatra, and on Flores Island, about 300 miles east of Java.

AUSTRALIAN REGION.

The Australian region, including Tasmania, is structurally closely connected with the Malayan region, the mountain systems of eastern Australia uniting with those of the East Indies and continuing southward into Tasmania.

Tin occurs in these mountains in the colonies of Queensland, New South Wales, Victoria, South Australia, West Australia, and Tasmania.

The tin is usually associated with granites supposed to be of Permian age, which cut Silurian slates, schists, sandstones, and conglomerates. It occurs in granitic dikes, in veins and stockworks in the granite, and in veins in the overlying sedimentary rocks, accompanied by fluorine and tungsten minerals, with arsenic, copper, and iron pyrites, and some rarer minerals. Near the lodes are placers, both residual and alluvial, and the larger part of the tin product of the region has been obtained from them.

Queensland, in the northeastern portion of Australia, has produced tin at a number of places, particularly at Herberton, Cooktown, Watsonville, Stanthorpe, Wild River, and the Kangaroo Hills. The only lode workings are at Herberton, Cooktown, and Kangaroo Hills.

The principal lode mines are at Herberton, in the southern part of the colony, in a mountainous district, with hills 2,000 to 4,400 feet high. The lodes occur chiefly in coarse arkoses and quartzites, and to a less extent in the granites, older slates, and schists. In many cases the lodes are replacements of the country rock along fissures. In other cases the tin appears in grains disseminated through apparently unaltered granite or porphyry. The rock is largely chloritized and serpentinized. Tourmaline, wolframite, topaz, fluorspar, bismuthinite, stibnite, galena, chalcopyrite, and magnetite accompany the ore.

In the Stanthorpe district, in the southeastern part of Queensland, gravels that have been partially worked by hand for tin are now being successfully worked by dredgers, although the tin content is small. One 114-hour run, during which time 5,500 tons of gravel were handled, gave 5,600 pounds of tin ore. Another run of 255 hours, during which time 10,000 tons of gravel were handled, gave 3,360 pounds of tin ore.

Tin was first discovered in Queensland in 1872, and the output reached its maximum in 1873, when 10,010 tons of ore were produced. In 1903 the production was 4,153 tons.

New South Wales, lying on the east side of Australia, is the second largest producer of tin of the Australian region. The richest occurrences are in the northeastern part, near the Queensland line, in the Vegetable Creek, Tenterfield, Deepwater, and Emmaville districts. Smaller deposits occur in the northwestern portion of the colony in the Stanley Mountains, in the central portion near Melrose and Fifield, and in the southern portion close to the Victoria line, near Germantown, Tumbarumba, and at a few other places.

The geology is in general very similar to that of the occurrences in Queensland. In the Vegetable Creek district the hills are formed of granite, with some diorite and acid dikes. The granite is thrust through upper Silurian shales, quartzite, and conglomerate. The tin-bearing granite is supposed to be Permian.

Tin veins occur in the granite and other igneous rocks, and also in the shales. They sometimes reach a width of 4 feet. There are also stockworks in the granite. Cassiterite in the veins is associated with quartz and feldspar, and all appear to have been deposited at the same time. The veins are said to average 3½ per cent cassiterite.

The accompanying minerals are tourmaline, topaz, fluorspar, wolframite, scheelite, molybdenite, beryl, arsenopyrite, magnetic, manganese oxides, and chlorite.

There are several series of tin-bearing gravels, some of which are Eocene, as shown by plant remains in the accompanying clays. These Eocene gravels have been preserved by lava flows. Flows occurred at different periods, and gravels formed during the intervals were covered by succeeding flows. These old gravels contain much zircon, topaz, beryl, garnet, emerald, and sapphire, and it was in digging for these gems that the tin was discovered. There is also a little gold in the gravels, which vary from 10 feet to one-half mile in width, and are from 1½ to 79 feet thick. The pay streaks average from 0.9 to 7 per cent cassiterite, but there is generally a heavy overburden of barren or almost barren gravel, although in some places tin ore may occur in the top gravels.

Dredgers have now been introduced in this region for extracting the stream tin.

During the year 1903 New South Wales produced 842 tons of tin and exported 613 tons of ore.

Victoria is but a small producer of tin, although in 1891 it produced 1,991 tons of tin ore. In 1892 the output fell to 457 tons, and in 1903 but 36 tons were produced. Of this amount 19 tons were saved by gold dredgers at Beechworth, 13 tons at Chiltern and Rutherglen in mining auriferous gravels, and 4 tons were obtained by sluicing in the Upper Yarra district.

No veins are being worked, although some are known near Mitta Mitta, close to the New South Wales border.

South Australia has not been a large producer, but in 1902 142 tons of tin ore were produced, part of which came from the Northern Territory.[a]

West Australia.—Tin ore, both as stream tin and in veins, occurs in three widely separated districts—at the heads of the Bow and Lennard rivers in the Kimberley district; at Brockmans Soak, Western Shaw, Moolyella, Coglegong, and Wodgina in the Pilbarra goldfields; and at Greenbushes in the southwestern portion of the colony.

The Moolyella diggings, which have been the most important of the Pilbarra goldfields, are all detrital, and were derived from veins carrying low percentages of ore.

The entire area is occupied by an intrusive quartz-feldspar-mica granite that often becomes coarse grained. Its age is unknown. In places pegmatite carries a low percentage of cassiterite, and its weathering has furnished the tin for the placers. The placers are about

[a] British Blue Book, Mines and Quarries, Genl. Rept. and Statistics, Part IV, Colonial and Foreign Statistics for 1902, 1904, p. 316.

exhausted, and none of the veins have been found rich enough to work.

In the Greenbushes field the rocks are largely crystalline, granitic, and gneissic, cut by dikes of diorite, tourmaline granite and pegmatite. Clay slate, dipping at a high angle, underlies much of the gravel.

Some of the pegmatite dikes contain a little less than 2 per cent tin. Veins up to 2½ feet wide, carrying tin and much tourmaline, occur in the granite. Zircon, garnet, monazite, and considerable amounts of niobates and tantalates occur with the tin.

Placers are worked in both residual and alluvial gravels. The output of western Australia for 1902 was 694 tons of ore, the metallic content of which is not given.

TASMANIA.

The mountains of eastern Australia continue into Tasmania, where they are also tin bearing.

The principal producing districts are Mount Bischoff, in the northwest part of the island, about 45 miles from the coast; the Stanley River field, on the river of that name, flowing from the north into the Pieman River, south of Mount Bischoff; the Mount Heemskirk deposits, still farther south, near the west coast, and the Blue Tier, a range of granite mountains south of the Ringarooma River, in the northeastern part of the island. Tin ore also occurs in other portions of the island in smaller quantities.

In general, the tin ore occurs with granite or granite-porphyry that is intruded into clay slates, sandstones, limestones, and conglomerates, which are frequently metamorphosed near the contact. Sheets of basalt and other effusive rocks sometimes cover both granite and sedimentaries, but have no genetic connection with the tin deposits. The ore occurs in veins cutting both granite and sedimentary rocks, in acid dikes, and as impregnations and stockworks in the granite.

At Mount Lyons tin ore is found in Silurian rocks 18 miles from the nearest known outcrops of granite, but the granite is probably not far below the surface.

The most important deposits are those at Mount Bischoff, in the northwestern part of the island. Here quartz-bearing porphyries, intruded through Silurian strata, contain impregnations and veins of tin ore, accompanied by much topaz. The dikes are often so much altered that the groundmass is composed of topaz and quartz. Tin ore also occurs along the contact of the slates and sandstones with the igneous rocks, in company with tourmaline, fluorite, wolframite, much arsenic and iron pyrites, and siderite. Granite occurs some distance from the mines. The porphyries have weathered deeply, and the residual material has been cemented with iron oxides, so that much of it has to be blasted. The Mount Bischoff mine is one of the largest tin mines in the world, its product for the year ending June 30, 1903, having been between 1,350 and 1,450 tons of tin. The mine has been worked both by great open cuts and by tunnels. One cut 1,000 feet wide and 100 feet deep gave ore carrying 3 per cent of tin oxide, but the average percentage is probably less. From one excavation, 66 by 66 feet, 240 tons of ore were taken, while 20 yards away there were barely traces of tin. Masses of very pure cassiterite, the largest weighing over 600 pounds, were taken out.

In the Blue Tier, a range of mountains near the east coast, between the Ringarooma River and Georges Bay, tin ore occurs in impregnations and stockworks in the granite. The deposits are of low grade, from under three-eighths to about five-eighths per cent of black tin, but occur in comparatively large masses. Topaz, fluorite, apatite, wolframite, scheelite, molybdenite, galena, copper and iron pyrites, and sapphire occur with the tin ore. Tourmaline is rare.

There are promising veins of tin ore in the Mount Heemskirk district of western Tasmania, and some veins are found also on the Stanley River farther north, where monazite occurs in considerable quantity with the ore.

The principal alluvial workings are on the Ringarooma and Georges rivers and their branches in the northeastern portion of the island. The deposits are of different ages, from Miocene to recent. Some of the older gravels are covered with basalt and are worked by underground mining, but most of the ore is obtained from shallow workings by ground sluicing. Most of the easily mined ore is worked out, and the larger and poorer deposits are now being hydraulicked. These placers give promise of long production. Tin was discovered in Tasmania in 1871, and the Mount Bischoff deposit was discovered the next year. The production reached its maximum of 6,013 tons of tin in 1878. For the year 1902 the output was 2,193 tons.

NEW ZEALAND.

Tin ore has been found in auriferous conglomerates at the base of the coal measures at Lankeys Creek, Reefton, Milford, and Dusky Sounds, on the west coast of Otago.

It has also been found in gravels and in gneissic granitoid rocks of the Remarkable Mountains, Stewart Island. On South Island stream tin has been found in the auriferous gravels of Humphreys Gully, near Hokitika.

BOLIVIAN REGION.

Bolivia is at present the second tin-producing region of the world. The mines are in the eastern cordillera of the Andes, in a district that extends from near Lake Titicaca eastward and southward, through a distance of over 300 miles, from above La Paz on the north, about 16° S. latitude, to Chorolque Mountain on the south, a little south of latitude 21° S. This region is just east of the great Bolivian Plateau, and contains many of the high peaks of the Andes.

The rocks of the region are arkoses, sandstones, slates, and shales of both lower and upper Silurian age, with intrusions of porphyritic igneous rocks. Trachytes occur in the southern portions of the region. The sedimentaries generally have a north-south strike and high easterly dip. Although there seems to be little or no granite in the tin district, it occurs in the ranges to the east.

There are four principal tin-mining districts in Bolivia—La Paz on the north, just east of the south end of Lake Titicaca; Oruro, farther southeast; Potosi, still farther on, and Chorolque, a little west of south of Potosi, in the same Department, the other districts being all in Departments of like names. Tin is also found in the Departments of Cochabamba and Santa Cruz, east of this belt, but none has been found west of this cordillera.

Bolivia derives by far the greater portion of its tin from veins, and is the world's largest producer of lode tin.

The tin veins or lodes occur in both sedimentary and igneous rocks, and, dipping steeply, generally run east and west across the strike of the bedded rocks, although occasional veins run north and south, or nearly so. The veins vary greatly in size and richness, reaching widths of 8 or 9 feet, and in places are almost solid ore, often carrying from 20 to 50 per cent cassiterite, but probably averaging from 10 to 12 per cent. In places the tin veins seem to be replaced in depth by iron pyrites, carrying but small amounts of tin sulphide and oxide, while in other places the veins are still rich at 1,000 to 1,200 feet below the surface.

The gangue is often a clay, probably a decayed feldspathic dike, though it is sometimes quartzose and exceedingly hard.

The accompanying minerals are tourmaline, fluorite, wolframite, arsenic, copper and iron pyrites, sulphides of bismuth and antimony, sphalerite, galena, barite, silver chloride, and gold, though all of these minerals may not be found in any one vein. Tourmaline seems not to be so abundant as in most tin regions. Many of the veins have been worked for silver, particularly at Oruro, and the tailings concentrated for tin, of which they frequently carry 2 per cent or more.

One mine on Huanuni Hill, in the Oruro district, was worked to a depth of 1,000 feet by the Spaniards. The ore was carried out by men, a man being able to make two trips a day, carrying 75 pounds at a load. At this depth there were still 5,000 tons of 25 per cent ore in sight. The development of the mines has been very slow on account of the lack of transportation facilities, everything having to be moved by pack mules or llamas. The building of the Antofagasta and Oruro Railroad has made a great difference, but many mines are still 90 miles or more from the railroad.

There is no coal in this part of the country and little wood, the only fuel being llama dung, and this is getting scarce. Gas engines and petroleum engines are therefore being installed.

Water is scarce in many places and aerial trams are being installed to move the ore to points nearer water and more convenient for milling. One of these aerial trams is nearly 2 miles long, and it has reduced the cost of transporting the ore to about one-tenth its former cost, from $1.25 per ton mile to 10 cents per ton mile.

Modern stamps have been set up in many places, but in others ore is crushed by Chilian mills, and in places a rocking-stone is still used. Ball, roll, and Huntington mills are also used.

Jigs, classifiers, buddles, and Frue vanners are used in concentrating the ores, but in some places they are still concentrated by hand in shallow streams of water.

Much of the "barilla," or tin concentrates, is shipped to Europe for smelting, the larger part going to London. A small portion only is smelted in the country.

Tin placers, called "veneros," occur at a number of places—Ocuri, Japo, Huanuni, and elsewhere—but their importance is not great as compared with the lode mines.

The production of tin in Bolivia for the year 1904 was about 10,300 tons.

With improvement in transportation facilities there will probably be a considerable increase in the output of tin.

Chile.—A few tons of tin ore per year are produced in Chile, but the output is unimportant. In 1901, 4 tons of tin were gotten out.

EUROPE.

In the European region England has produced and still produces much more tin than the rest of Europe combined. Spain, Portugal. France, Germany, Austria, Italy, and Russia produce small quantities.

England.—Tin has been mined in England for at least two thousand years and probably much longer. The mines of Cornwall, in the southwest part of England, are at present practically the only English producers.

The tin deposits here, as in most other places, are found in close connection with granites. Five large bosses of granite, with occasional smaller ones, extend in a northeasterly direction from Lands End for about 100 miles. The Scilly Isles are a sixth boss in the southwestern extension of this line. The granite is overlain by a clay slate of Devonian age—the "killas" of the Cornish miner—and both are cut by dikes (Cornish "elvans" or "elvan courses") of quartz-porphyry and serpentine.

The rocks are jointed in two principal directions, one set of joints following the line of granite masses northeast-southwest, and another crossing this set at right angles, with some medial joints. The veins follow these sets of joint planes.

The tin veins cut slates, granite, and dikes, and are evidently younger than the latter, although they frequently change their direction somewhat or are offset in passing through the dikes. The granites are supposed to be Carboniferous or Permian, so that the veins are younger than Carboniferous. Many of the veins outcrop in slate, but all can be followed into the granites. The veins are sometimes in fault fissures, as shown by slickensides, and are sometimes in brecciated zones.

Some of the veins carried copper ores in the slate but tin in the granites. The Dolcoath, the richest of the English tin mines, is on such a vein. This mine has reached a depth of about 2,100 feet, and is still in good ore, although most of the mines have become impoverished at lesser depths. The Dolcoath has been producing tin since 1854.

The veins in the slate are generally composed largely of quartz, while in the granite they contain feldspar with mica, chlorite, and tourmaline.

In the granite the lodes frequently have one definite wall, while on the other side the rock gradually loses its richness until it can not be economically mined. This is probably due to faulting, during which one side was covered with gouge comparatively impermeable to solutions. The cassiterite often replaces the feldspars, as does tourmaline, which occurs in great amount. Fluorite, topaz, zircon, copper, iron, and arsenic pyrites are accompanying minerals.

The ore mined generally runs a little over, but sometimes under, 1 per cent tin. The average richness of the ores from four of the largest mines during the ten years from 1871 to 1881 was as follows: Dolcoath, 59 pounds; Cooks Kitchen, 43 pounds; Tincroft, 53 pounds, and Carn Brea, 35 pounds, of black tin per ton.

The output of the English mines is slowly but steadily diminishing.

There are no placers now being worked in England, although they were formerly of much importance.

Ireland.—Tin has been found in small amounts in several places in Ireland under conditions much similar to those in Cornwall, but so far no workable deposits have been discovered, although a small amount of tin may have been extracted in early times. The known occurrences are at Dalkey, county Dublin, and in Goldmine Valley, county Wicklow. Tin is also reported from near the Lakes of Killarney, county Kerry.

France.—Tin is found in Brittany, in the western part of France, and in Creuse, in the central part, and in a few other places. A small amount has been produced.

The geology of Brittany is very similar to that of Cornwall. Granite is thrust through clay slate, and dikes of quartz-porphyry and serpentine traverse the country. Cassiterite occurs in quartz veins in the granite and in thin quartz veins and concretionary masses in the schistose or gneissic rocks between the granite and slate.

Topaz, emerald, and arsenopyrite occur in the veins with the cassiterite. In Creuse fluorite, wolframite, niobates, uranium-phosphate, calcium-phosphate, molybdenite, arsenopyrite, iron arsenate, native copper, melaconite, and barite occur with the tin.

The production in 1902 was 36 tons, and in 1903 23 tons, of tin ore.

Spain.—Tin is found in the provinces of Salamanca, Zamora, Orense, Pontevedra, and La Coruña in the west and northwest, and small amounts have been found in Almeria and at Cartagena in the southeastern part.

In Salamanca cassiterite occurs in quartz veins cutting gneiss and Silurian slate, with tourmaline, wolframite, some arsenopyrite, and copper sulphide as accompanying minerals.

In Zamora cassiterite occurs in quartz veins cutting granite and crystalline schists at their contact. Besides cassiterite the veins also carry much tourmaline and some fluorite, apatite, white mica, molybdenite, chalcopyrite, sphalerite, and galena. The arsenopyrite is sometimes argentiferous. White mica occasionally penetrates the cassiterite.

The occurences in other provinces are similar.

Alluvial deposits sometimes carrying gold occur in the vicinity of the veins, and a small amount of mining has been done since the time of Pliny.

The output for 1901 was 126 tons of dressed ore. In 1902 the output was 14 tons.

Portugal.—Tin is found in the provinces of Beira, Minho, and Tras-os-Montes, where it is found as stockworks in the granite, veins in the older slates, and in alluvial gravels in the vicinity of these deposits. The geology is much the same as in the neighboring Spanish provinces.

The mines have been worked spasmodically since Roman times. The output for the year 1901 was 34 tons, and for 1902 26 tons, of tin ore.

Germany.—The larger part of the tin mined in Germany comes from Saxe-Altenberg, near the Bohemian border of Saxony. The tin occurs mostly in stockworks in "zwitter," and where mined they carry from one-third to one-half per cent of tin. The zwitter is composed essentially of quartz with chlorite or lithia mica, and is an altered granite in which the feldspars have been replaced by silica. With the cassiterite there occur fluorite, wolframite, molybdenite, chalcopyrite, iron pyrites, arsenopyrite, bismuthinite, and bismuth. Tungsten minerals and arsenic are obtained as by-products.

The production in 1903 was 121 tons of ore, valued at $13,538.

Austria.—There is a small output at Graupen, Bohemia, a few miles south of Altenberg, under similar geologic conditions. The output is not large. In 1902 it was about 52 tons of ore, valued at $2,154.

Tin mines have been worked in Bohemia for hundreds of years, and there were formerly a considerable number of these mines, but they have been exhausted.

Russia.—The only deposits of tin known in European Russia are in Finland. On the north shore of Lake Lodoga tin ores are worked in connection with copper ores. The principal deposits are in bodies of sahlite (a green, nonaluminous pyroxene) in granite.

The production is small, only about 4½ tons of tin being produced in 1902.

Italy.—Although there is at present no output from Italy, it has in the past produced a small amount of tin.

Tin ore was found at Campiglia Marittima, Tuscany, in connection with beds of hematite in limestone of lower Jurassic age. Up to 1894 about 77 tons of ore had been produced. No production is known since that time.

AFRICA.

Tin has been reported from a number of places in Africa, but owing to the difficulty of transportation and the unsettled state of a large portion of the continent, little is known of most of the occurrences.

Swaziland.—Tin was discovered in western Swaziland in 1893, both in alluvial ground and in veins, in a country of quartz, hornblende, and talc schists intruded by granites, all cut by later acid dikes in which cassiterite occurs, accompanied by tourmaline, eschynite, monazite, corundum, garnet, and magnetite. The placers are shallow and easily worked and a considerable amount of tin ore has been extracted and shipped to England for smelting.

Transvaal.—Tin has lately been found at Buschveld, 65 miles north of Pretoria, in quartz veins 8 to 24 inches wide, traversing granite. The granite on both sides of the veins is impregnated with cassiterite. Chalcopyrite and hematite accompany the tin.

Cassiterite also occurs at Lydenburg, farther northeast, where it is accompanied by arsenopyrite. It is also found as stream tin and as veins in granite on Letaba River.

Kamerun.—Tin ores are reported in Kamerun in considerable amounts, but little is known of their occurrence.

Nigeria.—Tin probably occurs in both Northern and Southern Nigeria. In the former a company has been formed to mine tin near the Kamerun border. Some very pure tin in small rods of native manufacture has found its way to the London market from southern Nigeria, where tin ore occurs on Benoue River.

French Congo.—Tin is reported in the Crystal Mountains, on the Oubanghi, and at Djabbir, on the Ouelle Makua.

Madagascar.—Tin veins are doubtfully reported as occurring at Ambatofangehana.

ASIA.

Siberia.—Tin deposits occur in at least four different places along Onon River near the village of Olovianny Rudnik, where old workings were discovered by the Russians in 1811 and worked until 1852.

The rocks are very old, gray, argillaceous schists resting upon granite. Cassiterite is found in quartz veins cutting the schists, in the schists themselves, and in granite dikes cutting the schists. The gravels along the Onon are said to be stanniferous for 70 miles in this vicinity.

India.—Besides Burma and the adjoining country, considered in the Malayan region, tin occurs in India in the presidency of Bengal, in longitude 86° 07′ E., latitude 24° 10′ N., near Baragunda, with thin dikes of pegmatite, intercalated in gneiss, varying from 6 inches to 6 feet in thickness. Magnetite is thickly scattered through the pegmatite. Cassiterite is found over an area of 21 square miles in this neighborhood.

It was first found by natives, who smelted the cassiterite, thinking it was iron ore. When the white metal was obtained they thought it was silver and tried to sell it at a neighboring village as such.

The deposits have been prospected rather extensively, but no tin has been marketed from them, though they may be productive in the future.

Tin also occurs at Pihra, with lepidolite, in pegmatite dikes, at Simratara in granite, cutting mica-schists, and at a few other places.

Japan.—In Japan cassiterite occurs in veins in Satsuma, Hitachi, Suo, and Hyuga, and fluviatile deposits have been found in Mino and Bungo.

The only production at present is at Taniyama, in the province of Satsuma, where 21 quartzose veins, ranging from a few inches to 4 feet in thickness, are worked. They traverse soft tuffs and Mesozoic shales and sandstones, with occasional beds of dark-blue quartzite. The surface is almost everywhere covered with modern pumice, and exposures of volcanic rocks are common.

The cassiterite grains in the veins are of almost microscopic size. The ore runs from 10 to 13 per cent tin in places, and is accompanied by galena, pyrite, pyrrhotite, and sphalerite of secondary formation.

At Suzogoya, Hitachi province, tin occurs in quartz veins cutting Paleozoic sandstone, with dark-brown mica, magnetite, pyrite, and galena.

At Takayama and other places in Mino province cassiterite occurs with quartz, tourmaline, topaz, wolframite, beryl, sapphire, fergusonite, and naëgite, a new silicate of uranium and thorium.

At Kiwada, Suo Province, cassiterite is found in veins cutting metamorphosed Paleozoic clay slate. The vein stone consists of quartz with fluorite, scheelite, magnetite, chalcopyrite, sphalerite, garnet, pyroxene, and calcite.

At Iwato, Hyuga Province, cassiterite occurs with limonite.

Tin has been mined in Japan since the seventh century, but most of the mines are now exhausted. In 1901 the output was about 15.5 tons of tin.

MEXICO.

Tin has been found in a large number of places in Mexico over a considerable scope of country. It occurs in the States of Zacatecas, Jalisco, Guanajuato, San Luis Potosi, Sonora, Durango, and Lower California.

In general the geology of the different localities is much the same. The country rock is rhyolite and rhyolite tuff, of Tertiary age, generally associated with a fine-grained granite, but sometimes with thin-bedded Cretaceous shales and limestones, as at Sain Alto, Zacatecas. Cassiterite occurs along joint planes in pockets, bands, and impregnations, often in mamillary or botryoidal concretions, forming the so-called "wood tin," often beautifully colored red, yellow, brown, black, and other colors.

The accompanying minerals are quartz, fluorite, topaz, durangite, manganese minerals, biotite, hematite, and chalcedony.

At Sain Alto there is a small output of 1 to 3 tons of tin each year, which is used locally. The ranchers collect fragments of ore from cracks in the bed rock of the mountain streams after the winter rains cease and smelt it in rude shaft furnaces. Mining on a larger scale has so far not been very successful.

The placers now known are not rich enough to be worked.

Tin ore has been found in Lower California, but little is known of its occurrence.

ALASKA.

Tin has been found at a number of places in Alaska, but as yet there has been little production.

It has been found in place in Seward Peninsula, at Lost River, and Cape Mountain, and is reported from Brooks Mountain, Ears Mountain, and the Darby Mountains. Alluvial deposits have been found on Buck Creek and Old Glory Creek, and are reported on the Arctic slope north of Buck Creek, on Gold Bottom Creek, near Nome, and at one or two other places.

In the interior L. M. Prindle and the writer found pebbles of stream tin in the gold placers of Cleary Creek, near Fairbanks, in July, 1904, and miners report it in the gold placers of the Koyukuk.

At Lost River the country rock is a Silurian limestone, through which is thrust a granite boss about one-half mile in diameter. Quartz-porphyry dikes also cut the limestones in various places. These dikes are frequently much kaolinized, and in other places replaced by fluorite, which sometimes colors the dike violet or purple. The cassiterite occurs disseminated through the dikes, particularly in the kaolinized portions, and in veins in the limestone. Small amounts of tin are also found with pyrite in the granite. The accompanying minerals are tourmaline, topaz, fluorite, zinnwaldite, wolframite, quartz, epidote, garnet, chalcopyrite, iron pyrites, and galena. About 10 tons of ore, estimated to carry 10 to 20 per cent of tin, have been produced.

At Cape Mountain cassiterite has been found near the contact of the Carboniferous limestone and slates with granite, occurring in both sedimentaries and granite.

The Buck Creek placers occur in a slate country rock, which is probably underlain at no great depth by granite. The gravel is nearly all of slate and quartz. Pyrites, hematite, and a small amount of gold are the accompanying minerals. The cassiterite apparently comes from small stringers in the slate.

During the last two years probably 100 tons of stream tin, carrying 60 per cent tin, have been produced.

BRITISH AMERICA.

Small amounts of tin ore have been found in the auriferous gravels near Dawson, Yukon Territory, near Long Lake, British Columbia, and in graphitic gneiss derived from limestone at Graphite City, in the Ottawa Valley, Canada, where cassiterite is accompanied by quartz, rutile, titanite, augite, and pyrite.

None of the occurrences are of importance.

BIBLIOGRAPHY.

No attempt has been made to make the accompanying bibliography complete, but it is believed that it embraces the titles of those works that are most important and at the same time most easily accessible to the general reader.

GENERAL.

BECK, R. Ore deposits, their nature and occurrence. Translated by Walter H. Weed. New York, 1905.

LOUIS, HENRY. The production of tin. A reprint of a series of articles in the Mining Journal, London, 39 pp., 1 map, 1899.

PHILLIPS, J. A., and LOUIS, HENRY. A treatise on ore deposits. London and New York, 1896.

REYER, E. ZINN. Eine geologisch-montanistisch-historische Monografie. Berlin, 1881, 248 pp., with text figs.

ROLKER, C. M. The production of tin in various parts of the world. In Sixteenth Ann. Rept. U. S. Geol. Survey, pt. 3, 1895, pp. 458–538.

THE MINERAL INDUSTRY, New York, published yearly, gives excellent articles on the occurrence, production, and metallurgy of tin.

MALAYAN REGION.

COLLET, OCTAVE J. A. L'Étain, étude minière et politique sur les états fédérés malais. Bruxelles, 1903; 196 pp., 1 map, and a number of plates.

PENROSE, R. A. F. Tin deposits of the Malay Peninsula. In Jour. Geol., vol. 12, 1903, pp. 135–154.

SAUNDERS, W. T. Tin mining in the Straits Settlements. In Trans. Inst. Min. Eng. (Newcastle-upon-Tyne), vol. 27, pt. 4, 1904, pp. 343–350.

FRENCH INDO-CHINA.

LA CROIX, A. Sur les gisements stannifères de Hin-Boun (Laos). In Bull. Soc. franc. Min., vol. 24, pp. 422–425.

BURMA.

THEOBALD, W. Metalliferous resources of British Burmah. In Geol. Survey India, Records, vol. 4, pt. 4, 1873, pp. 91–93.

SUMATRA.

ROLKER, CHAS. M. Alluvial tin deposits of Siak, Sumatra. In Trans. Am. Inst. Min. Eng., vol. 20, 1891, pp. 50–84.

BANKA AND BILLITON.

Van der Wick, O. H. The occurrence of tin ore in the islands of Banca and Billiton. In Seventeenth Ann. Rept. U. S. Geol. Survey, pt. 3, 1895–96, pp. 227–242.

Verbeek, R. D. M. Ueber die Zinnerzlagerstätten von Bangka und Billiton. In Zeitschr. f. prakt. Geol., 1899, pp. 134–136.

GENERAL GEOLOGY.

Suess, Ed. La face de la terre, traduit par Emmanuel de Margerie, vol. 3, pp. 301 et seq.

AUSTRALIAN REGION.

QUEENSLAND.

Ball, Lionel C. Notes on tin, copper, and silver mining in the Stanthorpe district. Geol. Survey Queensland, Brisbane, 1904, pp. 9–21.

Cameron, Walter E. The Herberton tin field. Publ. No. 192, Geol. Survey Queensland, Brisbane, 1904, 1 map, 29 pp.

Skertchly, S. B. J. Tin mines of Watsonville. Publ. No. 119, Geol. Survey Queensland, Brisbane, 1897, 64 pp., 18 pls., and 37 figs.

Weedon, Thornhill. Queensland, past and present. Gov. printer, Brisbane, 1898, pp. 252–253.

NEW SOUTH WALES.

David, T. W. E. Geology of the Vegetable Creek tin-mining field, New England district, New South Wales. Geol. Survey N. S. W., 1887, 169 pp., with maps.

Genth, F. A. Contributions to mineralogy. In Proc. Am. Philos. Soc. Phila., vol. 22, No. 121, January, 1886, pp. 30–31. (Describes native tin.)

Pittman, Edward F. The mineral resources of New South Wales. Geol. Survey N. S. W., Sydney, 1901, pp. 130–150, with plates.

VICTORIA.

Annual Rept. of Secy. for Mines and Water-Supply. Victoria, 1892, p. 13; 1899, p. 16; 1900, p. 15; 1901, p. 16; 1902, p. 7; 1903, p. 7; and other reports.

SOUTH AUSTRALIA.

Brown, H. Y. L. Report on the gold discovery at Tarcoola; the Enterprise mine, the Earea dam tin find, etc., pp. 1–7, 1 map. Adelaide, 1900.

WESTERN AUSTRALIA.

Maitland, A. Gibb. The mineral wealth of western Australia. Geol. Survey of Western Australia, Perth, 1900, pp. 84–90.

———. Preliminary report on the geological features and mineral resources of the Pilbarra gold field. Bull. 15, Geol, Survey Western Austral., 1904, Perth, 118 pp., 8 maps, and 25 figs.

TASMANIA.

FAWNS, SYDNEY. Notes on the Mount Bischoff tin mine, Tasmania. In Mining Journal, London, vol 77, No. 3622, Jan. 21, 1905, p. 62. (Abstract of paper read before Inst. of Mining and Metal., London.)

KAYSER, H. W. F., and PROVIS, R. Mount Bischoff tin mine, Tasmania. In Minutes of Proceed. of Inst. C. E. London, vol. 123, p. 377 et seq.

MONTGOMERY, A. The mineral industry of Tasmania. In Eng. and Min. Jour., vol. 57, No. 17, Apr. 28, 1894, p. 389.

TWELVETREES, W. H. Report on the tin mines of the Blue Tier, county of Dorset. Tasmania Geol. Survey, Hobart, 1901, 33 pp., 9 figs.

WALLER, GEO. A. Report on the tin-mining district of Ben Lomond. In Rept. Secy. Mines of Tasmania for 1900–1901, Hobart, 1901, pp. 302–342.

———. Alluvial deposits of tin at the Scamander River and at St. Helens. In Jour. and Printed Papers of the Parliament of Tasmania, vol. 45, Hobart, 1901, pp. 72–83, 1 geol. sketch map.

———. Report on the tin deposits of Mount Heemskirk. Tasmania Geol. Survey, Hobart, 1902, 46 pp., 4 plates.

BOLIVIA.

BRADLEY, D. H., Jr. Mining in Bolivia. In Mining Magazine, New York, vol. 11, No. 1, Jan., 1905, pp. 41–48.

INTERNATIONAL BUREAU OF AMERICAN REPUBLICS. Bolivia, Govt. Ptg. Office, Washington, D. C., 1904, pp. 107–116.

MINCHIN, JUAN B. Tin in Bolivia. In The Mineral Industry for 1902, New York, vol. 11, 1903, pp. 584–597.

———. Tin production in Bolivia. Eng. and Min. Jour., New York, vol. 77, No. 6, Feb. 11, 1904, p. 244.

PASLEY, CHAS. S. The tin mines of Bolivia. Trans. Inst. of Mining and Metal., London, vol. 7, 1898–99, pp. 77–90 and 95.

STELZNER, ALFRED WILHELM. Die Silber-Zinnerzlagerstätten Bolivias. Ein Beitrag zur Naturgeschichte des Zinnerzes. Sonderabdruck aus der Zeitschrift der Deutschen geologischen Gesellschaft, Bd. 49, Heft 1, 1897, 94 pp., map and bibliography.

EUROPE.

CORNWALL.

COLENSO, JOHN N. Happy Union stream work. In Trans. Roy. Geol. Soc. Cornwall, Penzance, vol. 4, 1838.

FRECHVILLE, R. J. The great main lode of Dolcoath. In Trans. Roy. Geol. Soc. Cornwall, Penzance, vol. 10, pp. 146–156.

HENWOOD, W. J. Deposits of stream-tin ore in Cornwall. In Trans. Roy. Geol. Soc. Cornwall, Penzance, vol. 4, 1838, pp. 57–69.

MOISSENET, L. Observations on the rich parts of the lodes of Cornwall, translated by J. H. Collins. London and Truro, 1877, 150 pp., 8 plates.

PHILLIPS, WM. On the veins of Cornwall. In Trans. Geol. Soc. London, vol. 2, 1814, pp. 110–160.

———. Oxyde of tin. In Trans. Geol. Soc. London, vol. 2, 1814, pp. 336–376.

IRELAND.

KINAHAN, G. H. Notes on mining in Ireland. In Trans. Inst. Min. Eng., Newcastle-upon-Tyne, vol. 26, pp. 279, 280, 286.

FRANCE.

DAVY, L. Sur l'ancienneté probable de l'exploitation de l'étain, en Bretagne. In Comptes Rendus Acad. Sci., Paris, 1897, tome 125, pp. 337–339.

FUCHS and DE LAUNAY, L. Traité des gîtes minéraux et métallifères, vol, 2, Paris, 1893, pp. 136–145, figs. 197–200.

MALLARD, M. Note sur les gisements stannifères du Limousin et de la Marche et sur quelques anciennes foulles qui paraissent s'y rattacher. In Annales des Mines, sér. 6, tome 10, 1866, pp. 321–352.

PHILLIPS, J. A., and LOUIS, HENRY. A treatise on ore deposits. London and New York, 1896. pp. 331.

SPAIN.

PUIG Y LARRAZ, D. GABRIEL. Descripcion, fisica y geologica, de la provincia de Zamora. In Memorias de la Comision del Mapa Geologica de España, Madrid, 1883, pp. 411–437.

GIL Y MAESTRE, AMALIO. Descripcion, fisica, geologica y minera, de la provincia de Salamanca. In Memorias de la Comision del Mapa Geologica de España, Madrid, 1880, pp. 255–261.

THOMAS, CAPT. CHAS. Some Spanish tin deposits. In Trans. Min. Assn. and Inst., Cornwall, Truro, vol. 2, 1888–89, pp. 66–70.

PORTUGAL.

PHILLIPS, J. A., and LOUIS, HENRY. A treatise on ore deposits. London and New York, 1896, pp. 515–516.

GERMANY AND BOHEMIA.

BECK, R. Ore deposits, their nature and occurrence. Translated by Walter H. Weed. New York, 1905.

CHARLETON, ARTHUR G. Tin; mining, dressing, and smelting it abroad. London and New York, 1884. XI, 83 pp., ills. and plans.

HAWKINS, JOHN. Tin floors, etc. In Trans. Royal Geol. Soc. Cornwall, Penzance, vol. 2, 1822, pp. 29–48.

ITALY.

BERGEAT, A. Beiträge zur Kenntniss der Erzlagerstätten von Campiglia Maritima (Toscana), insbesondere des Zinnsteinvorkommens dortselbst. In Neues Jahrbuch für Min., Geol. und Pal., Stuttgart, 1901, vol. 1, pp. 135–156, figs., and 6 plates.

[Anonymous.] The discovery of tin ore in Italy, and its relation to the bronze manufacture of the ancients. In Iron, London, new series, vol. 14, No. 343, Aug. 9, 1879, pp. 166–167, and No. 348, Sept. 13, pp. 322–323.

RUSSIA.

KEPPEN, A. Industries of Russia. Mining and metallurgy, translated by J. M. Crawford. Pub. by Russian govt. St. Petersburg, 1893, pp. 30–31.

KORZOUKHINE, J. A. Gisements de minerais d'étain sur la Rivière Onon. In Bull. No. 4, Soc. Ing. Mines. St. Petersburg, 1899, pp. 22–35. A digest translation is given in Trans. Inst. Min. Eng., Newcastle-upon-Tyne, vol. 17, 1898–99, pp. 642–646.

PHILLIPS, J. A., and LOUIS, HENRY. A treatise on ore deposits. London and New York, 1896, pp. 555–558.

AFRICA.

De Launay, L. Les richesses minérales de l'Afrique, Paris, 1903, pp. 158–160.

Hampton, J. H. On the occurrence of tin. In Trans. Geol. Soc. South Africa, Johannesburg, vol. 4, pp. 37–40.

Merensky, H. Neue Zinnerzvorkommen in Transvaal. In Zeitsch. für Prakt. Geol., 1904, Jahrgang 12, Heft 12, pp. 409–411.

[Anonymous.] Tin ore in the Kameruns. In the Mining Journal, London, vol. 66, No. 3609, Oct. 22, 1904, p. 405.

INDIA.

Ball, V. A manual of the geology of India. In Geol. Survey India, pt. 3, Calcutta, 1881, pp. 313–322.

Mallet, F. R. Geological notes on part of northern Hozaribagh. In Geol. Survey India, Records, Calcutta, vol. 7, pp. 35–36.

Oates, R. The copper and tin deposits of Chota-Nagpore, Bengal, India. In Trans. Fed. Inst. Min. Eng., Newcastle-upon-Tyne, vol. 9, 1895, pp. 427–451, pls. xxiv–xxv.

Stephens, F. J. Geology and mineral resources of Kumason and Garhival. In Trans. Inst. Min. and Met. London, vol. 10, 1901–2, pp. 394, 411.

JAPAN.

Bureau des Mines. Les mines du Japon, Paris, 1900, pp. 294–297.

Monroe, Henry S. The mineral wealth of Japan. In Trans. Am. Inst. Min. Eng., vol. 5, 1876–77, pp. 297–298.

Rein, J. J. The Industries of Japan. English translation, 1889, London, p. 303.

Tsunashiro, Wada. See below.

Wada, Tsunashiro. Minerals of Japan. Translated by T. Ogarra, Tokyo. 1904, pp. 50–51.

———. The mining industry of Japan. Mining Bureau, Dept. of Agriculture and Commerce, Tokyo, 1893, pp. 1, 300, 305.

NEW ZEALAND.

Binns, George J. Mining in New Zealand. In Trans. Fed. Inst. Min. Eng. Newcastle-upon-Tyne, vol. 4, 1892–93, p. 67.

MEXICO.

Aguilera, Jose G. Bosquejo geologico de Mexico. Bol. del Inst. Geol. de Mexico, Nos. 4, 5, 6, 1895, p. 234.

Allen, D. K. Tin in Baja California, Mexico. In Mining Journal, London, vol. 54, Oct. 11, 1884, p. 1184.

Halse, E. The occurrence of tin ore at Sain Alto, Zacatecas, with reference to similar deposits in San Luis Potosi and Durango, Mexico. In Trans. Am. Inst. of Min. Eng., vol. 29, 1899, pp. 502–511 (with figs.).

Ingalls, W. R. The tin deposits of Durango, Mexico. In Trans. Am. Inst. Min. Eng., vol. 25, pp. 146–163.

———. Notes on the tin deposits of Mexico. In Trans. Am. Inst. Min. Eng., vol. 27, 1897, pp. 428–429.

Nevius, J. Nelson. The Sain Alto tin deposits. In Eng. and Min. Jour., New York, vol. 75, No. 25, June 20, 1903, p. 929.

ALASKA.

COLLIER, ARTHUR J. Tin deposits of the York region, Alaska. Bull. U. S. Geol. Survey No. 225, Washington, D. C., 1904, 61 pp., 7 plates (incl. maps).

RICKARD, EDGAR. Tin deposits of the York region, Alaska. In Eng. and Min. Jour., New York, vol. 75, No. 1, Jan. 3, 1903, pp. 30–31.

CANADA.

BROCK, R. W. Preliminary report on the Boundary Creek district, British Columbia. Prof. Paper No. 26, Summary Rept. Geol. Survey Canada, 1902. Ottawa, 1903, p. 130.

HOFFMANN, G. CHRISTIAN. Report of the section of chemistry and mineralogy. Report "R," Ann. Rept. for 1899, Geol. Survey Canada, new series, vol. 12, Ottawa, 1902, pp. 16–17.

OSANN, A. Notes on certain Archean rocks of the Ottawa Valley. Report "O," Ann. Rept. for 1899, Geol. Survey Canada, new series, vol. 12, Ottawa, 1902, p. 72.

UNITED STATES.

BLAKE, W. P. Tin. In Mineral Resources of the United States, U. S. Geol. Survey, 1883–84, pp. 592–640.

FAIRBANKS, H. W. The tin deposits at Temescal, southern California. In Am. Jour. Sci., 4th series, vol. 157, 1897, pp. 39–42.

GRATON, L. C. The Carolina tin belt. In Bull. U. S. Geol. Survey No. 260, 1905, pp. 189–195.

HEADDEN, WM. P. Notes upon the history of the discovery and occurrence of tin ores in the Black Hills of South Dakota. In Proc. Colo. Sci. Soc., vol 3, pp. 347–350.

ROLKER, C. M. The production of tin in various parts of the world. In Sixteenth Ann. Rept. U. S. Geol. Survey, pt. 3, 1895, pp. 522–538.

WEED, W. H. The El Paso tin deposits. Bull. U. S. Geol. Survey No. 178, 1901.

THE CAROLINA TIN BELT.[a]

By L. C. Graton.

INTRODUCTION.

The exact date of the discovery of tin in the Carolinas is not known. About 1883 a tin-bearing mineral was found in a street of the village of Kings Mountain, N. C., and shortly afterwards it became known that tin oxide, or cassiterite, occurred scattered upon the surface of the soil in and about the town. The excitement which this knowledge caused abated after some time because of failure to find the mineral in large quantities.

Between 1886 and 1890 interest was revived by the explorations carried on in the vicinity of Kings Mountain by parties from New York City. A second failure to locate valuable deposits of the ore led to another period of inactivity, which was brought to a close by the discovery in 1902 of tin ore on property belonging to Mr. S. S. Ross, near the town of Gaffney, S. C. In 1903 Mr. Ross shipped nearly 20 tons of cassiterite to England, and in 1904 a second shipment of about the same amount was made. This actual production of tin from the Carolina belt served as a stimulus to prospecting and development work, and at the present time there is considerable activity manifested throughout the region.

The writer visited the Carolina tin belt in the fall of 1904 and spent about three weeks in a study of the deposits. The work has been carried on under the supervision of Mr. Waldemar Lindgren, who spent a few days in the field with the writer.

LOCATION AND GENERAL GEOLOGY.

The Carolina tin belt, as at present explored, extends in a northeasterly direction from Gaffney, Cherokee County, S. C., to about 4 miles east of Lincolnton, Lincoln County, N. C., a distance of about 35 miles. (See fig. 12.) It lies in the Piedmont Plateau, 30 to 50 miles east of and approximately parallel to the Appalachian Mountains.

[a] A more detailed paper is in preparation.

The position of this belt is very largely dependent upon the distribution and structure of the formations. It has long been recognized that many of the rocks are ancient and highly metamorphosed sediments, and as early as 1856 Doctor Lieber, State geologist of South Carolina, had worked out much of the structure of the area in which the tin belt lies. The present idea of the geology of the region may be summarized as follows:

Sedimentary rocks—shales, limestones, and sandstones—have been intensely metamorphosed and contorted. Their age has not been definitely determined, but it is doubtless great. The resulting

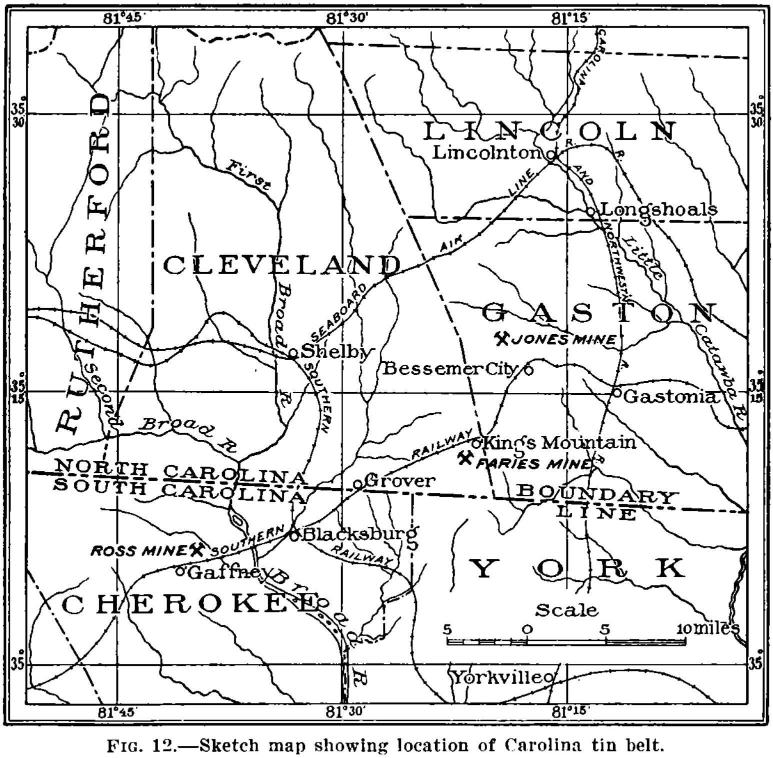

FIG. 12.—Sketch map showing location of Carolina tin belt.

products now appear as schists or slates, partly marmorized limestones, and impure quartzites, and have been bent up into a sharp anticlinal fold. The axis of this fold conforms with the general direction of the greater uplifts to the west, and hence the rocks strike northeastward. A noticeable turn or bend in the axis of the fold takes place near the boundary between North Carolina and South Carolina, and corresponds to the similar bend in the main Appalachians.

The anticlinal fold is shown particularly well near Blacksburg,

S. C. It took place so long ago that the crest has been worn away, but its topographic effects are seen in the two parallel ridges which mark the position of the quartzite beds. Blacksburg lies between these two ridges. Kings and Crowders mountains represent the eastern outcrop of the quartzite layer. The ridges are discontinuous and unsymmetrically developed with respect to the axis of the fold, so it is evident that relative resistance of the rocks and original structure were not the only elements which entered into the physiographic development of the region.

These original sediments have been invaded at several times by intrusions of igneous rocks. Possibly before any intense metamorphism took place, and certainly before it ceased, comparatively large masses of basic dioritic or gabbroitic rock were intruded. These are now represented by a dark greenish rock, composed very largely of hornblende, which may be called amphibolite. A foliation has been induced in the rock, and this generally corresponds with the bedding of the sediments. Very much more recently narrow dikes of diabase have been erupted, usually cutting across the strike of the older rocks. These, below the zone of weathering, are practically unaltered.

Of uncertain age, but decidedly later than the folding of the sediments, is a biotite-granite which approximately parallels the fold. It is best exposed on the west side of the anticline, but is also known in places on the east side.

Numerous dikes of pegmatite cut through both the amphibolite and the sediments. These masses usually, but not always, have the same or nearly the same strike and dip as the surrounding rocks. The pegmatite is the formation which is of interest in connection with the tin deposits, for in intimate association with some of it the ore is found.

DISTRIBUTION AND STRUCTURE OF THE TIN-BEARING ROCK.

The tin belt is limited to the occurrence of pegmatite. In most places, so far as at present known, the belt is narrow, comprising one or a few closely spaced dikes. In some localities, however, the number of pegmatite bodies increases, and at times also the distance between them is greater and the belt is wider. This pegmatite belt passes through Gaffney, S. C., northwest of Blacksburg, S. C., just southeast of the towns of Grover and Kings Mountain, N. C., a couple of miles west of Bessemer, N. C., through Longshoals, N. C., and about 4 miles east of Lincolnton, N. C. The belt reaches its maximum width of 2 miles not far south of the northern border of Gaston County, N. C. If these localities be noted upon the map, it is seen that the belt extends about northeast from Gaffney to a little north of the State line, and there turns more nearly northward, corresponding very closely with the axis of the Blacksburg anticline. But the correspondence is not exact, for at Gaffney the pegmatite dikes occur on the southeast side of the axis and hence dip to the southeast, while from Blacksburg northward they occur where the rocks dip northwestward, indicating that the belt crosses the axis of the anticline at some intervening point. The structure of the northern part of the area is much confused and has not been deciphered.

The pegmatite masses are called dikes, but they are very irregular. In dip, strike, and width individual bodies exhibit great variations. Forking or branching is rather common. Frequently a dike pinches out completely and it is not found again, but sometimes it reappears in the same plane or to one side. These variations take place both horizontally and vertically. For instance, a dike which may have a considerable continuous extent upon the surface may pinch out at a comparatively small depth and perhaps be found again below or at one side. Conversely, a dike which is short horizontally may be deep. Some of the dikes are more persistent than others, but it is probably only a matter of distance or depth when they, too, will show irregularities. In actual width the dikes vary from numerous small streaks, a few millimeters wide, injected into the country rock and collectively forming what may be considered an individual dike, to bodies probably 30 or more feet wide. One of the wider dikes occurs about a mile south of Kings Mountain village. The common width of the dike thus far exploited for tin ore is from 2 to 6 feet.

CHARACTER OF THE PEGMATITE AND THE ORE.

There are two varieties of pegmatite. One is composed almost exclusively of quartz and microcline, and, so far as known, carries no tin. It occurs rather commonly in the neighborhood of the Ross mine at Gaffney. The tin-bearing variety is particularly characterized by abundant muscovite-mica in large foils, in feathery aggregates, or in small, irregular grains mixed with quartz. It is not a lithium-bearing species. The amount of quartz varies, but is always considerable. Feldspar is sparingly present, and is largely of the plagioclase variety. In general appearance the rock is of light color and of variable grain.

It seems beyond question that these masses of rock are of igneous origin. There is no indication of their being the result of deposition from solution. The contact with the surrounding rocks is sharp and distinct, and no impregnation has taken place. On the other hand, the effect of the dikes on the wall rock, wherever it could be studied, has been exceedingly typical of the contact metamorphism due to an intruded igneous mass.

At various places throughout the belt these dikes carry cassiterite, the dioxide of tin. Development has not been sufficient to allow any extended generalizations as to the occurrence of the tin, but certain facts have been learned and may be briefly presented. The cassiterite is very unevenly distributed throughout the rock. In general it is concentrated along certain lines, usually steeply pitching in the dike and constituting ore shoots. These ore shoots are in general even more irregular than the dikes, and pinch, swell, branch, give out and come in again in a most erratic manner. Some of the ore bodies, however, have a considerable extent in two dimensions, and in certain cases persist as far as present explorations have gone. The cassiterite is crystalline, but only rarely has good crystal faces. In a few cases well-formed crystals have been found. It occurs from minute grains up to individuals weighing as much as 2 pounds, and aggregates which are almost entirely cassiterite sometimes weigh several hundred pounds. The mineral is usually dark brown to almost black, and has a metallic luster. In a few instances it has been found of lighter color. It is very friable, and in consequence often appears to be low in the scale of hardness.

Wolframite has been reported as an accompaniment of the cassiterite, but careful search has failed to reveal its presence. A veinlet about 2 millimeters wide carrying fluorite cuts the pegmatite at the Faries mine south of Kings Mountain. There also occur at that mine small masses of a brownish-purple mineral, which proves to be a phosphate of manganese and which is apparently of later origin than the tin. No minerals other than cassiterite and those above mentioned have yet been found in the pegmatite.

Granitic dikes older than the pegmatite and closely associated with it carry tourmaline; and quartz vein of uncertain relative age, also rich in tourmaline, likewise occur near the pegmatite dikes. While there may be a genetic connection between the pegmatite dikes and the larger masses of granite which occur nearby, no such relation has thus far been established.

Careful examination of the wall rock of the pegmatite dikes, both by crushing and panning and under the microscope, indicates that the tin mineral is confined to the pegmatite itself. No difference in the character of the pegmatite can be seen where cassiterite is abundant and where there is none.

From all obtainable evidence it seems probable that the cassiterite is an original or primary constituent of the pegmatite, existing as an accessory mineral, like magnetite in granite. Some factor as yet unknown has caused the segregation or concentration of the tin in certain places.

DEVELOPMENT AND ECONOMIC IMPORTANCE OF THE DEPOSITS.

Prospecting in the Carolina tin belt has been carried on more or less continuously since the discovery of tin in the early eighties. Development has naturally been more energetically pursued since the opening of a shipping property. Recent work has been done largely by Mr. Ross, of Gaffney, who owns the Ross mine, and by the Carolinas Tin and Development Company, of Gaffney. This company controls the Faries mine, south of Kings Mountain, and recently sold the Jones mine, 7 miles north of Kings Mountain, to the Carolina Tin Company, of Charlottesville, Va. The American Sheet and Tin Plate Company did considerable prospecting in the summer of 1904, and Messrs. Carpenter and Rudisill, of Kings Mountain, N. C., have explored rather extensively from Kings Mountain northward into Lincoln County, N. C.

The pegmatite belt continues southwestward from Gaffney, and northeastward from the center of Lincoln County, but beyond these points no authenticated discoveries of tin have been reported.

Ross mine.—The ore body of the Ross mine occurs in very much decomposed material, which is probably amphibolite. The mine is opened by a shaft 75 feet deep, from the bottom of which a short crosscut intersects the dike. A drift about 25 feet in each direction from the crosscut, and a 50-foot incline from the surface, follow the ore shoot. Seventy-five thousand pounds of cassiterite, which include a considerable amount of float ore gathered from the surface, have already been shipped.

Faries mine.—This property has a number of pegmatite dikes, of which one shows at the surface a fairly rich bunch of ore. A shaft near this outcrop is 40 feet deep and has about 200 feet of crosscuts and drifts at its bottom. These developments expose two converging pegmatite dikes, but the ore shoot seen on the surface has not been encountered and work is now suspended.

Jones mine.—Two pegmatite dikes carrying tin occur in amphibolite on this property. One is parallel to the foliation of the country rock and dips northwest, but the other is approximately vertical and crosses the strike of the amphibolite at a large angle. A shaft 175 feet deep has been sunk on the vertical dike, and drifts have been run in both directions at depths of 50 and 100 feet, and shaft and drifts are all in ore. At the 150-foot level a short crosscut to the south encounters some narrow streaks of tin-bearing pegmatite parallel to the main dike, but of too low grade to be profitable. A concentrating mill has been erected and nearly a carload of cassiterite is ready for shipment.

While no extended development has been done in the northern part of the area, some very encouraging results have been obtained in shallow openings, and that part of the belt appears to be the most promising.

It is possible that there is general dissemination of the cassiterite in very small quantities throughout the pegmatite, but such does not appear to be the case. In the segregations, or ore shoots, the amount of cassiterite varies greatly, from a small fraction of 1 per cent up to 20 per cent or more. It is probable that a number of shoots already known will average from 2 per cent of cassiterite up, and will be of sufficient size and persistency to prove profitable under good management. There seems to be no ground for expecting any marked change in the value of the deposits considered collectively, as depth is attained, although decided fluctuations will probably be encountered in certain individual deposits.

A little cassiterite has been obtained from placers near the Ross and near the Jones mines, but systematic search for stream tin has not been undertaken. In view of the much lower cost of winning placer tin than of mining it from lodes, it seems that this part of the prospecting ought not to be neglected.

Of the second shipment from the Ross mine, comprising nearly 18 tons of ore, analyses by Ledoux & Co. show that about seven-eighths averaged 70.44 per cent metallic tin, while the remaining portion contained 36.50 per cent, the total shipment thus averaging 66 per cent metal. This is a very good grade for lode tin. It is possible that ores from other parts of the belt, or other shipments from the same mine, may not equal this figure, but it is to be expected that careful and thorough concentration will result in a product of very good grade.

TESTS FOR CASSITERITE.

Because of the dark color and metallic luster of the cassiterite of this region, numerous dark heavy minerals have been mistaken for it. Of these, the iron ores ilmenite and magnetite are most common. It may therefore be of use to note here one or two simple tests for cassiterite. Magnetite can, of course, be detected by its attraction to a common magnet. Ilmenite is also feebly magnetic at times. The color of powdered cassiterite ranges from white to brown, and is never black. If a small piece of the mineral in question is ground to a very fine powder between two clean pieces of steel (the face of a hammer and a shovel will serve), it may generally be safely rejected as not containing tin if the powder is black. If brown or still lighter in color, the blowpipe test may be applied. So much of the finely ground material as can be piled on an area one-fourth inch square is added to twice its bulk of powdered charcoal and to three times its bulk of pulverized sodium carbonate, or ordinary washing soda. These three substances are thoroughly mixed and then transferred to a little depression in a stick of charcoal, where they are moistened to a thick paste. The flame of an alcohol lamp is then directed upon them with a blowpipe, care being taken to envelop in the flame as much of the material as possible and at the same time to produce an intense heat. If the operation is properly carried out, the presence of tin will be indicated by the appearance of small globules, which seem darker or less highly heated than the surrounding material. By continued heating numbers of these particles can be made to coalesce into a bead of appreciable size. The formation of such metallic beads or globules is not, however, a proof of tin, but may be due to the presence of any one of a group of metals of which tin is a member. Upon removing from the flame, the globules often become oxidized on the surface and covered with a white layer which masks their metallic character; but if the melted mass is crushed after cooling, the flattened pieces of metal may readily be observed. If a white insoluble residue results when the metallic beads are treated with concentrated nitric acid, it may be considered that tin is present.

CONCLUSIONS.

The Carolina tin belt appears to offer a promising field for exploration, although present indications are not such as to justify the assumption that it will supply the American market. Some of the developments seem certainly to have demonstrated the existence of considerable ore bodies, which if systematically and wisely developed ought to prove valuable.

Owing to the irregularity and the uncertainty of extent of the ore bodies, cautious methods of development are recommended. It should be borne in mind that in the case of these deposits a horizontal section of the rock is practically of as great instructive value as a vertical section. In other words, a surface trench 100 feet long reveals about as much as a shaft 100 feet deep. The former has the advantages of much lower cost and greater certainty in following the ore-bearing formation. In general, surface exploration in the way of pits and trenches should therefore be thoroughly carried out and promising results obtained before underground operations are started. Before any extensive plant for treating the ore is erected the developments should have demonstrated the presence of an ore body sufficiently rich and extensive to warrant such a procedure.

GEOLOGICAL SURVEY PUBLICATIONS ON QUICKSILVER, PLATINUM, TIN, TUNGSTEN, CHROMIUM, AND NICKEL.

The principal publications by the United States Geological Survey on the metals here grouped are the following:

BECKER, G. F. Geology of the quicksilver deposits of the Pacific slope, with atlas. Monograph XIII. 486 pp. 1888.

——— Quicksilver ore deposits. In Mineral Resources U. S. for 1892, pp. 139–168. 1893.

BLAKE, W. P. Nickel; its ores, distribution, and metallurgy. In Mineral Resources U. S. for 1882, pp. 399–420. 1883.

——— Tin ores and deposits. In Mineral Resources U. S. for 1883–84, pp. 592–640. 1885.

CHRISTY, S. B. Quicksilver reduction at New Almaden [California]. In Mineral Resources U. S. for 1883–84, pp. 503–536. 1885.

EMMONS, S. F. Platinum in copper ores in Wyoming. In Bulletin No. 213, pp. 94–97. 1903.

GLENN, W. Chromic iron. In Seventeenth Ann. Rept., pt. 3, pp. 261–273. 1896.

HOBBS, W. H. The old tungsten mine at Trumbull, Conn. In Twenty-second Ann. Rept., pt. 2, pp. 7–22. 1902.

——— Tungsten mining at Trumbull, Conn. In Bulletin No. 213, p. 98. 1903.

KEMP, J. F. Geological relations and distribution of platinum and associated metals. Bulletin No. 193, 95 pp. 1902.

PACKARD, R. L. Genesis of nickel ores. In Mineral Resources U. S. for 1892, pp. 170–177. 1893.

ROLKER, C. M. The production of tin in various parts of the world. In Sixteenth Ann. Rept., pt. 3, pp. 458–538. 1895.

ULKE, T. Occurrence of tin ore in North Carolina and Virginia. In Mineral Resources U. S. for 1893, pp. 178–182. 1894.

WEED, W. H. The El Paso tin deposits [Texas]. Bulletin No. 178, 6 pp. 1901.

——— Tin deposits at El Paso, Tex. In Bulletin No. 213, pp. 99–102. 1903.

WEEKS, F. B. An occurrence of tungsten ore in eastern Nevada. In Twenty-first Ann. Rept., pt. 6, pp. 319–320. 1901.

——— Tungsten ore in eastern Nevada. In Bulletin No. 213, p. 103. 1903.

MOLYBDENUM.

A MOLYBDENITE DEPOSIT IN EASTERN MAINE.

By George Otis Smith.

In Mineral Resources of the United States for 1903,[a] Dr. J. H. Pratt summarizes the production of the steel-hardening metals. He states that an increasing use of molybdenum steel has caused a greater demand for the ores of molybdenum. The principal property imparted to steel by the use of molybdenum is an increase in hardness and toughness. Molybdenum steel is recommended for large forgings for marine engines, for large guns, for boiler plates, and for high-speed tool steel. "The molybdenum increases the elongation of steel very considerably, and for wire drawing such an increase at a comparatively small cost is important."

The limited use of molybdenum is due not so much to any question as to its value as a steel-hardening metal as to the comparative rarity and high cost of the ores. The development of molybdenum deposits is similarly hampered by the uncertainty regarding the demand for the product. Doctor Pratt reports that the output of wulfenite and molybdenite for 1903 was 795 short tons, valued at $60,865. The probable value of molybdenum concentrates at New York is given as approximately $200 per ton. The molybdenite from the deposit described below would doubtless command a high price because of its purity, since no other metallic minerals appear to occur with it.

One of the principal deposits of molybdenum ore mentioned by Doctor Pratt is at Cooper, Me., and this deposit was visited by the writer in company with two members of the Maine Survey Commission in September, 1904. The town of Cooper is in Washington County, in the extreme southeastern part of Maine, and is the fourth township west of Calais. The nearest railroad station is Marion, in the second township south. At this locality prospecting for molybdenite has been carried on at several points, but the only important development thus far is that on the property of the

[a] Pp. 285–310.

American Molybdenum Company. At the mine, however, the writer was not permitted to examine the property thoroughly. A shaft has been sunk and some drifts are said to have been run on the molybdenite ore, but the secretive policy of the management prevented any observations which would furnish a basis for a statement of the probable extent of the deposit. Observations made at the surface, however, furnish data for a consideration of the character and origin of the deposit.

The molybdenite occurs both in pegmatite dikes and in the granite cut by these dikes. A number of distinct pegmatite dikes were seen on this property, varying in width from a few inches to several feet. In these the molybdenite occurs in lead-gray hexagonal crystals of short prismatic habit, or as less regular foliated masses, often with radiate structure. These crystals and bunches of molybdenite range from 1 to 2 inches in diameter and are intimately mixed with the quartz and feldspar of the pegmatite. The molybdenite is possibly more abundant near the contact with the country rock, yet there is no parallel arrangement of the minerals, but rather the intergrowth characteristic of pegmatites. The molybdenite is the only constituent of the pegmatite possessing well defined crystal faces, except in places where the feldspar crystals project into open spaces.

The molybdenite occurs also in small flakes or larger nests of flakes disseminated throughout the granite mass. The granite in other respects is the light-gray fine-grained variety common to this region and is probably of late Paleozoic age. It is comparatively poor in the darker minerals, but in places near the pegmatite dikes the flakes of molybdenite are sufficiently abundant to give the rock the appearance of a granite rich in biotite.

Molybdenite occurs at several other localities in Maine as well as in the other New England States. It is usually found in small flakes disseminated through the granite or gneiss, so that the Cooper occurrence is of special interest by reason of the light it throws on the origin of this mineral. The pegmatite dikes are probably approximately contemporaneous with the granite intrusion, representing the latest crystallization of the granitic magma and therefore intruding the consolidated granite. In this pegmatite magma molybdenum disulphide appears to have been a prominent constituent, and to have crystallized early in the consolidation of the dikes. The molybdenite in the granite may be either the result of impregnation at the time of the pegmatitic intrusion or an original constituent. The former view is supported by the apparently greater amount in the granite near the dikes.

The economic value of such a deposit as the Cooper molybdenite is partly conjectural. The conditions for quarrying and mining both the pegmatite and the wall rock appear favorable, and considerable work of this kind has been done. The rock lying on the dump contained varying proportions of molybdenite, but it seemed that most of the crude ore could be readily distinguished and separated from the barren rock by hand picking. The crucial test of the successful working of such a deposit is doubtless connected with the milling process rather than with the mining methods.

A compact plant for treating the molybdenite ore has been erected by this company, but the details as to cost of crushing the rock and of concentrating and cleaning the separated mineral could not be ascertained from the representative in charge.

The successful development of molybdenite deposits necessitates the adoption of economical and well-tested methods, both in mining and milling. The amount of development work done on the Cooper district at the time of the visit was sufficient to suggest the possibility that a valuable industry may be established here, but the success of the undertaking will depend largely upon careful business-like management.

VANADIUM AND URANIUM.

VANADIUM AND URANIUM IN SOUTHEASTERN UTAH.

By J. M. Boutwell.

INTRODUCTION.

The value of vanadium and uranium for commercial uses is stimulating search for compounds of these rare elements. Vanadium, which is used chiefly for hardening steel (it is claimed to be twelve times more effective for this purpose than tungsten), is scarce; and this utility and scarcity tend to create an increasing demand. Uranium, which is valued commercially for use in the manufacture of porcelain and glass[a] and scientifically for its radio-active properties, is also scarce and in growing demand.

The principal source of vanadiferous and uraniferous minerals in the United States has been an extensive area, embracing several localities in western Colorado.[b]

In 1898 the first determinations of these ores were made on a sample from Roc Creek, Montrose County, Colo., and in May, 1898, the first shipment of carnotite ores was made. Specimens from this deposit were then sent abroad, and it is probable that they were the object of the chemical studies which resulted in naming the mineral carnotite, and also in the discovery of its radio-active properties.[c] Deposits in this region have now been systematically opened and yield regular profitable shipments of both vanadiferous and uraniferous minerals. In consequence of these successful operations exploration has been carried on in adjoining areas, and deposits have been discovered in eastern Utah.

In the fall of 1903 the writer entered into correspondence with some of the discoverers of these new deposits and began gathering data and material from the Utah occurrences. Samples were subsequently sent by owners to the Survey for chemical determination, and it became desirable to investigate its occurrence in nature.

[a] Pratt, J. H., Production of steel-hardening minerals: Mineral Resources U. S. for 1903, U. S. Geol. Survey, p. 309.

[b] Hillebrand, W. F., and Ransome, F. L., Carnotite and associated vanadiferous minerals in western Colorado: Am. Jour. Sci., 4th ser., vol. 10, 1900, pp. 120–144.

[c] Kimball, Gordon, Eng. and Min. Jour., Jan. 16, 1904, p. 956.

Accordingly, after the completion of underground work in the detailed examination of the Park City mining district, late in the winter of 1904, the writer visited the two properties in Utah from which shipments had been made for commercial purposes. He made a necessarily hasty study of the geologic occurrence of the ores, collected specimens of the rare minerals, and also gathered data on deposits reported to occur elsewhere in the State. Since his return

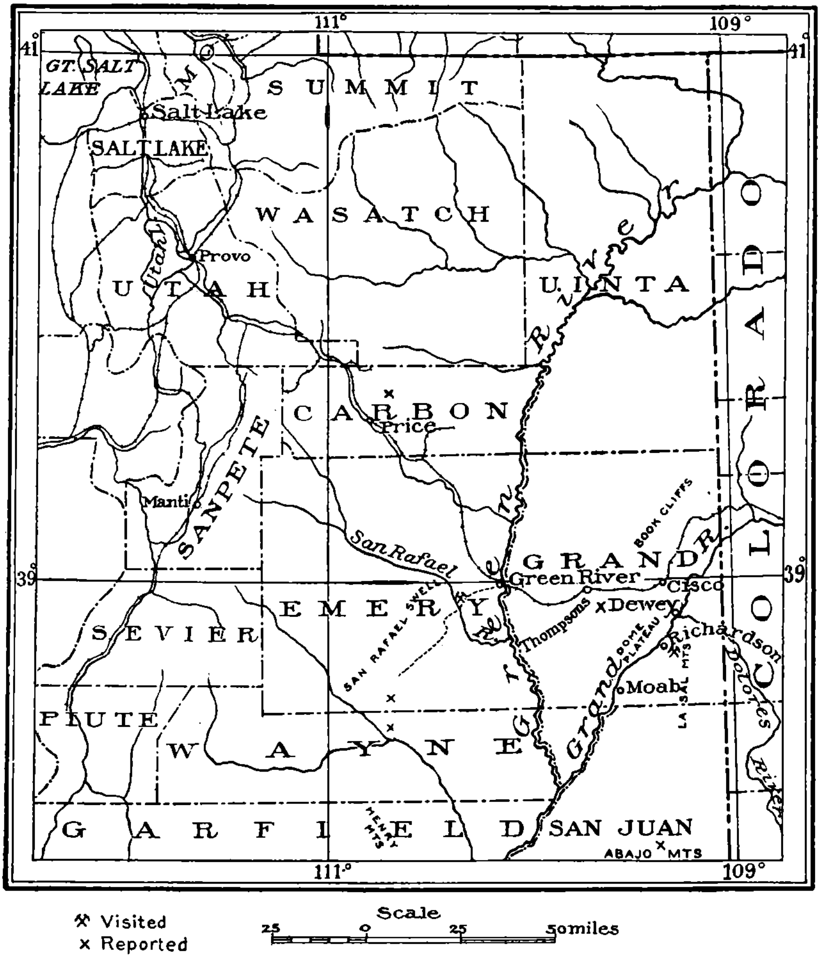

FIG. 13. Map of eastern Utah, showing location of vanadium and uranium.

to the office there has not been sufficient time for a complete study of the material collected. Doctor Hillebrand is engaged in a thorough chemical examination of the material, and the writer is studying its geologic occurrence. At the completion of this work the final results will be published jointly. Certain newly discovered facts regarding the chemical character and the geological occurrence may be of use in current exploration, and in order to give these out at once, this general statement is presented now as a preliminary report. After an introductory general description, the principal features of the two properties which have shipped ore are briefly described, and some of the other localities from which these minerals have been reported are mentioned.

The general chemical determination of the rare vanadium minerals collected by the writer has been made by Dr. W. F. Hillebrand, of the United States Geological Survey. For information regarding special deposits, the writer is indebted to Prof. J. E. Talmadge, of Salt Lake City; Mr. S. T. Lockwood, of Buffalo, N. Y.; Judge W. A. Warf, of Price, Utah, and Mr. Ira R. Browning, of Emery, Utah, and for valuable cooperation in field work to Manager James H. Lofftus, Richardson, Utah.

GENERAL DESCRIPTION.

The known deposits of uranium and vanadium minerals in Utah occur in the eastern and southeastern portion of the State in the margins of the basin of the Green, Grand, and Colorado rivers. This area is a geographic and geologic unit. The gentle southerly dip of the east-west Uinta Range gradually gives way to a flat dip, then in the Book Cliffs and the region immediately south to a slight northerly dip, and thus forms the Green River Basin. On its margins the underlying beds are turned up by the laccolithic intrusives of the La Sal group on the east, the Abajo cluster on the southeast, the Henry Mountains on the southwest, and the San Rafael swell on the west. The rare minerals appear to be restricted to Mesozoic sediments in or adjacent to these intrusive centers.

The Utah deposits thus occur in the same general geographic province as the deposits of western Colorado, and probably in an equivalent series of rock formations, but they differ in important mineralogical characteristics and in certain features of geological occurrence. In general the Colorado deposits occur in sandstone of Jurassic age, principally in the La Plata formation, except on La Sal Creek, where the thin-bedded sandstone in which the uraniferous deposits occur was believed to be the next overlying formation in the Jurassic, known as the McElmo formation.[a] Stratigraphic work on the formations constituting the country rock of the Utah deposits could not be undertaken during the limited time at the writer's disposal. It appears, however, by general correlation from previous surveys that the Cretaceous, Jurassic, and perhaps upper Carboniferous of the Colorado locality extend westward to the Utah localities, with the same

[a] Hillebrand, W. F., and Ransome, F. L., Carnotite and associated vanadiferous minerals in western Colorado: Am. Jour. Sci., 4th ser., vol. 10, 1900, pp. 120-144.

general lithologic characteristics, and there again form the country rock for vanadiferous and uraniferous deposits.

The principal Utah deposits, which are at Richardson, Grand County, on Grand River, are predominantly high-grade vanadium ores, with some carnotite. At other localities low-grade carnotite ores are found. The carnotite and certain of the vanadiferous minerals associated with the Richardson deposits occur in particular beds of sandstone adjacent to a strong fracture, and are in general like replacement deposits of metallic ores in limestone beds. The San Rafael deposits, near San Rafael River, are disseminations of carnotite apparently restricted to those sandstones and conglomerate beds in which plant remains occur.

As regards their quantity and grade, the deposits of carnotite which have been discovered thus far in Utah are poorer than those on La Sal and Roc creeks in Colorado, and, so far as known, no vanadiferous sandstone equal in commercial value to the Placerville deposits has been found in Utah. The vanadiferous minerals of Richardson, Utah, which are the most valuable deposits of this class yet discovered in the State, have a high commercial value, and have not, so far as known, been found in Colorado. Carnotite deposits northeast of San Rafael Swell have not proved of sufficiently high grade to be of commercial value. The possibilities of a carbonaceous sandstone, which is said to occur in large quantities southeast of San Rafael Swell and to contain some vanadium, remain to be determined.

RICHARDSON DEPOSITS.

Location.—The Richardson deposits occur in southeastern Utah, in the canyon of the Grand River, near Richardson post-office. This locality may be most conveniently reached from Cisco, on the Rio Grande Western Railway, by regular stage down the canyon, a distance of 27 miles. The deposit may be reached also, though more indirectly, by taking stage at Thompsons, on the Rio Grande Western, for Moab, 35 miles southwest, and driving thence up the canyon, about 12 miles, to Richardson. Trails also lead into Richardson from various eastern points, including several mining camps in the La Sal Mountains.

At its junction with several strong streams from the northwest slopes of the La Sal Mountains the canyon of the Grand River opens out into an extensive amphitheater. Its flat bottom extends along Grand River and eastward from the stream for several miles, and is inclosed by precipitous cliffs carved into massive erosion forms, mammoth tables, lofty columns, and graceful spires. About 2 miles east of the little settlement of Richardson, on the east bank of the

Grand, the desert plain is broken by low hogbacks. Along the crest of one of these the deposits under discussion are found.

General geology.—The geology of this region has never been studied in detail, and is known only broadly by correlation with that of regions which have been studied to the north and in western Colorado. Such hasty observations as the writer was able to make en route, supplemented by suggestions of geologists who have worked in neighboring areas, serve to establish the general geologic position of the formations in this region.[a]

The route from Cisco to Richardson passes down from younger to older geologic formations, as the general dip is gently northward from the intrusive core of the La Sal Mountains and beneath the Green River basin. Leaving the Cretaceous shales, which form the main surface of the high-lying Green River basin, one descends southward through variegated bedded Cretaceous sandstones, including Dakota Cretaceous, into a thick formation of red beds, mainly sandstones. These comprise, both topographically and lithologically, three parts—(1) cliff-making, well-bedded, brownish-red sandstone, approximately 1,000 feet thick, with persistent cross-bedded members, underlain by (2) bench-making, shaly, dark-brown sandstone, several hundred feet thick, with alternately more and less massive resistant members, and at the bottom (3) cliff-making, thin-bedded, brownish-red sandstone, with well-defined persistent stratification. A cliff-making, light pinkish-purple, shaly sandstone, which includes coarse cross-bedded sandstones and conglomerates, with well-rounded granitic and porphyritic pebbles, underlies this series, with unproved stratigraphic relationship, and outcrops on the banks of the river and adjoining plains on the east. This formation appeared roughly conformable with the overlying sandstones, but this point was not specially studied and observations were insufficient to warrant any positive statement in regard to it.

Peale observed that on Dome Plateau (which overlooks the Richardson amphitheater from the west) the lower portion of the Jurassic formation covers a considerable area south of the hogback that borders the Grand River Valley at this place.[b] He further notes, and shows in a section, that in the vicinity of the junction of Grand and Dolores rivers the Triassic forms the greater part of the surface, but that the Grand cuts through both Jurassic and Triassic and exposes the Carboniferous in the canyon bottoms. The general map

[a] The writer gladly acknowledges valuable suggestions as to the probable age of the formations in question from Dr. Whitman Cross, of this Survey, who has studied equivalent formations in detail in Colorado. Mr. Cross is now engaged in the preparation of a bulletin for the Geological Society of America on the Red Beds in southwestern Colorado, in which he will discuss their probable correlation with formations to the west.

[b] Hayden, F. V., Tenth Ann. Rept. U. S. Geog. and Geol. Surv. Terr., 1878, p. 179.

of this region (Sheet XIV, by Holmes, in the Hayden Atlas) gives the area included in the Richardson amphitheater as upper Carboniferous, inclosed by and dotted with inliers of red beds of "Jura-Trias" age.

The stratigraphic relation between the sandstone series and the underlying conglomeratic formation is significant. If no unconformity exists at this horizon it is possible that the conglomerate formation is equivalent to Triassic conglomerates of the Dolores formation in western Colorado.[a] On the other hand, if an unconformity does exist here, the conglomerates may be correlated with Carboniferous conglomerates of Colorado. The final solution of this important stratigraphic problem must await detailed comparative study, preferably by geologists familiar with the Colorado section.

The structure of this series partakes of the general north-northwest monoclinal dip of the region. This is interrupted, however, by a zone of deformation which enters the Richardson amphitheater at the northeast, near the mouth of Fisher Creek, crosses in a southwesterly course, indicated by breccias and steeply upturned beds, and passes out on the southwest along a zone marked by intense crumpling and probable faulting. Crumpling, fissuring, and faulting on a small scale are common throughout this zone. No igneous rocks were found in place, although some are reported by prospectors to occur about 10 miles south, on Grand River, and about 15 miles southeast, in the foothills of the La Sal Mountains.

Character of the ores.—The deposits are chiefly compounds of vanadium, including vanadio-arsenates of copper, barium, and calcium. These and perhaps additional compounds of vanadium occur, in all instances observed, in aggregates of small, brittle, green, greenish-yellow, and yellowish-green crystals. Individual crystals are about one-sixteenth of an inch in diameter, and have the forms of thin, imperfectly terminated folia or plates. They are grouped parallel or radiate in sheaves or wreaths. The light-olive or yellowish-green varieties are distributed irregularly, while the darker green, roughly circular crystals are usually in rosettes or wreaths. The olive and yellowish crystals have a characteristically pearly luster, and the deep green ones usually show a dull, waxy luster. Small oval masses of amorphous carnotite and also small yellow crystals, slightly darker than this carnotite, are intimately associated with the green crystals. The exact mineralogical description of the several species will be reserved for the final paper. From his preliminary analyses, Doctor Hillebrand has decided that one of the minerals is a new variety of

[a] Cross, C. W., Description of the Telluride quadrangle: Geologic Atlas U. S., folio 57, U. S. Geol. Survey.

calcio-volborthite, highly arsenical, and another is a new, hydrous, copper vanadate, distinct from volborthite and calcio-volborthite.

Occurrence of the ores.—Both the vanadium crystals and the associated amorphous carnotite occur along the previously mentioned strong northeast-southwest fracture zone, coating walls of cracks and within certain beds of sandstone. The fracture zone, 5 to 25 feet in width, is the main line of deformation in the region. It traverses the country in a N. 60° E. direction, and dips to the southeast at an angle of 70°.

The rocks which it cuts are well-bedded, brownish-red, gray, and white sandstone, with a little olive shale. They dip generally to the northwest at angles ranging from 35° to 40°. In the immediate vicinity of the fracture they are shattered, fissured, and faulted. Faulting on the main fissure has brought green shale in the foot wall against gray sandstone in the hanging wall. The sandstone dips normally to the northwest, but the beds in the foot wall have been intensely crushed and sheared and now stand at high angles for a distance of at least 20 feet west of the fault. The amount of dislocation is not apparent on this property, but the direction may have been downward on the west or foot-wall side. Stratigraphically these beds probably lie at about the base of the main red sandstone series and thus a short distance above the conglomeratic series.

The vanadium crystals are characteristically found in thin patches, 1 to 10 inches in diameter, upon the walls of sandstone blocks in the shattered zone. They are most abundant next to the main fissure. Yellow crystalline material, ranging in color from orange to canary yellow, also occurs in this manner, and some amorphous carnotite is occasionally found there. The more usual mode of occurrence of the carnotite, however, is in small oval masses, one-sixteenth to 1 inch in diameter, along certain beds of gray sandstone in the hanging wall. These bodies are also most abundant adjacent to the fissure, but are found as far away as development has proceeded, about 4 feet. As regards their origin, it is sufficient for present purposes to state that the mineral now appears from general aspect to have been formed by replacement of the sandstone, as a complete and gradual transition series may be traced from unaltered gray sandstone to pure amorphous carnotite. On the walls of the oval cavities in which this carnotite is found small clusters, rosettes, and wreaths of the dark-green variety of vanadium crystals frequently occur. This is the most intimate relationship between the vanadiferous and uraniferous minerals observed, and appears to indicate an earlier date of deposition for the vanadiferous compounds. On some of the specimens of yellowish-green crystals minute pieces of a robin's-egg blue mineral appear, which resemble bits of silk thread in luster, structure, and general appearance. The composition of this mineral has not been determined.

These minerals show along croppings for about 1,000 feet along the fracture zone and have been found to a depth of 32 feet below the surface.

History and development.—These deposits have been extensively prospected and opened along two claims, each 1,500 by 600 feet, owned by the Welsh-Lofftus Uranium and Rare Metals Company, and slightly on adjoining claims to the north and south. They are stated to have been discovered in March, 1898, by a man named Welsh, and prospected the same year by James H. Lofftus. After doing some prospecting and making various small shipments for testing, in June, 1902, Mr. Lofftus sent about 500 pounds to Buffalo for analysis and experiments in reduction. In September, 1903, the material was discovered to be radio-active,[a] and some was sent to Curie, at Paris, who failed to affirm the presence of radium. In May, 1903, the company was incorporated, under the laws of New York, to work these deposits on two claims, known as the Jesse D. No. 1 and Jesse D. No. 2, and to reduce the ores at the company's experimental plant at Buffalo, N. Y.

The fracture zone along which the property extends, and in which the vanadiferous and uraniferous minerals lie, has been opened at about twenty places by prospect pits, short tunnels, and shafts. The principal development has been at the southwest end of the property, where a shaft has been sunk in the fracture to a depth of 32 feet, and levels have been driven northeastward along the main mineralized zone, at depths of 18 and 32 feet, for distances of 18 and 40 feet, respectively.

In the course of this development work numerous shipments of cabinet specimens and small amounts, aggregating about 2,000 pounds, were made, and in 1904 somewhat more than half a carload was shipped to Buffalo for experimental purposes. The ores yield concentrates of uranium oxide and a high-grade mixture of crystals of the various vanadium minerals.

The property has never been systematically operated, but the work done shows the walls of the openings in the fracture zone to be extensively coated and blotched with the vanadiferous minerals and that certain beds carry small masses of carnotite. The presence and grade of the desirable minerals have been proved, but further development is required to demonstrate that the available amount of this rare product is sufficient to make this property a regular shipper.

Traces of these minerals in this same general fracture zone are reported to have been followed from this locality to deposits in Colorado, and also southwest from Richardson for several miles.

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[a] Lockwood, S. J., Eng. and Min. Jour., Sept. 27, 1902.

SAN RAFAEL DEPOSITS.

Location.—About 15 miles southwest of Green River station (Rio Grande Western Railway) deposits of carnotite have been found in several places. These deposits lie on the western margin of the Green River basin in a series of eastward-dipping cuestas (hogbacks) which rise gradually to San Rafael Reef. West of this series of ridges is a race course, or wide, open valley, analogous in form and probably in origin to the race courses around the Black Hills and the Bighorns. Rising steeply from this is a high, precipitous rock wall, over the notched crest of which the flat-topped central plateau of San Rafael Swell appears. The sandstone which floors the central area, and also apparently that which makes the encircling reef, was considered by Dutton to be Triassic.[a] Thus the soft beds forming the low, concentric valley, over 1,000 feet in thickness, with the gypsum beds intercalated in their upper portion, are also doubtless Triassic. The overlying coarse sandstones and fine conglomerate forming the crest of the cuesta which incloses this inner valley may thus be Jurassic; next above are slightly less resistant, olive, maroon, and gray carbonaceous shales with interbedded sandstones, which underlie and probably pass into a sandstone that may be Dakota Cretaceous. The Green River Cretaceous which then comes in underlies the main Green River basin and apparently passes upward into the heavy series which forms the Book Cliffs.

The deposits are found about a mile east of the gorge cut by San Rafael River at two or possibly three horizons that embrace a thickness of about 100 feet, and extend along their strike for about 2 miles. The particular series in which these ore-bearing members lie are coarse sandstones and fine conglomerates, which dip eastward at angles ranging from 10° to 30° below the variegated shales and about 200 to 250 feet above the main red shale formation. They may thus be tentatively considered to be of Jurassic age.

The values lie in a light-yellow mineral which in certain cases appears to be carnotite. Part of this material is crystalline, part is granular, and part forms a thin coating of faint yellow, greenish-yellow, and light-green color. The pay is much disseminated and very lean; no massive pieces of amorphous carnotite comparable to the Colorado ores have been found.

Ore has been taken from eight separate spots which are located in three general groups. In these groups there are certain common and certain distinguishing features. Thus in all of them the pay occurs in sandstone or conglomerate and in intimate association with plant remains. In the northern group, however, it is in the form of mas-

[a] Dutton, C. E., Geology of the High Plateaus of Utah, p. 19.

sive carnotite, cementing quartz grains in a certain cross-bedded sandstone, or as a faint stain upon petrified wood. In the southern group massive carnotite occurs in an 18-inch bed of conglomerate, either as cement or merely coating pebbles of chert, jasper, quartz, and possibly petrified wood, or within gray clay nodules. None was seen in the overlying cross-bedded sandstones, though a little appeared in the underlying white sandstone. At the third locality the pay is found in a bed of gray, blackened, slightly carbonaceous sandstone, in two layers, either upon or immediately adjacent to plant remains. It forms a thin, glistening coating upon fossil bark, wood, and cellular tissue, and in some instances has entirely replaced cell walls. A query as to the derivation of the carnotite from the organic remains is naturally suggested, but it seems more probable that they acted only as a chemical precipitant, by reason of their carbonaceous content. No fissures were observed during the hasty examination, but deliberate search would probably have revealed sufficient partings along which solutions rich in uranium might have passed until they met the carbonaceous precipitant.

History and development.—All deposits in this locality are embraced in a single property comprising eight claims, which extend along the strike of the country rock in a north-south direction for a distance of about 2 miles. The deposits are stated to have been discovered by sheep herders and to have been subsequently prospected and claimed by Judge J. W. Warf, of Price. They are now owned by parties residing in Green River. The croppings have been pretty thoroughly worked, and a shipment of 30,000 pounds was sent to Germany. The workings are all surface prospects and test cuts, of which the most extensive are an open cut 7 to 18 feet wide by 40 feet long and 5 feet deep, on the carnotite-bearing conglomerate, and a trench about 5 feet wide and 100 feet long, 2 to 3 feet deep, to open a bed of plant remains, stained with the yellow mineral regarded as carnotite. The lean character of the remainder of the ore, added to the report that no response has been received from the shipments, leads to the conclusion that the ore is of too low grade to pay, under the most favorable conditions, and doubly so under the high expense of working and shipping under existing conditions.

SAN RAFAEL DEPOSITS (SOUTHEAST SIDE).

Southeast of the San Rafael Swell, in Wildhorse Canyon, and 8 to 10 miles north of Hanksville, Wayne County, considerable deposits of a black, vanadiferous sandstone and some carnotite in float are reported to occur. The material is a dense, black, carbonaceous sandstone, which contains combustible matter and after burning yields a residue that includes some vanadium (Hillebrand). Small blotches of carnotite appear on the surface of the rock. Various analyses given out through the press have shown good percentages of both uranium and vanadium. In the sample tested in the laboratory of this Survey, however, no uranium was detected.

These deposits were discovered in the fall of 1903 by sheep herders, and prospected in 1904 by Messrs. Browning and Beebe. The black vanadiferous sandstone is reported to be present in large quantity in the Cretaceous formation. Owing to its distant location the writer was unable in the limited time available to visit this property. The owners are said to be actively developing their property, and future work may reveal pay ore in sufficient quantity to make this deposit commercially profitable.

MISCELLANEOUS PROSPECTS.

In more inaccessible regions adjoining those in which the above-described deposits are found prospectors, herders, and explorers have from time to time reported the occurrence of these rare minerals. Our increasing knowledge of the subject not only tends to make these reports seem plausible, but to lead one to regard it as possible that valuable deposits, perhaps more valuable than any yet discovered in the State, may exist at some of these localities.

On the east, deposits of carnotite are reported to have been traced from Colorado southwestward into the region of the Abajo Mountains, in southeast Utah. The rocks in which carnotite occurs, in the Colorado localities, on the east side of the La Sal Mountains, are known to extend southwestward in that direction. Accordingly it would not be surprising if valuable deposits, comparable with the rich Colorado ores, should occur in them, especially in the vicinity of the Abajo eruptive center.

Carnotite is also reported to occur west of the La Sal Mountains, at Mill Creek, on Grand River, north of Moab and south of the Richardson locality.

North of Richardson and about 10 miles south of Thompsons Springs bedded deposits of uranium are said to have been found. They are reported to have been opened to a depth of 4 feet and proved to exist in considerable quantity and to be of good quality.

On Cold Creek, 20 miles north of Price, a sandstone is said to bear blotches of carnotite, together with green and yellow stains, possibly of copper, and fossil plant remains.

Southward, between Price and the Henry Mountains, small amounts of carnotite are reported to occur at three different places.

Vague reports of occurrences at four or five other points have come to the writer, but they are too uncertain to be worthy of publication.

COPPER.

THE COPPER PRODUCTION OF THE UNITED STATES.

By Walter Harvey Weed.

GENERAL CONDITIONS.

The United States supplies about 60 per cent of the entire copper production of the world. According to estimates recently made[a] the production for 1904 exceeds that for 1903 by about 8.6 per cent, aggregating approximately 783,000,000 pounds. The value of this product is $95,000,000, exceeding that of the gold production, and being surpassed only by that of coal and iron. Of this enormous production about two-thirds was exported in 1904.

Our imports are practically all from Mexico and Canada. They consist of ores shipped into the United States for treatment, Canadian imports being practically all shipped for treatment at the smelters at Northport and Everett, Wash. Those from Mexico consist of concentrates from Sonora, matte from Cananea, which is practically an American mine, and of matte from Boleo, Lower California. At New York some ore is imported from Spain and from Newfoundland. Strange to say, copper from Chile and from other foreign ports has been reshipped from Liverpool to Baltimore for refining, a rather remarkable instance of American competition. The Spanish mines still supply the greater part of the pyrite used in the United States, and as this pyrite carries from one-half per cent to 3 per cent copper, the cinder from the sulphuric-acid works is converted into copper by the Pennsylvania Salt Company and other works.

The profit of copper mining is shown by the fact that seventeen copper companies declared dividends during 1904, aggregating $26,161,000, a very favorable showing when compared with the 77 gold, silver, and lead companies, including the smelting trust, whose total dividends amounted to $19,106,000.

[a] Eng. and Min. Jour., Jan. 5, 1904, p. 6.

The increase in the production of copper during 1904 is mainly due to Arizona mines, but the tremendous development carried on in Utah, notably at Bingham, and in the Frisco district, indicates that this State will soon take a more prominent place as a copper producer. When carefully studied, the figures show that the Lake Superior district can hardly maintain its relative part of the average increase in the production and consumption of copper; that the same is true of the Montana mines, and that the Arizona mines will show a still greater increase, and are likely in the near future to take the lead in the world's production. At the present time the Boston and Montana mines of Butte are the greatest producers in the world, followed by the Anaconda, Lake Superior, and Rio Tinto mines, in the order named.

Some doubt having been expressed as to whether the copper production of the world can keep pace with the consumption and

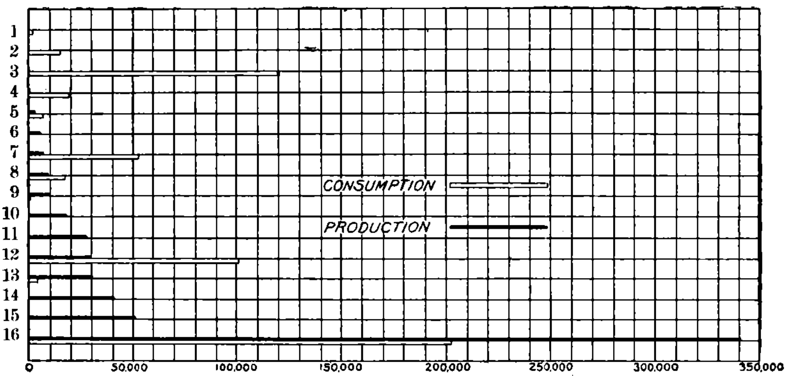

FIG. 14.—Production and consumption of copper, in tons, in the various countries of the world. 1, Holland and Belgium; 2, Asia; 3, England; 4, Austria-Hungary; 5, Italy; 6, Africa; 7, France; 8, Russia; 9, Scandinavia; 10, Canada; 11, Australia; 12, Germany; 13, Japan; 14, South America; 15, Mexico; 16, United States.

whether there will be a scarcity of copper in the future, with a period of high prices as a result of the rapid increase in the consumption of copper, not only for the electrical trades, but in the general manufacture of machinery, which consumes even more than that used in the manufacture of electrical apparatus, the above diagram is presented to show graphically the production of the different districts and of the world.

Our exports for 1904 amounted to 231,354 long tons, all but 1,430 tons going to Europe.

The copper deposits of the United States are remarkable not only for their size and productiveness, but also for the variety of the ores. The great copper deposits of other countries consist of chalcopyrite (copper pyrite), while in the United States ores of this character form a relatively small part of the total output. In a general way each of the great copper-producing districts of this country is distinguished by a characteristic ore. In Michigan it is native copper; in Montana, chalcocite (copper glance) or enargite (sulpharsenide of copper); in Arizona it is largely copper oxides and carbonates; in Tennessee and California, chalcopyrite; in Colorado, tetrahedrite (gray copper). The native copper of Michigan occurs in porous trap sheets and in interbedded conglomerates of pre-Cambrian age; the rich ores of Butte occur in quartz-pyrite veins in Tertiary granite, while the great deposits of Arizona occur chiefly in carboniferous limestones about Tertiary igneous masses. The differences in the character of the ore correspond in turn to very different modes of ore treatment, and this corresponds to a classification of the ores into native, oxide, and sulphide ores. The production for 1903, grouped in this way, is as follows:

Production of copper in the United States in 1903.

	Pounds.
Native copper	192,400,577
Copper from sulphide ores	466,097,000
Copper from oxide ores, siliceous and basic	40,648,271

The copper production of Colorado, amounting to 4,158,368 pounds, is derived mainly from the treatment of copper-bearing silver and gold ores from the mines of Colorado and adjacent regions.

OXIDIZED COPPER ORES.

The only places where oxidized copper ores are produced in large amount are the Globe, Clifton, and Bisbee districts of Arizona. At Bingham, Utah, six-tenths of 1 per cent of the total output is oxidized ore, and in the early development of almost all the great copper mines of the country more or less oxidized ore has been found, but the Arizona districts have been preeminently deposits of oxidized ore, and it is only in recent years that sulphide ores have been encountered. The oxidized ore is of two kinds: The infusible—lean, siliceous, oxidized ores; the fusible—iron-bearing or calcareous ores.

The advantages of smelting and bessemerizing over the old and wasteful practice of smelting oxide ores in a cupola furnace, with direct reduction to black copper, has led to the endeavor to mix the oxide ores with those carrying sulphur, and, fortunately, favorable railroad rates have been secured in Arizona, which permit an interchange of low-grade ores.[a] Thus, Globe, Ariz., ships its infusible, lean, oxidized ores to Bisbee and Douglas, where they are used for converter linings, and receives in return the sulphide ores, which are, as yet, somewhat scarce at Globe. At Clifton, Ariz., but one mine supplies any amount of oxide ores, the amount being

[a] James Douglas, Eng. and Min. Jour., Jan. 5, 1905, p. 10.

approximately 500 tons a day in a total output of 2,000 tons per day. At Globe, whose output is very much smaller than that of the two other camps, being about one-ninth that of Bisbee and one-fourth that of Clifton, the oxidized ore is as yet predominant, and the sulphide ores supply barely enough sulphur for matting in the furnaces.

NATIVE COPPER ORES.

The Lake Superior district.—The native copper ore produced in the United States is all derived from the Lake Superior district. This district is unique among the world's producers in the character and occurrence of the ore, the cheapness with which it is mined and converted into bar copper, and the enormous sum paid out in dividends. The ore occurs in a series of upturned conglomerates and lava flows, which aggregate many thousands of feet in thickness, and which dip at steep angles to the west. These rocks extend along the northern border of the Keweenaw Peninsula of Michigan, the outcrops forming the Copper Range, which is from 4 to 6 miles wide, curving with the peninsula, and passing through the center of the peninsula at Hancock and Houghton.

At the present time production is limited to the mines in the vicinity of the two towns just named, coming either from the group of mines north of Portage Lake, including the Calumet and Hecla and other world-famous producers, or from the southern part of the range, southwest of the towns noted. The geologic conditions are simple, the ore occurring either as the cementing material of conglomerates, formed of reddish and chocolate-colored felsites and porphyries, or in irregular pellets filling cavities (amygdaloids) in the porous trap sheets. The ore is, however, confined to well-defined shoots of limited horizontal extent, and does not occur in paying quantity throughout the entire extent of a bed. The Calumet and Hecla ore shoot is, however, very large, being 3 miles long and productive to a depth of 5,000 feet, the greatest depth yet reached. The ore body is 12 to 15 feet thick, and three-quarters of the entire production of the region comes from the mines on this ore shoot.

The discovery of the rich ore shoot of the Champion and Trimountain mines and the reopening of the Baltic mine emphasize the fact that but little is known of the character of this southern part of the range, where about 250 feet of glacial drift hides the rocks in all but a few ravines. There is no probability of a lack of ore from this region for a very long period, though the existing mines are not likely to increase their production rapidly.

The native copper ores are treated by mechanical concentration, resulting in the production of a shotlike material, composed almost wholly of native copper, which requires simply melting down in a furnace. The process of mechanical concentration, which all but the "mass" copper undergoes, is peculiar to the district. The ore is pulverized by steam stamps, each head capable of handling 250 tons of ore a day, the resulting product being classified and jigged or passed over slime tables, etc. The cost of treatment by this method varies somewhat with the different ores of the district, but is cheap compared with ordinary smelting, and permits the successful working of the lowest grade ores handled anywhere in the world, the Atlantic mine treating ore carrying but 0.6 per cent copper and paying dividends. The Calumet and Hecla ore averages about 2.5 per cent.

SULPHIDE ORES.

Aside from the Lake Superior and Arizona deposits practically all the copper ores of the United States are sulphides. As already stated, the most common copper-ore mineral the world over is chalcopyrite, usually disseminated through pyrite or magnetic pyrite. Ore of this character is, moreover, found in nearly every type of deposit. It occurs disseminated through igneous rocks and in the contact zones about them, in quartz-pyrite veins, in replaced limestone, and is the characteristic mineral of the great lenses of cupriferous pyrite.

The Eastern or Atlantic border States contain a great number of copper deposits scattered along the front of the Appalachian region from Maine to Alabama. The only deposits now being worked on a large scale are those of Ducktown, Tenn., where remarkably low-grade sulphide ores are being smelted at a profit. The ore bodies form great thick lenses in crystalline schists. The copper occurs as chalcopyrite in pyrrhotite (magnetic pyrite), with small amounts of country rock and various silicates. The ore is low grade, averaging less than 2 per cent copper, as smelted. Similar ore bodies exist at Ore Knob, N. C., at various places in southwestern Virginia, and in Vermont, but are not worked. Other deposits of the same character, but composed essentially of pyrite, carried copper ores near the surface. This gradually disappeared with depth, and the properties are now worked for the pyrite alone, as at Tolersville, Va., and Charlemont, Mass.

Copper-bearing veins are worked at Virgilina, Va., and at Gold Hill and elsewhere in Virginia and Georgia, but the production is small.

The Mississippi Valley contains but few copper deposits, those of Mine La Motte, St. Genevieve, and Sullivan, Mo., being the best known. The product is small, but the ores carry nickel and cobalt. They are described by H. F. Bain and E. O. Ulrich on pages 233–235 of this bulletin.

Montana.—The enormous amount of copper produced by Montana is derived almost entirely from the mines of Butte. It is all sulphide ore, and 90 per cent of the output of the mines is concentrating ore, carrying about 3.5 to 4 per cent copper, which is concentrated to a 20 per cent product with a 25 per cent loss, before going to the smelting furnaces. The copper occurs largely as copper glance, either in compact shoots or disseminated in minute veinlets and particles through altered granite or the normal quartz-pyrite vein filling. Bornite and enargite constitute a large part of the ore. The ore occurs in well-defined replacement veins and in later veins which fault them. The ore bodies are in places enormous, stopes of 150 feet across being found in some of the mines. The workings extend to a depth of 2,400 feet and are still profitable. Owing to the heavy timbering required and the high wages paid, the cost of mining is relatively high, while the cost of metallurgical treatment of such enormous quantities of ore—6,500 tons a day being treated in the Washoe smelter—is, everything considered, comparatively low, notwithstanding the extremely siliceous character of the ore.

An account of the vein system and geological structure will be found in a previous bulletin.[a]

Utah.—Copper mining in this State began only a few years ago, but is already of very large proportions. The principal centers of production are at Bingham, Park City, and the Frisco district, all described elsewhere in this volume.

California.—Although a great number of copper deposits are scattered along the western border of the gold belt and the western foothills of the Sierra Nevada, the only large producing mines are those of the Shasta district, in which great lenses of pyritic ore occur in a shear zone traversing metarhyolites, etc.

The largest ore body, that of the Mountain Copper Company, is a solid mass of pyrite and pyrrhotite with chalcopyrite, in sheared metarhyolite. This mass is 100 to 400 feet wide, 800 feet long, and 600 feet deep, averaging 5.23 per cent copper, with 2 ounces silver per ton and some gold. The limonite gossan was worked for many years for gold and silver. The ore is massively schistose, the banding being due to zinc blende.

The Bulky Hill deposits,[b] in the same county, yield barytic ores resembling those of Vancouver Island.

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[a] Bull. U. S. Geol. Survey No. 213, p. 170.

[b] See Bull. U. S. Geol. Survey No. 213 p. 123; Bull. U. S. Geol. Survey No. 225, p. 172.

THE COPPER DEPOSITS OF THE EASTERN UNITED STATES.

By Walter Harvey Weed.

An investigation of the copper deposits of the Atlantic and Appalachian States, begun by the writer in 1902, is still in progress. The number of localities at which copper is known is very great, but there are few mines now in operation, and most of the old workings are filled with rubbish or are flooded and inaccessible. Nevertheless, the work has progressed far enough to prove that the deposits found from Alabama to Maine are of many kinds, and while usually of low grade are sometimes large enough to be profitably worked under present economic conditions, as is proved by the successful operation of the mines at Ducktown, Tenn. During the last year the writer visited several properties in the Blue Ridge region of Virginia, near Front Royal, the "gossan lead" of southwest Virginia, the Ore Knob and neighboring mines of northwestern North Carolina, the Goldhill, N. C., properties, and the Magruder (Seminole) mine of Georgia. The results of this and all the field work on the Appalachian copper deposits will appear in a bulletin to be published early in the year.

The Appalachian copper deposits occur in two distinct fields, viz, the mountain region and the Piedmont Plain to the east. The first-named extends in a northeast-southwest direction, coincident with the Allegheny and Blue Ridge mountains, from Pennsylvania through southwestern Virginia and western North Carolina to the Ducktown district of Tennessee and Georgia. The second extends parallel to the first and embraces the gold belt of Virginia, Carolina, and Georgia.

At the present time mining work is being carried on at the following localities: At the Blue Ridge district east of the Shenandoah Valley, near Front Royal, Va., and near Luray, Va.; at the Goldhill district, near Salisbury, N. C.; the Virgilina district, along the State line, 70 miles east of Danville, Va.; at or near Dillwyn, Va.; in the hilly country of Floyd, Carroll, and Grayson counties, Va.; in Lincoln County, Ga., and last and greatest of all, of course, at Ducktown, Tenn.

In the Blue Ridge region several companies are operating near Front Royal. One copper company is prospecting the Sealoch property east of High Knob, a property that has attracted the attention of capital for the last thirty years. In 1899 various capitalists, represented by an able mining engineer, spent some time and considerable money in prospecting this property, sinking a shaft to a depth of 87 feet, but finding no copper below the first 20 or 25 feet from the surface. At that time a brief visit to the property was made by the writer, and the opinion was expressed that no true veins existed and that the copper ores would not be found to extend to great depth. Since that time another shaft has been sunk on a different part of the property and the development work affords no reason to change the opinion previously expressed. At the present time a new company is driving a crosscut tunnel, hoping to cut an ore body at the depth of about 100 feet beneath the outcrop on which the last shaft was sunk. The property is equipped with machinery, and a steam drill is being operated. The rock is a tough and dense diabase, somewhat sheared, known as the "Catoctin schist." An examination of this tunnel showed no ore and no sign of a vein, but the tunnel had evidently not yet penetrated to the rock immediately beneath the copper-bearing outcrop. This work is likely to be of much benefit, as it will settle the question of the cupriferous on noncupriferous character of the rocks below the zone of surface seepage.

About 1½ miles southwest of this locality, at the extreme headwaters of Rappahannock River, the Manassas Gap Company has sunk a 60-foot shaft and several shallower openings, and has driven several tunnels in the mountainside, one 197 feet long. Very rich specimens of ore have been obtained from the surface of this property, and, in fact, like the Sealoch property, the surface showings have been very good.

On the ridge due south of Front Royal and west of Hominy Hollow another company is now at work and some ore is being shipped. Along the main axis of the Blue Ridge at points east of Overall and Stanley, stations on the Norfolk and Western Railroad near Luray, outcropping ores have incited development work, which is now being pushed by several stock companies.

So far as known the general conditions of all these properties are the same. The ores occur in a dense and heavy trap rock, which is an altered diabase, but as it has in part a schistose structure it is given the name of Catoctin schist. According to Keith this rock consists of several old lava flows, superimposed, and is approximately 1,000 feet thick. It rests upon old andesite, and is, in turn, cut by granite, which near the contact is so sheared and altered that it is commonly mistaken for a shale. A grit or sandstone, known as the Weverton sandstone, whose finer beds contain fossils of Cambrian age, overlies and flanks this Catoctin schist, and the copper solutions from the trap rock have in part penetrated the sandstone for a few feet and deposited ores in small amounts on joints and fractures. The ore found in this section is commonly the red oxide of copper, with some native copper, and the green carbonate (malachite). These minerals occur usually associated with quartz, calcspar, and epidote. In the Manassas Gap properties grains and films of copper pyrite and of peacock copper, or bornite, also occur.

In southern Virginia, in Carroll, Grayson, and Floyd counties, there are a number of copper properties which were formerly rather prominent producers; in fact, the mineralization of this section has been well known ever since Revolutionary times. The famous Bertha zinc mine and the Wythe lead mine are situated in this section. Near these mines there is an opening known as the Iron Ridge mine, which is on the south end of the great gossan lead of Virginia, a vein or series of veins whose outcrop of brown hematite ore can be traced for 10 miles or more to the northeast. This hematite ore has been very extensively worked and the capping removed down to the unaltered sulphide ores which underlie the limonite. The unaltered ore is from a few feet to 50 or more feet in thickness. It consists of magnetic pyrite or pyrrhotite, with scattered specks of copper pyrite. Occasionally bunches and layers of rich copper ore have been found, but the main body of the deposit contains, I am told by one of the largest shippers from this region, not over three-fourths of 1 per cent of copper. Owing to the predominance of the magnetic sulphide, which is low in sulphur, this ore has not been valuable for acid making, and hence has remained undeveloped. If the reported success in utilizing the sulphur from similar ores at Ducktown, Tenn., proves to be true, the ores of this great ledge may some day prove workable. At the present time no development work is being prosecuted on this lead.

At a place north of Hillsville, the county seat of Carroll County, the New York and Virginia Copper Company has opened up a vein of dark-greenish colored amphibolite-schist containing smooth, rounded masses of copper pyrite, some of them as large as a hickory nut. These concretions show slickensides and movement, and occur in a sheared zone about 8 feet wide. The amount of copper is, however, too small to pay for working, and the gangue is unfavorable either for cheap concentration or for smelting. The dump heap shows a few hundred tons of this low-grade ore. At the present time the property has been dismantled and the machinery shipped to the Toncray mine, about 12 miles east of Christiansburg, a property which is regarded by local residents as the best in this part of Virginia.

In Buckingham County, Va., about 6 miles northwest of Dillwyn, a copper property was opened up last winter by Mr. B. X. Dawson. The green carbonate that prevailed at the surface gave way at a depth of 12 feet. The sulphide ore from a depth of 45 feet showed a 3½-foot vein, consisting of chalcopyrite (copper pyrite) and some glance in a matrix of silicified schist and quartz. The vein is of the Gold Hill type—i. e., it is a schist vein—and in part consists of white pearly mica- (sericite-) schists, impregnated with particles of chalcopyrite, with a wall of greenstone, an altered igneous rock. The property is 4 miles from Alpha, the nearest stop on a branch line of the Chesapeake and Ohio Railroad. Further notes on the Virginia district, Goldhill, N. C., and Ducktown deposits will be presented in a special bulletin on Appalachian copper deposits.

COPPER IN THE RED BEDS OF THE COLORADO PLATEAU REGION.[a]

By S. F. Emmons.

The singular frequency and world-wide distribution of copper ores in the "Red Beds" of the rather ill-defined Permian and Triassic horizons has long been a subject of remark among geologists. The manner of occurrence of these ores is generally such as to afford no very decided evidence as to their origin, and not unnaturally there has been a very wide divergence of opinion upon this subject among those who have had opportunity to study them.

I have taken as my text for some general remarks upon this class of deposits certain copper ores which came under my observation during the past summer in the region of the Grand Canyon of Arizona. These ores occur in the stratified rocks, apparently unconnected with any igenous intrusions, and their genesis seems particularly obscure. I can hardly pretend, in view of the very limited time I was able to devote to these observations, to throw any new or very decided light upon the moot question as to the origin of this class of deposits, but I have thought that it might be useful to the active workers in this field to have brought to their attention some of the problems involved.

I have called the Permian and Trias rather ill-defined formations, because, in this country especially, paleontologists often find it difficult to draw the line between the two. As is often the case in our geological nomenclature, the respective names have lost their original meaning. The Permian takes its name from the Russian Province in which, in the opinion of many geologists, it is not typically developed, and consists, in part at least, of Triassic sediments. The Trias, or three-membered formation, consists, in middle Germany, it is true, of three prominent members—a lower sandstone (Buntsandstein), a middle marine limestone (Muschelkalk), and an upper sandstone and shale (Keuper), but this triple lithological division rarely obtains outside of that country.

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[a] Read before the Geological Society of Washington, November 9, 1904.

The Permian in the Mansfeld region of middle Germany consists of barren red sandstones and conglomerates (Rothliegende) below and limestones (Zechstein) above the copper-bearing shales (Kupferschiefer).

In the "Red Bed" development of either formation in all parts of the world there is, however, a strong resemblance in the sediments of which they are composed, and hence, presumably, in the conditions that prevailed during sedimentation, so that for present purposes it is relatively unimportant whether the deposits under consideration belong more properly to one or the other of these two series. The conditions referred to are an abundance of coarse material, frequent cross-bedding, ripple marks, and raindrop impressions, and a great abundance of plant remains, indicating shallow-water deposition in the vicinity of land masses. The frequent occurrence of interbedded deposits of rock salt, gypsum, and other soluble salts points, moreover, to deposition in more or less closed seas, and the prevailing red color to climatic conditions favoring oxidation of the iron-bearing constituents, hence chemical activity in general.

The most famous copper deposits in these beds are those of Mansfeld, in Germany, which have been worked for about 700 years and are still producing about $5,000,000 worth of metal annually. There the copper occurs finely disseminated in the lower 2 feet of the Zechstein formation, the ore-bearing seam rarely exceeding 10 inches in thickness and carrying on an average about 2 per cent of copper with a little silver. Some nickel and lead are associated with the deposits.

The Permian in many other parts of Germany, in northeastern Bohemia, and notably on the west flank of the Urals, in Russia, carries copper ore in workable quantities, in all cases associated with plant remains.

In Alsace-Lorraine it is the Triassic sandstones that carry copper under similar conditions. In Bolivia, at Corocoro and Cobrizos, argentiferous copper ores are worked in Permian sandstones that carry gypsum and some rock salt. As reported by David Forbes, however, these deposits are in a region in which igneous action has been very active and the beds in which the copper occurs are much folded and disturbed. The ore occurs in several successive sandstone strata, upturned at tolerably steep angles, which are hence called by the miner "veins."

In this country copper ores have been worked at many points in the red sandstones of the Appalachian system, generally classed as "Trias," notably in Nova Scotia and northern New Jersey, while their occurrence in limited amount in these sandstones is very widespread. In the West they have been noted over large areas in the red-sandstone formations of western Texas, New Mexico, and the

Colorado Plateau region. Before proceeding, however, to a detailed consideration of these western deposits, I will briefly consider the various genetic theories that have been held in Europe to account for the Mansfeld and allied deposits.

The Mansfeld deposits were long held to be typical examples of the chemical precipitation of metallic salts contemporaneously with mechanical deposition of the sediments in inclosed lakes or oceans under the reducing influence of organic remains. The metals were assumed to be held in solution as sulphates, associated with the usual alkaline sulphates of sea water. The latter would be decomposed by the action of organic remains with an evolution of sulphureted hydrogen, which in its turn would precipitate the metals from their sulphate solutions as sulphides. The bent-up position of the fish skeletons found in these beds was held by Freiesleben and others to be an indication that the fish inhabiting these waters had been poisoned by the sulphates of the metals held in solution. It was assumed that sea water very generally contains small amounts of copper salts, and Dieulafait, in 1880, had shown that the evaporated salts of the Mediterranean waters contained appreciable amounts of copper, and estimated that a cubic meter of sea water would contain one one-hundredth of a gram of copper.

As studies of ore deposits assumed a more objective phase there came to be doubters as to the efficiency of this theory. It was observed that the various European deposits were not confined to a single definite horizon, as at Mansfeld, and that the ores occurred in connection with fractures and other disturbances.

As Posepny's views became more prevalent, it came to be very generally believed that even the Mansfeld deposits had been introduced since the deposition of the strata, though Von Groddeck, one of the most enlightened of the German writers on ore deposits, whose nearness to that region should have given special opportunities for their study, stoutly maintained their sedimentary origin up to the time of his death. Beck, however, in his text-book on ore deposits, classifies all these Triassic or Permian deposits among his epigenetic or later-formed class.

Of late years there has been a recrudescence of the theory of sedimentary ore deposition, as a reaction against the extreme views held by Posepny, that all ore deposits are of later origin than inclosing rocks, and those of Vogt, who wishes to refer most of them to an igneous source.

Professor Bergeat, who now occupies the chair of Von Groddeck at the mining school of Clausthal, is a leading exponent of these later views, and has explained to me personally that he lays great stress upon the discovery by the Russian oceanographers that at the present time iron sulphides are being deposited in large quantities in an ooze at the bottom of the Black Sea; also, on the occurrence of eruptive tufas in the Mansfeld series of beds, thinking it possible that gaseous emanations, or hot springs carrying copper, might have accompanied their eruption or have hastened precipitation. He differs also with the geologists of the Posepny-Beck school as to the facts in the Mansfeld district, maintaining that it is not true that the shales are richer in the vicinity of the fractures which dislocate them, as they maintain. He says that copper occurs in the very uniform percentage of 2 per cent in a thin bed immediately over the conglomerate, which carries no lead or nickel. Where there are verticals or faults these carry some nickel and lead, and the bottom bed becomes barren in their vicinity, the copper occurring some little distance above it with the nickel. When there is considerable distance between the faults, the copper comes down again to the lower layer, which, however, carries no nickel or lead.

One of Bergeat's students has recently published a new study of the iron deposits in the Devonian limestone of Nassau, in Germany, which have long been held as typical instances of metasomatic replacement. In this he maintains that previous geologists, assuming this origin to be so well established as to be almost axiomatic, have wrongly read the facts, and that the ores are syngenetic or of sedimentary origin.

In these discussions it seems to me that writers should be careful to assure themselves that they start with a common premise, and that when one speaks of a sedimentary or syngenetic origin of a deposit he means the same thing as his opponent. Ore deposits may be defined as concentrations of useful metals into bodies rich and large enough to be worked at a profit, but it is rare that the process of concentration has been single. In most cases they are the result of many and quite different processes, and the question is, Which of these is the characteristic one by which it should be defined? The German geologists seem to consider that if sedimentation has played any part in the formation of the materials of a deposit it is therefore to be considered sedimentary. I believe rather that the process that has brought it into its latest phase as a workable deposit is the one that should characterize it, and hence can conceive the possibility that in the case cited above, of the Mansfeld deposits, each of the opposing views may be partially right. The copper salts might have been originally disseminated through the general series of sediments and later gathered together into a concentrated form in a disturbed region as a result of conditions accompanying the disturbance.

This, for instance, is the view held by many with regard to the lead and zinc deposits of the Mississippi Valley, which Beck includes in his epigenetic class, although their materials are assumed to have been deposited contemporaneously with the limestone in a Silurian ocean. On the other hand, Beck classes the Lake Superior iron ores as sediments, though he accepts Van Hise's explanation that they are concentrations, metasomatically replacing the sediments in which they occur.

The tendency to return to the sedimentary theory is shown by Weidman in his recent report on the Baraboo iron ores, where he claims that there are no evidences of metasomatic action, and hence assumes that these ores are of sedimentary origin, in expressed opposition to the views of Van Hise and others. The moral to be drawn from these rather conflicting statements seems to be that, while we should give proper attention to the possibility that the materials of a deposit may have been originally formed contemporaneously with the inclosing sediments, we should not at once assume a syngenetic origin for the deposits as they exist to-day.

I will now pass in hasty review a few of the known occurrences of copper ores in the Permian and Triassic beds of the West which seem to bear upon the question under consideration. They appear to have been first noticed in northern New Mexico west of Santa Fe, at Abiquiu, and in the Nacimiento Mountains by J. S. Newberry during the Macomb expedition of 1859. They consist of copper ores, mainly carbonates, occurring in the lighter colored sandstones overlying the red beds which contain plentiful plant remains, frequently replaced by copper carbonates, and which Newberry regarded as of Triassic age. The same deposits were afterwards reported upon by F. N. F. Cazin (1880) and considered of economic value.

The flat-lying red beds of northern Texas, along the valleys of the Red and Brazos rivers, have long been known to carry copper, and attempts have been made in recent years to exploit them. They have recently been reported on by E. J. Schmitz (1896),[a] who says they consist mainly of carbonates and silicates, largely as a replacement of plant remains, and also impregnating marls and as pebbles in a conglomerate. The beds are considered by him to be of Permian age, and the copper ores have been traced over wide areas in a radius of more than 40 miles. There are no plutonic phenomena in the region, and his judgment is that the occurrences "give indisputable evidence of the origin of the copper ores by precipitation during the deposition of the copper-bearing stratum, or by replacement and metamorphosis shortly after the deposition of the strata." He finds a resemblance of these to the Mansfield deposits, though they are more irregularly distributed, and argues a similarity of origin.

[a] Trans. Am. Inst. Min. Eng., vol. 26, pp. 97–108.

About 40 miles east of the Rio Grande Valley, in New Mexico, is a disconnected series of mountain ranges along a common line of uplift, known in various parts, proceeding from south to north, as the Franklin Range, San Andreas Mountains, Sierra Oscura, and the Sandia Mountains. In these some rather singular deposits, resembling but not entirely analogous to the above, have been noted by Peters, Herrick, and Turner.

The deposits in the Sierra Oscura were described by E. D. Peters in 1882,[a] and later by H. W. Turner, 1902.[b] They occur along the east flanks of the range, in red beds which lie between Carboniferous limestones below and red sandstones and shales above, the latter being thought by Turner to resemble the Permian of western Texas. These beds dip eastward, away from the granite core of the range. The copper ore occurs in beds of arkose sandstone and of shale, two ore-bearing horizons being recognized in the former. The ore consists mainly of glance and carbonate in minute grains disseminated through the rock; also in nodules, especially in the shales, which often have a kernel of sulphide, chalcopyrite, bornite, or chalcocite; likewise replacing plant remains. Among the latter Peters recognized the form characteristic of the Abiquiu quarries (*Podozamites crassifolia*). The arkose sandstones contain rolled grains of iron oxide, in part magnetic. Deposits of chalcopyrite are found on certain fault fissures cutting the beds, but Turner thinks the ores were deposited prior to the main faulting of the region, and that the copper was precipitated from the waters in which the inclosing sediments were laid down.

C. L. Herrick, writing in 1898,[c] describes the occurrence in the San Andreas Mountains, as well exposed in the abrupt escarpments due to faulting on the east side of the range, which afford frequent and good exposures.

The Carboniferous limestones, which rest on granite, are cut at intervals of half a mile or more by a series of vertical veins from 5 to 20 feet thick. These veins, which carry various metallic minerals in a gangue of quartz, fluorspar, calcite, siderite, or barite, can be traced to the contact with the granite, but do not appear to have entered the latter rock. There is a thin band of red sandstone at the contact, in which has accumulated a bed of hematite carrying copper ores consisting of glance, malachite, cuprite, etc. The copper does not occur to any considerable extent in the limestone above or the granite below. Without explicitly stating his reasons, Herrick assumes that the iron ores in this band have leached down from above, but that the copper came up from the depths.

[a] Eng. and Min. Jour., vol. 34, p. 270.
[b] Trans. Am. Inst. Min. Eng., vol. 33, p. 678.
[c] Am. Geol., vol. 22, pp. 285–291.

In all the above instances no near-by occurrence of igneous rocks is noted by the respective authors, though their absence is not explicitly stated, except by Turner.

To the northwest of the San Juan Mountains in Colorado extends the flat, slightly dome-shaped uplift of the Uncompahgre Plateau, formed, as shown by the deeper canyon cuts, by Mesozoic rocks, at the base of which the Triassic red sandstones rest directly upon granite and schist.

On the south side of this uplift Carboniferous beds are interposed between the Mesozoic and Archean, while just across the Colorado boundary in Utah projecting points of a laccolith breaking through the Cretaceous beds form the Sierra La Sal.

Copper ores of economic value having been reported in this region, I made, in the summer of 1899, a reconnaissance examination of some of the deposits in the Unaweap Valley, which is a deep cut across the Uncompahgre uplift about 15 miles south of Grand Junction, Colo. I found here a series of distinct fault fissures crossing red sandstones, which in some cases could be traced down into the underlying granite exposed in the valley bottom. Some of the lower beds of the sandstones are quite calcareous, passing into a deep red, impure limestone. The vein fissures are a few feet wide and carry fragments of the red limestone even well down into the granite. The ore is largely chalcocite and bornite, with some carbonates, resulting from the alteration of chalcopyrite, in a gangue of quartz and calcite with occasional fluorspar. It is said to carry values in gold and silver. The principal accumulations of ore occur where the fissures cross the calcareous beds near the base of the red sandstones. Here it spreads out for a considerable distance laterally, while above and below the metallic minerals decrease in quantity. In one tunnel in the granite, which follows the vein for about 300 feet, only occasional small specks of copper ore were seen. From the observations made during this visit the vein materials might equally well have been assumed to have been brought up from below by waters ascending along the fissures, or to be the concentration by circulating waters of materials originally disseminated throughout the sedimentary beds.

In the same summer Messrs. F. L. Ransome and A. C. Spencer made a reconnaissance through the country farther south from Telluride westward to Paradox and Sinbad valleys in order to study the occurence of uranium, vanadium, and copper ores. All these ores were found as impregnations of the lighter colored sandstones immediately overlying the "Red Beds" or Dolores formation. They are, however, not universally or uniformly distributed, but occur where there are some disturbances, mainly a faulting or fissuring of the beds. The copper impregnations in the sandstones are usually spherical concretions or nodules, blue or green in color, averaging about the size of a pea, while the uranium mineral, carnotite, is yellow and forms streaks running generally parallel to the bedding. Vein deposits of copper ore were also found, where the veins are fault fissures, generally of slight displacement, carrying crushed sandstone and calcite, with argentiferous chalcocite and some copper carbonates. The latter impregnate the sandstone country rock in specks, and sometimes color the entire bed green to a distance of 100 feet or more from the vein. The distance over which the uranium minerals were observed by Ransome and Spencer is in round numbers about 100 miles, and similar occurrences have been reported, since the recent excitement over radium-bearing minerals, another hundred miles farther west, in the region known as the San Raphael Swell, in Utah, which probably occur at the same horizon and in similar conditions with those noted in Colorado. In all these cases there are no igneous rocks in the immediate vicinity of the deposit.

It may be well to mention here the Silver Reef deposits, not far from the town of St. George, in southern Utah, which lies on the western border of the Plateau region. Their origin was the subject of very lively discussion some twenty-odd years ago. They occur presumably at about the same horizon as those already mentioned—namely, in the light-colored sandstones immediately overlying the "Red Beds." The ores consist of impregnations of these sandstones by chloride of silver, which is associated with and often replaces plant remains. Copper ores, mostly carbonates, also occur in the same beds, though in subordinate quantities.

Newberry maintained that these ores were deposited contemporaneously with the sandstones, but the majority of other observers held to the view that the metals were subsequently introduced, basing their opinion upon their apparent connection with the disturbed and fractured condition of the rocks and upon the occurrence of igneous rocks in the vicinity. Not having visited the locality, I hesitate to form an opinion as to the probability of either theory.

Mr. H. F. Lunt has recently published[a] a short notice of copper ores occurring at the same horizon. These occur on the east side of the Colorado River, about 125 miles north of Flagstaff, in the white Mesa sandstone which immediately overlies the Triassic "Red Beds." They consist, according to Mr. Lunt, of the replacement of the cement of a particular stratum of cross-bedded sandstone by chrysocolla, with some tenorite, some specimens of which contain up to 32 per cent of copper. The ore is apparently associated with small vertical crevices, and sometimes shows vein structure, though it generally grades off rather indefinitely into the white sandstone.

[a] Trans. Am. Inst. Min. Eng., vol. 34, p. 989.

It certainly is very singular, even if only a coincidence, that such peculiar occurrences of ore, possessing certain common characteristics, should have been found in a region so difficult of access and so little explored as is the Plateau province, apparently at the same geological horizon, over an area which, taking the Grand Canyon as its southern base, is 300 miles long by 200 miles wide.

We now come to the region of the Grand Canyon itself. The Grand Canyon, the last of the great trenches cut by the corrasion of the Colorado River in the practically horizontal beds of the Plateau province, lies in the great plateau of northern Arizona. Here the river, bending at a sharp right angle, changes from its general southern to a westerly course, and follows this general course, with many windings, through a distance in a straight line of about 180 miles. Throughout the greater part of this extent the harder limestones of the upper part of the Carboniferous, known as the "Aubrey formation," form the undulating and generally forest-covered surfaces of the Plateau, which has an average elevation of about 7,000 feet. From whatever direction one approaches the canyon on this plateau one gets no premonition of its existence until within a few feet of its rim, when one looks down over a vertical escarpment of 2,500 feet into the maze of tributary canyons cut through the next bench or shelf, generally formed by the lower Carboniferous or Red Wall limestones, with whose general appearance all are familiar from Holmes's admirable drawings.

It would take too much time and involve too much repetition of what has already been written to go at any length into the geological structure of this region, and I will only mention a few facts that bear upon the subject under consideration.

The canyon is now reached by rail over a 60-mile branch of the Atchison, Topeka and Santa Fe Railroad, which leaves the main line at Williams station, about 40 miles west of Flagstaff, the former starting point for the canyon. Between and to the north of these two stations the grand mass of San Francisco Mountain and its many outliers represent a recent basaltic eruption on the surface of the plateau, while en route to the canyon one passes the little hill known as "Red Butte," a monadnock of Permian beds, apparently the only portion of this covering of the Carboniferous that has escaped erosion within a radius of many miles. The plateau at the southern edge of the canyon is called the Coconino Plateau; that opposite to it, on the northern rim, is the Kaibab Plateau, which extends north nearly to the Utah line, a distance of about 60 miles.

The Carboniferous beds, which are well exposed along the immense extent of canyon walls, consist in round numbers, first, of about 500 feet of upper Carboniferous limestone underlain by an equal amount of cross-bedded white sandstone, which together characteristically form the upper vertical member of the canyon walls. Below these are 1,200 feet of red sandstones with some thin shales and limestone horizons, which form walls less strictly vertical and whose base is generally covered by talus. Under these are 550 feet of blue limestones, which form a second platform within the upper canyon walls. Powell gave the names of Upper and Lower Aubrey and Red Wall limestone to these respective formations, but where and on what grounds he drew his lines of division I am unable to determine. The lower limestones, which form vertical cliffs, generally colored red on the surface, are evidently in part at least Red Wall limestone. They correspond to the lower Carboniferous limestones of Utah and Colorado, while the upper beds, consisting of a great thickness of prevailingly siliceous sediments capped by calcareous beds, correspond also, in a broad way, with the other developments of the Carboniferous in those regions.

E. P. Jennings[a] has recently published a brief account of the copper deposits of the Kaibab Plateau. These are best developed near Jacobs Lake, 30 miles south of the Utah line, where they are 16 feet thick, of unknown width, and more or less continuous for 5 miles, and he says that outcrops of ore have been found at various points along the plateau surface from Jacobs Lake south to the Grand Canyon, a distance of 40 miles. He describes the ore beds as white chert impregnated with malachite and azurite, small amounts of earthy cuprite, copper glance, and chalcopyrite having also been observed. The beds are intersected by many small faults, the ore near these faults having been crushed and recemented by silica and copper. He finds no evidence of copper in the Paleozoic strata below these beds as exposed, either along the fault which forms the western escarpment of the plateau or in the walls of the Grand Canyon, but mentions a few copper-bearing dikes with the usual contact impregnation of copper ore and copper-stained rock in the metamorphic series at the bottom of the canyon, nearly a mile below the copper-bearing beds. He says there are no other known eruptives that could have furnished the copper. To the north and east, however, are Triassic sandstones sufficiently copper bearing to be mined with profit; hence he concludes that these ores must have been formed by the leaching down of deposits in the Triassic strata that originally covered them, by carbonated alkaline waters, and reprecipitation in the Carboniferous limestone. This theory is, to say the least, ingenious and plausible, but it can hardly be finally accepted until the region has been systematically studied.

I saw ores similar to those described by him that came from a mine on the Coconino Plateau to the west of the railroad, and hence

[a] Trans. Am. Inst. Min. Eng., vol. 34, p. 839.

at the same horizon. My own observations were made at a still lower horizon, however—namely, the Red Wall or lower Carboniferous limestone—in the so-called Grand Canyon mine, that is being worked by a shaft 200 feet deep and by a crosscut tunnel that connects with ore. This mine is reached by the Grandview trail, which descends the canyon walls about 12 miles east of "Bright Angel," the point reached by the railroad, and about a mile west of the Old Hance trail, by which travelers descended into Congress Canyon when the approach was by coach or wagon from Flagstaff. The mine is situated at the upper edge of the platform formed by the Red Wall limestone and 2,500 feet below the rim of the canyon wall. It is opened by a shaft 200 feet deep and by a crosscut tunnel that connects with the bottom of the shaft. A second tunnel was started 200 feet lower down and has been driven a distance of 500 feet, but has not yet reached the ore.

The ore is mostly blue and green carbonates with chrysocolla, but chalcocite has been found in the center of the larger masses, one of which, to judge by the opening left, must have been 8 or 10 feet in diameter. There are no gangue minerals, and of other metallic minerals none were seen except a very little finely divided pyrite. One small specimen of chalcopyrite was seen, which was said to have come from the mine. The limestone country rock in the neighborhood of the deposit has been bleached and partially marbleized. This limestone is very much decomposed along a rather ill-defined shear zone, which trends about N. 65° E. Much of the decomposed portion is a white clay-like material, which the miners thought to be porphyry. I could, however, find nothing in or near the mine which I could consider as surely of eruptive origin.

The ore is very irregularly distributed through the shear-zone material, generally in the form of strings and flakes of carbonate on cracks and thin seams. It sometimes occurs also in the limestone at considerable distances from the shear zone. At times it is concentrated into bunches, which often show a kernel of sulphide, or again it forms the lining of small caves or vugs, when it may assume very beautiful crystalline forms.

The deposit is situated in the line of one of the north-south monoclinal folds which are characteristic of this region and which often pass into faults, but the strike of the shear zone is, as nearly as could be determined, at right angles to that of the monocline. A winze had gone down 40 feet below the level of the upper tunnel and was still in ore, but the lower tunnel had not reached ore, though, as well as could be determined without instrumental measurement, it should already have cut the shear zone.

The nearest eruptive rock is an 80-foot bed of basalt, a mile or two distant, near the bottom of the canyon, which runs a few feet above the contact between the Algonkian and underlying crystalline schist. As seen through the glass it had the appearance of an intrusive sheet, and the occurrence of a seam of asbestos at its contact with the limestone seemed to favor this idea. Mr. Walcott, who has actually examined the bed, says, however, that it is of effusive origin and must have been poured out at the bottom of the sea. In either case it could not have had any connection with the ore deposition, since it was apparently truncated by pre-Cambrian erosion and the Tonto (Cambrian) beds are deposited unconformably over its edges.

The only other eruptives in the region are the effusive basalts of the San Francisco Mountain, which are of very recent origin and were poured out after the removal by erosion of the Permian covering of the plateau.

Thus all the facts I was able to determine in my visit that bear upon the genesis of the deposit favor the idea that the ore has been leached down from above and is of secondary origin, rather than that it is an original deposit from uprising solutions.

As regards the processes of deposition which have prevailed in these deposits, the applicability of what is known as "adsorption" has recently been advocated by Dr. Ernest Kohler.[a] This process depends upon a selective property exercised by certain clay substances which enables them to separate out copper from its dilute solutions. It has been practically tested in the laboratory of the Survey by Doctor Sullivan at the suggestion of Mr. Waldemar Lindgren. Certain kaolin-like clays from the Clifton-Morenci district when agitated in a dilute solution of sulphate of copper were found after a brief period to adsorb all the copper contained in the solution. Doctor Kohler states that most of the copper deposits in the Permo-Triassic beds in Europe are associated more or less intimately with finely divided clays, and suggests that even in the case of the association of copper with organic remains it was a thin film of clay around them that induced the precipitation.

In the case of the Grand View deposits of the Colorado Canyon the decomposed limestone in the chert zone would seem to be of sufficient clayey consistency to have removed the copper from dilute percolating solutions.

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[a] Jour. für prakt. Geol., February, 1901, pp. 49–59.

THE COPPER DEPOSITS OF MISSOURI.

By H. Foster Bain and E. O. Ulrich.

Introduction.—Attempts to mine copper have been made in Missouri since 1837, and at different times copper furnaces have been operated in Shannon, Ste. Genevieve, Jefferson, and Crawford counties, while a matte carrying in addition nickel and cobalt has been steadily produced in Madison at Mine la Motte. Copper has probably been shipped in small quantities also from several other counties. Shumard,[a] writing in 1860, enumerated fifteen counties in which copper was known to occur, but he failed to include Ste. Genevieve, the one from which the main output has come. Very little attempt had then been made to develop the deposits. At present a small furnace near Sullivan is in operation, and the old "copper mines" of the Mine la Motte estate are being reopened.

General distribution.—Copper-bearing pyrite is widely distributed in Missouri, as it is in many other States, and the brilliant colors of its alteration products lead to its ready recognition. It has been noted in Benton, Clark, Crawford, Dade, Dallas, Dent, Franklin, Greene, Iron, Jasper, Jefferson, Laurence, Maries, Madison, St. Francois, Ste. Genevieve, Shannon, Washington, and probably a number of other counties. For the most part these occurrences may be at once dismissed as of no economic importance. The five which have yielded ore have already been noted. With the exception of one or two sporadic occurrences of merely mineralogic interest, copper is found only in the southern part of Missouri, within the region broadly known as the Ozark uplift.

For the better understanding of the description of the deposits the following general table of formations is here presented. It will be noted that changes have been made in the older classification of the rocks, and one new name, Elvins formation, is introduced. The reasons for the changes are discussed in full in a bulletin of the Survey now in press,[b] in which also fuller data regarding the deposits will be found.

[a] Shumard, B. F., Report of progress, Geol. Survey Missouri, 1861, pp. 7–9.
[b] Bull. U. S. Geol. Survey No. 267.

Classification and synonymy of the formations of the "Magnesian" or "Ozark" series in Missouri.

Period.	Series.		Formation.	Thickness.	Synonyms.
Ordovician.	Saratogan and Canadian.		Joachim limestone	0-150	First Magnesian limestone. Folley limestone.[a]
Ordovician.	Saratogan and Canadian.		St. Peter ("Crystal City") sandstone.	0-200	First or Saccharoidal sandstone. Cap au Gres sandstone. Pacific sandstone. "Key sandstone" in Yellville district of Arkansas.
Ordovician.	Saratogan and Canadian.	Potosi or Yellville group.	Jefferson City limestone	50-250	Second Magnesian limestone. Winfield limestone. Finley limestone.[b] ? Marshfield sandstone.
?	Saratogan and Canadian.	Potosi or Yellville group.	Roubidoux formation	70-225+	Second sandstone. Moreau sandstone. St. Elizabeth formation and Bolin Creek sandstone member. ? Marshfield sandstone. ? Bolivar sandstone.
Cambrian.	Saratogan and Canadian.	Potosi or Yellville group.	Gasconade limestone	450-650	Third and Fourth Magnesian limestones and Third sandst. Includes Osage limestone, Cole Camp sandstone of Winslow; also Gasconade limestone, Gunter sandstone, and Proctor limestone, of Ball and Smith. Lesueur limestone.
Cambrian.	Saratogan and Canadian.	True Saratogan.	Elvins formation	0-120	Basal part of the Potosi limestone and the "Potosi slates and conglomerates" of Nason.
Cambrian.	Acadian.		Bonne Terre limestone	0-400+	? Fourth Magnesian limestone in part. Fredericktown limestone. Bonne Terre limestone. Decaturville limestone.
Cambrian.	Acadian.		La Motte sandstone	0-300	Second sandstone of Shumard in part.
Archean granites and porphyries.					

[a] The names Folley limestone, Cap au Gres sandstone, and Winfield limestone, together with a number of other new names, were published by Keyes in 1898, in a paper entitled Some Geological Formations of the Cap au Gres Uplift: Proc. Iowa Acad. Sci., vol. 5, pp. 58-63.

[b] The names Finley limestone, Marshfield sandstone, and Decaturville limestone appear in a provisional table of geological formations in Missouri published by Shepard in 1904: Bull. Brad. Geol. Field Sta., p. 42.

The deposits.—The Ste. Genevieve copper mines are not now in operation. They have been described by Mr. F. L. Nicholson.[a] The principal deposit occurs as a bedded chert breccia in the lower part of the Jefferson City limestone. Copper, in the form mainly of chalcopyrite and malachite, forms the cement of the breccia. The bed where seen varies in thickness from 18 inches to 3 feet. The recent completion of the Southern Missouri Railway to within 3 miles of the deposits so alters the mining conditions that the deposit is believed to be worthy of further prospecting, and to that end drilling is recommended.

At Mine la Motte the copper occurs as chalcopyrite in low percentage, intimately intermingled with galena. Its production is largely

[a] Nicholson, Frank L., A review of the Ste. Genevieve copper deposits: Trans. Am. Inst. Min. Eng., vol. 10, 1882, pp. 444-456.

incidental to the mining of the latter and the saving of nickel and cobalt. An effort is now being made to develop certain deposits which show distinct bands rich in copper.

In Shannon County copper occurs at a number of points and efforts have been made since 1837 to develop a copper industry. The best known prospects are the Slater, Jerktail, Sutton, and Casey. At the first three the copper, mainly malachite, but subordinately chalcopyrite, occurs as the cement of a basal conglomerate where the Gasconade limestone rests upon the sloping surface of Cambrian porphyry hills. At the Casey the ore occurs as an impregnation of a horizontal shale bed much higher in the formation, if not, indeed, in the overlying Roubidoux.

In all these occurrences the copper is believed to be due to concentration from the surrounding rocks, and the locus to have been determined mainly by geographic conditions obtaining at the time the limestone was formed. The deposits are bedded and may easily be prospected by drilling.

Near Sullivan the Missouri Copper Mountain Mining Company is working a body of copper ore consisting of residual clay in which are balls and nests of chalcopyrite and malachite. A twenty-day run in November resulted in the production of 22,500 pounds of metallic copper. The ore body is the result of the decomposition of the Roubidoux and the beds immediately below. This is the horizon at which specular hematite commonly occurs throughout the region, and in the bottom of many of the old iron pits a certain amount of copper is found.

Summary.—Copper in the form of sulphides and carbonates has been found at many points in southern Missouri and has been mined in several localities, notably in Ste. Genevieve, Madison, Shannon, Jefferson, and Crawford counties. Very large deposits, rivaling those of the West, have not been found and are not to be expected. The character of the ore and the low cost of flux, fuel, and labor make it possible to work some, at least, of the deposits with profit.

The deposits show a preference for certain stratigraphic horizons, and, being bedded, may be prospected with ease and economy. The common association of sulphides with specular iron in this region points to the advisability of the investigation of the old iron pits of the sandstone region. While any copper deposits found will probably not be large, they should be easily and cheaply mined. In Shannon County the most favorable localities are along the contact of porphyry and dolomite at points where the conglomerate beds at the base of the latter fill in shallow basins in the crystalline rocks. In the disseminated lead district of southeastern Missouri copper occurs in connection with the lead, and at a few points can be saved to advantage.

ORE DEPOSITS OF BINGHAM, UTAH.

By J. M. Boutwell.

INTRODUCTION.

In an earlier progress report upon this subject, general features of geography, history and development, and geologic features of direct economic bearing were briefly sketched, and conclusions regarding the character and occurrence of the ores, etc., were presented.[a] At that date, however, the incompleteness of the study precluded final statements upon these latter subjects and rendered it undesirable to discuss problems of genesis. Since the publication of that progress report the contributions by the several authors have been completed.[b]

As the present volume is expected to appear before the complete report, a bare general statement of these additional conclusions, together with a brief sketch of recent developments, is now presented for immediate use. For the detailed evidence upon which these conclusions are based the reader is referred to the forthcoming report.

CHARACTER OF ORES.

Bingham is the leading copper-producing camp in Utah. The copper shipments are made up almost entirely of sulphide ores, in which low-grade primary sulphides, massive chalcopyrite, and pyrite predominate. The grade is raised, however, by secondary black copper sulphides, including chalcocite, tetrahedrite, and tenorite. Some argentiferous lead ores, mainly galena, are also shipped regularly. The copper ores yield accessory gold, silver, and iron; the argentiferous lead ores, accessory copper.

The copper content in the average sulphide ores is low, ranging from $2\frac{1}{4}$ to $4\frac{1}{2}$ per cent; but the accessory gold, averaging from 10

[a] Boutwell, J. M., Ore deposits of Bingham: Bull. U. S. Geol. Survey No. 213, pp. 105–122.

[b] The complete report is now in press, and is expected to appear this spring. It is Professional Paper No. 38, entitled "Economic Geology of the Bingham Mining District, Utah, by J. M. Boutwell, with a Section on Areal Geology by Arthur Keith and an Introduction on General Geology by S. F. Emmons." Copies may be obtained free of charge upon request to the Director of the United States Geological Survey, Washington, D. C.

cents to $1, and silver, averaging from 2 to 5 ounces, raise the total value of the ore per ton—$11 to $15—well above the commercial limit. Tellurium has been found associated with some of the black copper sulphides, in one instance in considerable amount, with proportionately high values of gold and silver. Zinc blende occurs in the argentiferous lead ores, but is not saved.

OCCURRENCE OF THE ORES.

The productive area is roughly limited to a region that is characterized by intrusives, and within this area the largest ore bodies occur in metamorphosed limestones adjacent to intrusives and fissures.

The copper ores occur in large masses in metamorphosed limestone, and also in grains disseminated through monzonitic intrusives. The large bodies lie within massive marbleized limestones adjacent to intrusives and fissures. Associated with this ore in the coarsely crystalline marbleized limestone are the following minerals: Garnet, epidote, tremolite, sphalerite, specularite, pyrrhotite, etc. The ore bodies are in the form of lenticular beds lying roughly parallel with the bedding of the country rock, and exhibit a massive banded structure which is continuous with the bedding of the inclosing country rock. These beds are localized into elongated lenticular shoots which dip roughly with the bedding and pitch moderately. These shoots sometimes assume great size, being several hundred feet in length along their strike, nearly 200 feet thick, and have been followed downward continuously for several hundred feet.

The disseminated auriferous copper ore occurs throughout extensive stocks of mozonite, but particularly in areas where it is fractured, fissured, and altered. Irregular grains of chalcopyrite and cupriferous pyrite are there found in small veinlets, intergrown with secondary silica, sericite, etc., chiefly along joint or fracture planes, and subordinately in altered areas immediately adjacent to such planes. Definite shoots have not been proved.

The argentiferous lead ores occur in veins filling fissures which trend northeast-southwest and traverse all kinds of rocks known in the district. The veins are widest in limestone and in shales which contain calcareous and carbonaceous matter. Their general structure is a rough banding parallel to the walls of the fissures, but these bands are not sharply defined, the minerals of one band being irregularly intergrown with those of adjoining bands. The relative distribution of minerals in these bands indicates that the general order of deposition from older to younger was sphalerite and tetrahedrite, pyrite, and galena, calcite, quartz, rhodochrosite, and barite.

In brief, sulphide copper ore occurs chiefly in large lenticular shoots along beds in marmorized limestone in the vicinity of fissures and intrusives. Smaller but more uniform veins of argentiferous lead ore traverse all rocks, are largest in limestone, and most numerous in the vicinity of intrusives.

ORIGIN OF THE ORES.

It is sufficient for present purposes to state that in general it appears that the large bodies of copper ore were formed through replacement of limestone directly or indirectly under the influence of igneous magmas; that the argentiferous lead ores were deposited from aqueous solutions in northeast-southwest fissures, mainly by filling, partly by replacement, and that the disseminated copper in monzonitic intrusives is secondary.

RECENT DEVELOPMENTS.

The rapid and extensive development of its mining industry in recent years has placed Bingham not only in the lead of copper-producing camps in Utah, but among the great copper camps of the country. In 1900 the mines of this district produced only a little over a hundred thousand tons of ore; in 1904 they are reported to have produced nearly a million tons of copper ore alone. The recent striking advance of Utah in the production of the precious metals is also due mainly to this great increase in the output of copper ore at Bingham; for the ordinary sulphide copper ore of this camp carries, as above stated, from 10 cents to $1 in gold and from 2 to 5 ounces in silver, while some of the black copper sulphide ores run high, a sample from one of the large mines affording 58.6 ounces silver and $76 in gold.

The period from 1896 to 1900 was characterized by consolidation of large tracts under individual companies and extensive underground exploration of several great properties. This exploration resulted in opening large bodies of the primary copper sulphide ore and considerable rich black sulphide ore. Then followed an epoch of preparation for extraction, shipment, and reduction on a large scale. These preparations have now been completed, and in the last two or three years one property after another has settled down to shipping regularly.

The leading producer of the camp, the Highland Boy mine of the Utah Consolidated Company, has conducted extensive underground development and yearly added to its surface improvements. Underground, the mammoth No. 1 ore shoot has been followed down more than 100 feet farther, from the Nos. 7 and 7½ levels to No. 8 level, and proved to maintain great size and paying values. A large new ore body has been discovered in the hanging-wall limestone, 160 feet above the quartzite foot, and new ore also opened at other points. In consequence the capacity of the smelter has been increased, and 700 tons of ore are now treated daily. The property is stated to have produced during 1904 approximately 15,000,000 pounds of copper and to have paid $900,000 in dividends.

The United States Mining Company in 1900–1901 conducted considerable exploration in the Old Jordan and Telegraph mines for copper in limestone, and recently it reopened and extended workings on the Galena fissure in search of argentiferous lead ores. A 1,000-ton smelter was erected for treating copper ore, and a smelter of 400-ton capacity has just been completed for treating its argentiferous lead ores. An aerial tramway of Bleichert pattern transports the ore from the Jordan, Galena, and Telegraph mines to the railroad, a distance of 3 miles. During 1904 this company is reported to have treated at its new smelter 11,000,000 to 12,000,000 pounds of copper, including its own and custom ores.

The Bingham Copper and Gold Company, operating the Commercial and Dalton and Lark properties, has maintained regular daily shipments of 200 tons from the former and has unwatered and reopened the latter. In the course of reopening the consolidated properties on the eastern slopes large bodies of minable copper ore are stated to have been found in the Dalton and Lark, and in the Brooklyn. During 1904 the output of copper from these properties is reported to have been approximately 11,500,000 pounds.

The Boston Consolidated Company, after persistent search for the old Stewart ore bodies at a depth, has opened on the Work and Peabody levels a large shoot of rich copper sulphide ore. Extensive underground development is being prosecuted at lower levels with a view to catching this shoot at greater depths. Regular shipments were maintained in 1903–4, and it is reported that these will be increased during the present year.

Several smaller companies have also conducted successful development work. Some of these newer companies have already entered the shipping class. Among these new enterprises mining and concentration of the low-grade copper-bearing igneous rock is most important.

The Utah Copper Company has secured an extensive tract in the vicinity of Upper Bingham, which includes the Wall group, and has erected a 500-ton concentration mill in main Bingham Canyon, about 1⅓ miles below Bingham. The ore is mineralized monzonite belonging to the great laccolithic stock at Upper Bingham, and carries low values in copper and gold. It is now mined on a large scale, and it is planned to increase the output in the future by using the open-cut method. Concentration is about 20 into 1, by the usual wet methods. Water is obtained from the abandoned West Mountain placer shaft, and an additional supply may be obtained from Mound Springs near Garfield Beach, about 12 miles distant. The results of this experiment during its first year are reported to have been so satisfactory that it is proposed to increase the daily capacity of the mill to 3,000 tons. The holdings of other companies, notably the Boston Consolidated, embrace large bodies of this monzonite Utah copper may initiate an important new phase of copper mining in Bingham.

The Yampa Consolidated Company has developed a new shipping mine in the Yampa limestone on the Yampa and adjoining claims on the north slope of Carr Fork. A smelter erected in lower Bingham Canyon was found inadequate and has been entirely rebuilt, with a capacity to treat 600 tons of Yampa ore daily.

The old Columbia property has been taken as a central group in forming another consolidation known as the Ohio Copper Company. Exploration on an increased scale has resulted in largely increasing the output from this property, which is now treated at the rate of 120 tons a day at the remodeled Winamuck mill. The Erie mine is now included in the holdings of the Ohio Company.

In upper Bingham Canyon, in the Kempton mine, a large body of high-grade ore has been opened, but owing to disagreement as to its ownership it has not yet been mined. Following the settlement of the litigation between the Butler and the Liberal, consolidation was effected and profitable operations were resumed. In the Silver Shield mining was interrupted by an uncontrollable flow of water in 1902. Subsequently the property was consolidated with the Bully Boy, and an effort made to drain it by extending the Franklin tunnel under the Niagara to the Silver Shield fissure. It is understood that ore has been found at this deeper level in Silver Shield ground near its limits. The Nast, after being reequipped for more extensive and deeper development, has produced ore sufficient to supply its 50-ton mill regularly. The old Fortune, now the Fortuna, mine has been reopened, and is being thoroughly developed.

Among the still more recent and extensive consolidations are the New Haven Copper and Gold and the Utah-Apex companies. The New Haven property embraces the Zelnora, Morning Star, and Frisco. An extensive plan for the development of these properties as a whole, by which the Frisco tunnel is being driven westward to tap the Zelnora vein in depth and to prospect the intervening ground, is now being actively carried out.

The Utah-Apex comprises the Red Wing Extension, Highland Boy Consolidated, and adjoining properties on the north side of

Carr Fork. It is also being opened by a long crosscut tunnel to prove in depth the character of veins which have been superficially prospected. The actual results of exploration in these properties are reported to have been most promising, but they have not been observed by the writer.

The above statements indicate some of the more important recent developments in the district. Valuable ore bodies have been discovered in the metamorphosed limestones, and a few bodies of lead ore have been encountered in exploring the fissures. These discoveries have, as a rule, been within the known productive area, and have resulted from the more thorough exploration of old ground. There still remain within this area several very promising unexplored stretches of the great ore-bearing limestones.

These recent explorations have in a practical way increased the known available copper resources of the camp in two directions: First, the continuation in depth of the great shoot in the Highland Boy mine and the proved persistence of its copper values give a reasonable expectation that similar ore shoots may be followed down with profit in other mines; second, the demonstration by the Utah Copper Company that the disseminated ores in the monzonite bodies can be worked at a profit opens the field for profitable exploration of other large copper-bearing bodies of this rock.

These significant recent developments indicate a probable continued growth of the prosperity of the district and an increase in the output for 1905.

THE CACTUS COPPER MINE, UTAH.

By S. F. Emmons.

An important new enterprise in the mining industry of Utah is the Cactus mine, which belongs to the Newhouse Mines and Smelter Company. This property was visited by the writer in August, 1904, in the course of a visit to the Frisco district of southwestern Utah, with the purpose of determining the area to be covered by the topographical map which shall serve as the basis for a study of the economic geology of that region. Two days were devoted to a reconnaissance examination of the Cactus mine and its immediate surroundings, and from the notes taken at that time the following brief description has been prepared in advance of the results of a detailed study of the entire district, which will be made as soon as practicable.

Location.—The Cactus mine is situated in Beaver County, Utah, on the western slope of the San Francisco Mountains, about 4½ miles northwest of the town of Frisco, which lies at the eastern base of the same range and a short distance north of the old and well-known Horn Silver mine.[a]

The San Francisco Mountains form a north-south ridge of the Basin range type, which constitutes the eastern rim of one of the southern arms of ancient Lake Bonneville, called by Gilbert[b] Preuss Valley but now more frequently known as Wawah Valley. The region is characterized by extreme aridity, the only water being found in isolated and widely scattered springs, which furnish only an extremely limited supply of this most important element. It possesses the weird beauty of outline and coloring peculiar to the desert, and, owing to the clearness of the dry atmosphere, the view from any elevated point ranges over a hundred miles or more of alternating broad desert valleys and sharply sculptured mountain ridges. One of the most striking features of the landscape, seen from any high point in the San Francisco Mountains, is their greatly longer slope toward the west and their relatively short and abrupt

[a] A brief description by the writer of the geological structure of this mine will be found in Trans. Am. Inst. Min. Eng., vol. 36, p. 675.

[b] Lake Bonneville: Mon. U. S. Geol. Survey, vol. 1, 1890.

escarpment to the east, the bottom of Wawah Valley being over 1,500 feet lower than the valley on the east, in which are situated the town of Frisco and the Horn Silver mine.

History.—The Cactus mine lies in Copper Gulch, a narrow ravine running in a northwest direction down the western slope of the range toward the Wawah Valley. This mine formely belonged to a French company, which opened the deposit down to the hundred-foot level and erected a small concentrator in the bed of the gulch. That this company was not financially successful does not seem sur-

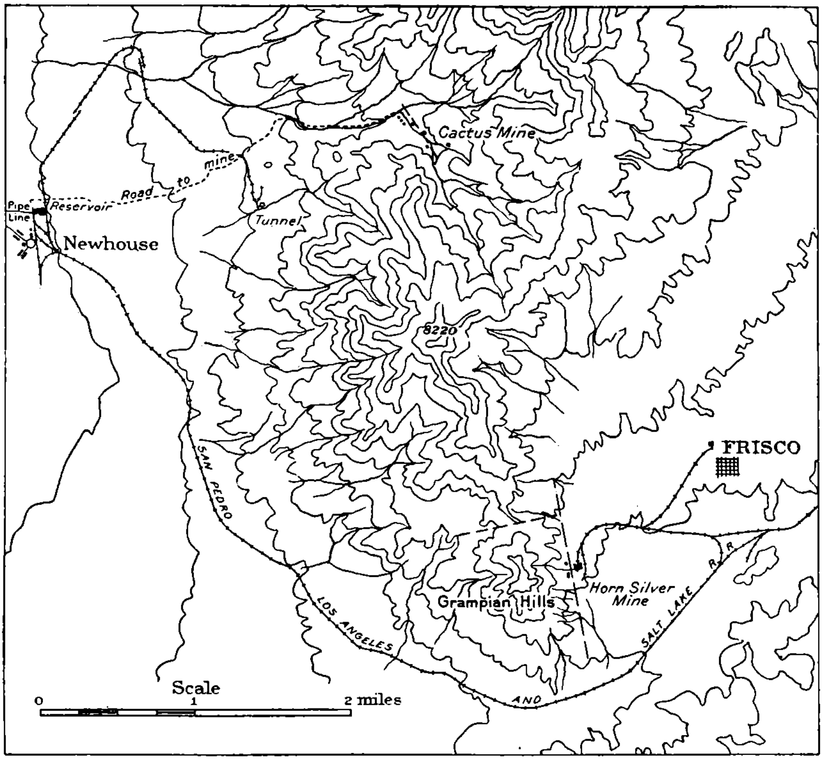

FIG. 15.—Sketch map showing location of the Cactus mine, Utah.

prising when the almost absolute want of water and the difficulty of access to the locality are considered. After the property had long lain idle it was purchased by the present owners, who have proceeded to develop it on a plan which at first strikes one as financially daring to the point of audacity, and yet on closer examination appears to be based on a careful scientific study of conditions and cost. It is stated that the development of the mine, the building of the necessary railroad connections, plant, etc., will have cost the promoters over a million dollars before they are in condition to obtain any return from the reduction of their ore. On the other hand, they claim to have in sight 2,100,000 tons of ore (estimating 19 cubic feet to the ton), which will carry, on the average, 3 per cent of copper.[a]

Development.—The mine has been opened by a new vertical shaft 600 feet in depth, with levels at 100-foot intervals and drifts for several thousand feet along the length of the deposit, and by a cross-cut tunnel over 5,000 feet long, which is to tap the vein at the 600-foot level.

A supply of water being absolutely indispensable for the economic working of the mine, especially the concentration of ore, the Wawah Springs, on the opposite side of the valley of the same name, have been bought at a cost of $60,000 from their Mormon owner, who had held them at this price for over fifty years. The water from the group of sixteen springs has been gathered together into a collecting reservoir with a capacity of 36,000 gallons. An iron pipe line 8 miles long has been laid across the valley, connecting the springs with a receiving reservoir having a capacity of 300,000 gallons and situated just above the proposed town of Newhouse. The springs being 600 feet higher than the valley bottom, the receiving reservoir was built at an elevation of 400 feet above this bottom, thus affording a head of 200 feet to overcome friction, etc. The capacity of the springs is estimated at a minimum of 1,400 gallons per minute at all seasons. The plant consists of a power generator destined to furnish power for drilling, hoisting, etc., at the mine, and a concentrator now building of an estimated capacity of 600 tons of ore per day, capable of being enlarged to 1,500 tons. The town which is growing up around this plant is situated on the sagebrush-covered Quaternary slopes of the valley, about 1½ miles out from the tunnel entrance at the foot of the mountains and a little over 500 feet below it. A railroad line, 2½ miles long, with 4 per cent grade, will connect the tunnel entrance with the concentrating works and be operated by a Shay locomotive, while a standard-gage railroad line, 7 miles long, runs around the southern end of the Grampian Hills, connecting the town with the Frisco branch of the Oregon Short Line, which is now operated by the San Pedro, Salt Lake and Los Angeles Railroad, controlled by W. A. Clark.

Geology.—Only a rough sketch of some of the broader features of the geological structure of this range can be given at present, as the writer's observations have been limited to general views obtained from the Horn Silver and Cactus mines and to traverses across the range opposite the respective mines. The accompanying topograph-

[a] The writer has made no attempt to verify these figures, but merely presents them as given to him, because they furnish an interesting example of mining enterprise in the West.

ical sketch gives an accurate reproduction of the general outlines of a portion of the range and the relative position of the two mines and their dependent towns of Frisco and Newhouse.[a]

The range is divided by saddles, which evidently have a structural signification, into three massifs or orographic blocks. The southern, known as the Grampian Hills, which lies opposite the Horn Silver mine, is composed mainly of bedded blue limestone. Along the east base of this massif runs a north-south fault, separating the limestones from recent andesitic rocks which fill the valley in which lies the town of Frisco, and form low, broken hills extending out eastward from the San Francisco Range to the north of that town. It is within the fault fissure, which at that point is over 100 feet wide, that have been found the important ore bodies of the Horn Silver mine. In this mine the Horn Silver fault appears to have a trend a little east of north, but, according to Mr. W. A. Hooker, the mining engineer who made a detailed study of this mine in 1879, the average direction in the 2 miles over which it has been traced is N. 10° W.

The saddle which separates the Grampian Hills from the central massif is the locus of an east-west fault, which branches off at right angles from the Horn Silver fault and which brings up monzonite (a granitic rock intermediate in mineralogical composition between granite and diorite) on the north side into juxtaposition with limestone on the south. The central massif extends north as far as the depression of Copper Gulch, which cuts diagonally across the range in a northwesterly direction. The higher portion of the massif is apparently composed of limestones overlain by quartzites. On its southwestern face, as described in the above-mentioned article, is a body of monzonite which has intruded an extensively altered limestone, the latter being changed along a wide contact border to a garnet rock abounding in the lime-silicate minerals characteristic of contact metamorphism. At the northern point of this massif is an extensive outcrop of a similar granitic rock, having apparently a somewhat more dioritic facies, in which occur the deposits of the Cactus mine. Whether or not these two bodies are connected at the surface was not determined, but they evidently form part of the same batholith of monzonite which has intruded and altered the limestones.

The northern massif, which extends for some miles beyond the limits of the map, is higher than either of the others. Its culminating point, for which the name "Golden Horn Peak" is suggested, has an abruptly escarped face to the southwest, suggestive of faulting, that affords an excellent section of the sedimentary rocks of

[a] This sketch has been prepared from unfinished plane-table sheets of Mr. F. McLaughlin, topographer, who is engaged in making a detailed survey of the district.

which it is composed. These consist of an upper series of red quartzites, estimated at over a thousand feet in thickness, beneath which are several hundred feet of white quartzites, the whole underlain by limestones. No monzonite outcrops were observed along the immediate western face of the massif, but the alteration of the blue limestones into white marble which extends in irregular tongues and clouds through the general belt of the unaltered rock at the base of the cliff suggests that this rock probably occurs at no great depth below the surface.

No fossils have yet been found in the sedimentary rocks of the region, and their age is purely a matter of surmise. The heavy quartzites in this portion of the Great Basin have hitherto proved to be of Cambrian age, but limestones underlying Cambrian quartzites have not yet been observed so far east as this, though they are known to occur near the east base of the Sierra Nevada. The monzonites are evidently later than all the sedimentary rocks; the andesites are presumably of still more recent age, and, from analogy with other regions, probably Tertiary. The faulting must necessarily have taken place at a still later period, since it cuts all these rocks.

The deposits.—The deposits of the Cactus mine are opened in the bed of Copper Gulch just above the point where it bends from its northwest trend to take a more direct westward course down the valley slopes. It occurs entirely within the monzonite body, which here occupies the bed of the gulch and the hills immediately south and west of it. The ore occurs within a zone of fracture and brecciation of irregular width which is somewhat wavy and variable, both in strike and in dip, but in general follows the bed of the gulch below the forks, having an average direction of about N. 30° W. In dip it is nearly vertical, the little departure from the perpendicular that could be detected being to the northeast.

The ore is mainly pyrite, generally rather coarsely crystalline, with a little chalcopyrite, and contains practically no lead or zinc. It carries a little silver and a fraction of an ounce of gold, the precious metals, it is claimed, being sufficient in amount to repay the cost of mining and concentration. No other metallic minerals were observed by the writer except a small amount of sooty sulphide of copper in the secondarily enriched zone, where the ore in considerable stretches is said to run up to 7 per cent of copper and in spots to contain 20 to 100 ounces of silver to the ton. At the outcrop there is little evidence of the existence of ore beyond an occasional green stain on the granite, and yet, in the winze at the forks of the gulch, sulphide showing little or no oxidation is found within a few feet of the surface. This is a little remarkable in this arid climate, where oxidation is apt to extend to a considerable depth, and would seem to indicate that in spite of the limited rainfall the corrasion of the gulch had kept pace with the oxidation of the ore. The disintegration of the rock within and along the shattered zone has evidently facilitated its wearing away and probably had much to do with determining the location of the gulch.

The width of the zone of faulting varies from 15 to 30 feet, as shown by the underground workings of the mine, which, as already stated, have reached a depth of 600 feet, longitudinal drifts with frequent crosscuts being driven along the zone at vertical intervals of 100 feet. The rock within this zone is shattered rather than sheeted, though some sheeting is visible. There are no well-defined and continuous walls, but rather indefinite boundaries between the impregnated zone and barren country rock are afforded by frequent slip planes. At certain points there is apparent evidence of cross faulting. In the upper 50 to 100 feet there is the appearance of rounded bowlders of country rock within the fault zone, which has been thought to indicate an open fissure into which they had fallen from the surface. It appears more probable, however, that these were originally angular fragments in the shattered zone that have been rounded by the disintegrating action of surface waters. Where most clearly seen the pyritous ore bodies sometimes form a sort of cement to these rounded fragments, and fill cracks and interstices in the shattered rock. It is likewise concentrated in irregular patches, in which case alone is massive chalcopyrite visible. The decomposed country rock in the midst of the ore zone contains abundant sericite, and a black mineral, apparently hornblende, often simulates a metallic ore, and sometimes occurs in radiate groups of prisms of strikingly fresh appearance. They may be tourmaline.

Conclusions.—The deposits are evidently the impregnation by pyritous ore of a strong fault zone, and the structural conditions indicate that this fault zone may be a northern continuation—possibly a branch—of the Horn Silver fault. Its direction is more to the westward of north than is the latter, but structural faults rarely follow an absolutely straight line, and, as shown by the topography, the south fork of Copper Gulch is very nearly in line with the Horn Silver fault. Moreover, at the east base of the saddle at the head of this fork there is a contact of lime rocks with granite that has the appearance of a fault contact and is quite in line with this fault. If this assumption proves to be correct, it is probable that the fault zone continues farther to the northwest, across the gravel slopes at the west base of Golden Horn Peak, and a further extension of the copper deposits in that direction might naturally be looked for.

It is a singular fact that, while in the Horn Silver deposit lead and zinc have been the predominant metals, copper occurring as an important constituent only when it has been reconcentrated by secondary enrichment, in the Cactus mine copper and the omnipresent iron sulphides are practically the only metals present. It will be of interest to see whether a geological study of the region will succeed in establishing a genetic reason for this association of minerals and determining whether, as suggests itself at first glance, it is due to the differing character of the country rocks that inclose the respective deposits.

PUBLICATIONS ON COPPER.

Boutwell, J. M. Ore deposits of Bingham, Utah. In Bulletin U. S. Geol. Survey No. 213, pp. 105–122. 1903.

——— Economic geology of the Bingham mining district, Utah. Professional Paper U. S. Geol. Survey No. 38, 1905. Also Bulletin U. S. Geol. Survey No. 225.

Diller, J. S. Copper deposits of the Redding region, California. In Bulletin U. S. Geol. Survey No. 213, pp. 123–132. 1903.

——— Mining and mineral resources in the Redding district in 1903. In Bulletin U. S. Geol. Survey No. 225, pp. 169–179. 1904.

Douglas, J. The metallurgy of copper. In Mineral Resources U. S. 1882, pp. 257–280. 1883.

——— The cupola smelting of copper in Arizona. In Mineral Resources U. S. 1883–84, pp. 397–410. 1885.

Emmons, S. F. Geological distribution of the useful metals in the United States—Copper. Trans. Amer. Inst. Min. Eng., vol. 23, p. 73. 1893.

——— Economic geology of the Butte (copper) district, Montana. Folio No. 38, U. S. Geol. Survey. 1897.

Gignoux, J. E. The manufacture of bluestone at the Lyon mill, Dayton, Nevada. In Mineral Resources U. S. 1882, pp. 297–305. 1883.

Howe, H. M. Copper smelting. Bulletin U. S. Geol. Survey No. 26, 107 pp. 1885. (Out of print.)

Irving, R. D. The copper-bearing rocks of Lake Superior. Monograph V, U. S. Geol. Survey, 464 pp. 1883.

Lindgren, W. The copper deposits of the "Seven Devils," Idaho. In Mining and Scientific Press, vol. 78, p. 125. 1899.

——— Copper deposits of Clifton-Morenci, Arizona. Professional Paper U. S. Geol. Survey No. 43. 1905.

——— Copper deposits at Clifton, Arizona. In Bulletin U. S. Geol. Survey No. 213, pp. 133–140. 1903.

Peters, E. D. The roasting of copper ores and furnace products. In Mineral Resources U. S. 1882, pp. 280–297. 1883.

——— The mines and reduction works of Butte City, Montana. In Mineral Resources U. S. 1883–84, pp. 374–396. 1885.

Ransome, F. L. Copper deposits of Bisbee, Arizona. In Bulletin U. S. Geol. Survey No. 213, pp. 149–157. 1903.

——— The Globe copper district, Arizona. Professional Paper U. S. Geol. Survey No. 12. 1904.

——— Geology and ore deposits of the Bisbee quadrangle, Arizona. Professional Paper U. S. Geol. Survey No. 21. 1904.

——— Description of the Globe quadrangle [Arizona]. Folio 111, U. S. Geol. Survey. 1905.

——— Description of the Bisbee quadrangle [Arizona]. Folio 112, U. S. Geol. Survey. 1905.

SPENCER, A. C. Mineral resources of the Encampment copper region, Wyoming. In Bulletin U. S. Geol. Survey No. 213, pp. 158–162. 1903.

——— Reconnaissance examination of the copper deposits at Pearl, Colorado. In Bulletin U. S. Geol. Survey No. 213, pp. 163–169. 1903.

——— Copper deposits of the Encampment district, Wyoming. Professional Paper U. S. Geol. Survey No. 25. 1904.

VAUGHAN, T. W. The copper mines of Santa Clara Province, Cuba. In Eng. and Min. Jour., vol. 72, pp. 814–816. 1901.

WATSON, T. L. Notes on the Seminole copper deposits of Georgia. In Bulletin U. S. Geoi. Survey No. 225, pp. 182–186.

WEED, W. H. Types of copper deposits in the southern United States. In Trans. Am. Inst. Min. Eng., vol. 30, pp. 449–504. 1901.

——— Ore deposits at Butte, Montana. In Bulletin U. S. Geol. Survey No. 213, pp. 170–180. 1903.

——— Copper deposits of the Appalachian States. In Bulletin U. S. Geol. Survey No. 213, pp. 181–185. 1903.

——— Copper deposits in Georgia. In Bulletin U. S. Geol. Survey No. 225, pp. 180–181. 1904.

——— The Griggstown, N. J., copper deposit. In Bulletin U. S. Geol. Survey No. 225, pp. 187–189. 1904.

——— Notes on the copper mines of Vermont. In Bulletin U. S. Geol. Survey No. 225, pp. 190–199. 1904.

WEED, W. H., and PIRSSON, L. V. Geology of the Castle Mountain mining district, Montana. Bulletin U. S. Geol. Survey No. 139, 164 pp. 1896.

LEAD AND ZINC.

LEAD AND ZINC RESOURCES OF THE UNITED STATES.

By H. Foster Bain.

USES OF LEAD AND ZINC.

Lead and zinc are the most important of the base metals. In value of annual production, approximately $45,000,000, they rank below gold, silver, copper, and iron. They still exceed in output aluminum, tin, platinum, and several other metals which per unit are more valuable. This intermediate position is mainly a reflex of their intermediate value in the arts. Of low tenacity, they have small value in the form of wire or beams, and hence can not compete in the main uses of iron and steel. Of low electrical conductivity, they are shut out of competition with copper in its main field. Of considerable abundance, they have not that element of scarceness which contributes to the value of gold and silver. Despite these facts, the two metals have wide uses, dependent in the main upon their high malleability and their capacity to form compounds useful as pigments. Both metals enter largely into the sheet-metal trade, and lead is used in quantity for the manufacture of pipe. Both metals are, in most situations, relatively inert as regards chemical change, and, by virtue of this, lead is used for lining acid tanks of various kinds, while zinc is in high favor as a roofing material and for galvanizing. Among the less important uses for the metals is that of the manufacture of alloys, both readily forming such combinations with other metals. Zinc enters largely into the composition of the various brasses and friction metals, and lead is used in smelting to collect or alloy gold and silver. Indeed, it is as a by-product from the smelting of the precious metals that the bulk of the lead of commerce is derived.

Within expanding limits it is proving possible to substitute these metals, zinc in particular, for the more expensive tin and copper, and to a considerable extent because of this fact there is an active and growing demand for them which warrants a brief review of the resources available for this increasing output. In many cases the figures of production available are estimates only, but they are believed to show with a fair degree of accuracy the relative importance of the different countries or districts, and are quoted for that reason.

WORLD'S PRODUCTION OF LEAD.

In 1902, the last year for which complete statistics are available, the world's production of lead is estimated[a] at 926,895 metric tons. Of this amount, the United States produced approximately 26 per cent, Spain 19 per cent, Germany 15 per cent, and Mexico 11 per cent. Spain and Mexico afforded the principal surplus production, both Germany and the United States using somewhat more lead than they mined. Great Britain, France, and Russia were the main bidders for the surplus. The following table, quoted from Mineral Industry and Mineral Resources, is of interest in this connection:

Production, imports, exports, and consumption of lead in the chief countries of the world in 1902.

[In metric tons.]

	Austria-Hungary.[a]	Belgium.[a]	France.[a]	Germany.[a]	Italy.[a]	Russia.[a]	Spain.[a]	United Kingdom.[a]	United States.[b]
Production	13,543	19,500	18,817	140,331	26,494	250	177,560	27,100	342,160
Imports	8,706	53,000	72,730	39,006	7,563	23,000	Nil.	235,522	65,235
Total	22,249	72,500	91,547	179,337	34,057	23,250	177,560	262,622	407,395
Exports	53	50,000	6,454	23,100	5,650	Nil.	172,480	24,408	129,637
Consumption	22,196	22,500	85,093	156,237	28,407	23,250	5,080	238,214	277,758

[a] The Mineral Industry during 1903, p. 230.
[b] Mineral Resources of the United States, 1903, p. 257. (Stocks included with exports and imports, and production including that from foreign ores smelted in bond as well as that from domestic ores.)

WORLD'S PRODUCTION OF ZINC.

The production of zinc ore and of spelter for 1902 is estimated in Mineral Industry, as below. The distribution by individual countries is unusual, the Rhine district, for example, being ordinarily given without division, and the figures are doubtless somewhat inaccurate as to detail.

[a] The Mineral Industry during 1903, p. 230.

Production of zinc ore and spelter in principal countries in 1902.[a]

[In metric tons.]

Country.	Spelter.	Ore.
Germany	174,927	702,504
United States	143,552	[b] 500,000
Belgium	124,780	3,852
United Kingdom	40,244	25,462
France	36,282	57,982
Holland	20,760	
Russia	8,280	
Austria	7,960	31,927
Spain	5,569	127,618
Italy	485	149,965
Sweden		48,783
Algeria		33,139
Greece		18,020
Tunis		18,400

[a] The Mineral Industry during 1903, pp. 347–348.
[b] Personal estimate.

World's production of spelter, 571,705 metric tons.

It will be noted that the mining districts and the smelting centers are by no means identical. Belgium and Holland in particular have a smelting industry much larger than their local mining interests. In the United States the mining industry, the smelting industry, and the home consumption are in approximate equilibrium. In 1903, 35,188 short tons of ore and 1,521 short tons of spelter were exported. The total production of spelter for the year is given by Mr. Kirchhoff as below:

Production of spelter in the United States, 1903.[a]

	Short tons.
Kansas	88,388
Illinois	47,659
Missouri	9,994
Eastern and Southern States	12,301
Colorado	877
Total	159,219

In the above total are included 3,302 tons of dross spelter. The small amount of metal produced by the Indiana furnaces is included in that credited to Illinois.

The zinc-oxide production for the year is estimated at 62,962 tons. There is in addition a small amount imported, but the exports of

[a] Mineral Resources of the United States, 1903, p. 254.

plate, sheets, bars, and manufactured articles probably balance this. The zinc industry of the United States is practically independent of that abroad, neither exports nor imports forming more than a small fraction of production and consumption, though this country produces only a trifle less than 27 per cent of the world's supply of spelter.

LEAD RESOURCES OF THE UNITED STATES.

In 1903 the total lead production from domestic ores in the United States is estimated in Mineral Resources[a] at 280,000 short tons, having a total value of $23,520,000. In addition, 88,324 tons were obtained from foreign ores smelted within the country, but most of this was offset by exports.

Two grades of lead are recognized in this country. One is "soft lead," derived from non-argentiferous ores, found mainly in the Mississippi Valley; the other is the desilverized lead, coming principally from the Rocky Mountain States and the Great Basin. The production by States for 1903 is estimated by Mr. Kirchhoff as below.[b]

Lead content of ores by States, 1903.

	Short tons.
Idaho	99,590
Utah	51,129
Colorado	45,554
Montana	3,303
Nevada	2,237
Oregon, Alaska, South Dakota, Texas	1,765
Arizona	1,493
New Mexico	613
Washington	538
California	55
Missouri, Kansas, Wisconsin, Illinois, Iowa, Virginia, and Kentucky "soft lead"	86,597
Total lead content of ores smelted	292,874
Miscellaneous or unknown	2,831

Data regarding the past production of the United States are incomplete, but preliminary estimates based on the best obtainable statistics allow the following approximations to be made:

Estimated total lead production of the United States.

	Short tons.
Desilverized lead	4,300,000
Soft lead	1,700,000
Total	6,000,000

[a] Mineral Resources of the United States, 1903, p. 39.
[b] Idem, p. 243.

DESILVERIZED LEAD.

Idaho.—The most important single lead-producing State is Idaho, and in this State more than 96 per cent of the output is from the Coeur d'Alene district. The geology and ore deposits of this district are separately discussed in this bulletin by Mr. Ransome. The most important Idaho district aside from the Coeur d'Alene is that of Wood River. This district, located near Hailey, is estimated to have produced about 3,000 tons of lead in 1903. The ores occur in closely folded limestones, quartzites, and shales of Carboniferous age in connection with certain intrusive masses of granite. They are argentiferous, and have been discussed in some detail by Mr. Lindgren.[a]

Utah.—The second producer among the Western States is Utah. The only available distribution of the production, estimated by the Director of the Mint in round numbers at 55,500 short tons in 1902, is as below:

Production of lead, by leading counties, from Utah ores, 1902.[b]

	Short tons.
Summit	38, 624
Juab	10, 133
Beaver	2, 511
Tooele	1, 975
Salt Lake	1, 627

The production of Summit County comes from the Park City district, and that of Salt Lake County from the Bingham Canyon and Cottonwood districts. These are elsewhere discussed by Mr. Boutwell. The Juab County production is principally from the Tintic region, which has been described by Messrs. Tower and Smith.[c]

The Beaver County production is from the Frisco district, in which the famous Horn Silver mine is the most important producer. This property has been briefly described by Mr. Emmons.[d] The ore body occurs along a faulting fissure at the contact of an altered igneous rock and a dolomite of uncertain age, and near an intrusive mass of monzonite. The limestone, where in contact with the monzonite, has been subjected to contact metamorphism. The mine is essentially a lead mine, though zinc and copper occur in quantity and silver has always contributed largely to the value of the ore.

[a] Lindgren, Waldemar, Twentieth Ann. Rept. U. S. Geol. Survey, pt. 3, 1900, pp. 190–218.

[b] Tatem, B. H., Report of the Director of the Mint, 1903, pp. 200–206.

[c] Tower, G. W., and Smith, G. O., Geology and mining industry of the Tintic district, Utah: Nineteenth Ann. Rept. U. S. Geol. Survey, pt. 3, 1899, pp. 601–767.

[d] Emmons, S. F., The Delamar and Horn Silver mines: Trans. Am. Inst. Min. Eng., vol. 31, 1901, pp. 675–683.

The Tooele County production is mainly from the Mercur district, which has been described by Mr. Spurr.[a]

Colorado.—No very accurate recent statistics of the production by counties in this State are available. The estimates of Mr. E. L. White, commissioner of mines, for the year 1903 are given below:

Lead production in Colorado in 1903, by counties.

	Short tons.
Lake	18, 177
Pitkin	16, 635
Mineral	4, 300
San Juan	3, 485
Clear Creek	1, 726
Ouray	1, 675
Hinsdale	230
Others	4, 529
Total	50, 757

The Lake County production is from the Leadville mines, which have been described in detail by Mr. Emmons,[b] and the Pitkin County production from the Aspen mines, described by Mr. Spurr.[c] The San Juan output is from the Silverton mines, described by Mr. Ransome.[d] The Mineral County production is that of the Creede mines; that of Hinsdale County is from Lake City, and that of Ouray County is from mines near the town of the same name. The Lake City and Ouray mines have been studied by Mr. Irving and a preliminary statement of the results is given in this bulletin. The Clear Creek County mines are also described by Mr. Spurr, while the Summit County mines, among the most important of the minor producers, have been discussed by Mr. Emmons, in the Tenmile District Special folio.[e]

Minor western production.—Aside from Idaho, Utah, and Colorado, relatively little lead is produced in the Western States. While lead-bearing minerals are widely distributed, the deposits are not worked, and the fact that this condition has continued through many years of active development of the mining industry may be fairly interpreted as having basis in the original quantitative distribution of lead. California, so famous for the abundance and variety of mineral products, has never been an important producer of either lead or zinc. Montana, with its great wealth of copper and

[a] Spurr, J. E., Economic geology of the Mercur mining district, Utah: Sixteenth Ann. Rept. U. S. Geol. Survey, pt. 2, 1895, pp. 343–456.

[b] Emmons, S. F., Geology and mining industry of Leadville: Mon. U. S. Geol. Survey, vol. 12, 1886, 870 pp.

[c] Geology of the Aspen mining district, Colorado, with atlas: Mon. U. S. Geol. Survey, vol. 31, 1898, 260 pp.

[d] Report on the economic geology of the Silverton quadrangle: Bull. U. S. Geol. Survey No. 182, 1901, 265 pp.

[e] Geologic Atlas U. S., folio 81, U. S. Geol. Survey, 1898.

gold, produces relatively little lead and zinc, though efforts are now being made to develop the latter.

Without entering upon an extended review of the situation, it becomes evident that so far as the West is concerned lead production is confined almost entirely to the States of the Rocky Mountains and the Great Basin. A fuller study would show that the big lead-producing camps are all located in districts where both igneous and sedimentary rocks are involved. At Leadville, Aspen, and Park City the sedimentary rocks are largely dolomites and limestones; at Coeur d'Alene they are shales and quartzites. The igneous rocks include various eruptives, commonly grouped under the term "porphyry." The association of the ore with igneous rocks is apparently more extensive than with sedimentary—witness the deposits of Clear Creek and San Juan counties, Colo.—but it remains true that the large and important bodies are found where both classes of rocks are present. It has already been pointed out that the western lead ores are almost without exception argentiferous, and it may be further stated that they are usually intimately associated with a wide variety of sulphides of still other metals.

SOFT-LEAD DEPOSITS.

Appalachian.—Along the eastern front of the Appalachians, extending from Maine to Alabama, and also at certain localities in western New York, there are scattered deposits which were somewhat actively exploited up to the middle of the last century. The best general description of these was given by Whitney,[a] who wrote at a time when the work was in the main still open to inspection. Very little attempt is now being made to work these deposits. A few are being developed, more on account of the accompanying zinc than the lead, and these will be later considered.

Wisconsin, Illinois, and Kentucky.—Practically all the soft lead now produced comes from the Mississippi Valley, and nearly all from Missouri. The older mines of Wisconsin, Iowa, and northern Illinois are worked mainly for zinc. The mines of southern Illinois and western Kentucky yield fluorspar, with lead and zinc as by-products, and the small deposits of central Kentucky are worked for lead and barite.

In the summer of 1904 an attempt was being made to work some of the lead deposits near Georgetown, Ky. The Mutual Mining Company had opened a small vein near Duval and another near Kissinger. The Lexington limestone, which is rough textured, blue, and nonmagnesian, forms the country rock. The veins seen were 1 to 2 feet wide, with sharply defined walls, and had courses respectively

[a] Whitney, J. D., Metallic Wealth of the United States, 1854, 510 pp.

S. 13° E. and S. 11° E. There is faulting of some magnitude in the region, but none determinable at the mines, though the walls show slickensided surfaces. The vein material is essentially barite. In the latter are disseminated crystals of galena and blende. In druses are small crystals of calcite, and coating the barite is often a crust of strontianite. In the same region, but south and east of Lexington, fluorspar is found in similar veins. None was noted at the Georgetown localities. Very little mining has been carried on here, and the opportunity would seem to be rather for the development of a barite than a lead industry. Such galena as was found was being separated by fine crushing and table concentration. A small furnace is in intermittent operation.

Missouri.—The Missouri lead deposits are found in the southern half of the State, in the Ozark region. Small deposits are scattered over nearly all of the area, but the main production comes from two districts, known as the southwestern and the southeastern. The mines of the southwestern district are mainly in Jasper and Newton counties, where, in connection with the mining of zinc, a large tonnage of lead is annually produced. In the southeast, St. Francois, Madison, and Washington counties are the principal producers. The total production of ore from Missouri in 1903 is estimated in Mineral Industry [a] at 128,800 short tons, and the production of the individual counties as below:

Production of lead ore in Missouri in 1903.

	Short tons.
St. Francois	92,351
Jasper	20,974
Madison	7,083
Washington	2,387
Scattered	6,005
Total	128,800

In general, it may be stated that of the Missouri lead output approximately four-fifths comes from the southeast and one-fifth from the southwest. Since, however, a considerable quantity of the ore of the southwest is marketed as a sublimed lead the proportions of pig lead produced would be somewhat different.

The lead deposits of southwestern Missouri will be considered in connection with zinc. Those of southeastern Missouri may be conveniently divided into two groups—the deposits of St. Francois and Madison counties, and those of Washington and Franklin counties. The former were described a few years since by Mr. Winslow.[b] The

[a] The Mineral Industry during 1903, p. 225.

[b] Winslow, Arthur, The disseminated lead ores of southeastern Missouri: Bull. U. S. Geol. Survey No. 132, 1896, 31 pp.

entire district is now being reinvestigated by Dr. E. R. Buckley, State geologist.

In St. Francois and Madison counties there are two great dolomite formations, to which Mr. Winslow gave the names St. Joseph and Potosi, in St. Francois County, and which Mr. Keys[a] called the Fredericktown dolomite and Lesueur limestone, in Madison County. The lower, now called the Bonne Terre,[b] lies on the La Motte sandstone, which is of irregular thickness and constitutes the basal member of the sedimentary sequence. Along the western border of the productive territory the granite and porphyry hills of the pre-Cambrian rise through and above the sedimentary beds. To the east of the mining district these older rocks rise again, so that the sediments seem to have been laid down in a great pre-Cambrian erosion trough.

The Bonne Terre limestone, which is the lead-bearing member of the sequence, is a noncherty dolomite, approximately 400 feet thick where uneroded. At the base the dolomite is frequently interbedded with the sandstone of the La Motte formation, and for as much as a hundred feet above the base dark, shaly material is common in the formation. Chlorite, from the decomposition of the pre-Cambrian crystallines, and probably also glauconite, are abundant in this portion of the formation. The upper member of the formation is also shaly, and with the shale are thin beds of conglomerate which Nason[c] has called the "Edgewise beds," which should be taken as the base of a formation intervening between the Bonne Terre and the true Potosi. In this formation are some 70 feet of noncherty dolomite, above which in turn are the characteristic cherty dolomites of the Potosi.

The ore bodies are found for the greater part in the lower shaly portion of the Bonne Terre, but also to a less extent in the upper shaly beds; in the Bonne Terre mines the ore continues from the one member to the other. The ore bodies are famous for their great size—measured in hundreds of feet in horizontal dimensions and up to a hundred in vertical—and for the almost entire freedom of the galena from mixture with other metallic minerals. In particular there is an entire absence of zinc, though elsewhere in the Mississippi Valley the association of galena and blende is always intimate. Small quantities of copper, nickel, and cobalt occur, and on the Mine La Motte estate these are sufficient in amount to warrant separate treatment.

It is possible to suggest reasons for the stratigraphic localization of these great ore bodies, but so far no entirely satisfactory hypothesis has been advanced to explain their irregular distribution in a hori-

[a] Keyes, C. R., Geology of the Mine La Motte sheet, 1895, pp. 48–53.
[b] For full discussion of the stratigraphy, see Bull. U. S. Geol. Survey No. 267, in press.
[c] Am. Jour. Sci., 4th ser., vol. 12, 1901, p. 359.

zontal plane. For the present prospecting is carried on only with the drill, and in the inception of each enterprise the prospecting is essentially blind. There are at present seven companies in St. Francois County and three in Madison County which are outputting. A number of others have not yet reached the producing stage. There is a very large area of unprospected territory of possible value, but in the present condition of knowledge the heavy charge incident to the preliminary drilling of this ground prevents the rapid opening of more mines.

In Washington and Franklin counties, north and west of the disseminated lead district, galena occurs in intimate association with blende and barite in the Potosi formation. The ore occurs in crevices and flats in many particulars similar to those of Wisconsin. The individual ore bodies are not large, and the workings are shallow. In the aggregate, however, the area has yielded a considerable amount of lead, and a small output is steadily maintained. Somewhat similar ore bodies extend well into central Missouri, and those of Miller County have recently been described by Messrs. Ball and Smith.[a] Economically they are, for the present, at least, unimportant. It is interesting to note that the contrast of these deposits with those of St. Francois and Madison counties in character and form of ore body and in the mineralogical association of the galena is coincident with a change in the formation which constitutes the country rock.

In Missouri, as in the other States producing soft lead, the ore bodies show no association with igneous rocks or even with marked disturbance of the strata. In general they are instead associated with relatively undisturbed sedimentary rocks. In most cases the country rock is dolomite or magnesian limestone.

FUTURE PRODUCTION OF LEAD.

The consumption of lead, both in this country and abroad, has been steadily increasing for some years. It is to be expected that it will continue to do so. In the United States the price has not shown any very direct relation to the increase, as is seen from the table following:

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[a] Ball, Sidney H., and Smith, A. F., Geology of Miller County, Missouri: Bureau Geol. and Mines, Bull. vol. 1, 2d ser., 1903, 207 pp.

Production of lead in the United States, 1896–1904, with average yearly price of lead and silver.

Year.	Lead.		Silver, average price per ounce in New York.
	Quantity.	Average price per pound in New York.	
	Short tons.	*Cents.*	*Cents.*
1896	[a] 188,000	[b] 2.98	[c] 67.5
1897	[a] 212,000	[b] 3.58	[c] 60.4
1898	[a] 222,000	[b] 3.78	[c] 59
1899	[a] 210,000	[b] 4.47	[c] 60.1
1900	[a] 270,824	[b] 4.37	[c] 62
1901	[a] 270,700	[b] 4.33	[c] 59.5
1902	[a] 270,000	[b] 4.069	[c] 52.7
1903	[a] 280,000	[b] 4.237	[d] 53.5
1904	[d] 313,553	[d] 4.309	[d] 57.2

[a] Mineral Resources of the United States, 1903, p. 242.
[b] The Mineral Industry, 1896–1903.
[c] Report Director of the Mint, 1903, p. 312.
[d] Engineering and Mining Journal, January 5, 1905.

Since the minimum of 1896 there has been a total but not uniform increase in price for lead and a slightly variable but general increase in production. In the meantime the price of silver, the production of which is so intimately connected with that of most of the American lead output, has fallen. For the period as a whole the relations of production to price have been general rather than specific, as might be expected in view of the time and expense necessary to open up any considerable additional producing territory. For the last three years there has, however, been a much more direct relation of lead production both to the price of lead and to that of silver. The industry as a whole is now so closely controlled that production follows price in normal sequence. The quick response indicated by the figures for the last two years can only be interpreted to mean a considerable reserve of ore already developed and ready for mining. The American mines are abundantly able to care for the American consumption. That a considerable amount of foreign-mined lead is marketed in this country therefore means lower mining costs at some of the competing foreign mines. The lead-smelting capacity of this country is beyond its present needs, and the building of new furnaces is an expression of the attempt to realize the profits of better localities or of new industrial combinations.

ZINC RESOURCES OF THE UNITED STATES.

As already noted, the smelting and mining centers of the zinc industry are not always coincident. In the United States, furthermore, the ore from the separate districts varies greatly in grade and in price, so that the statistics of production of the metal afford but imperfect knowledge of the importance of individual mining districts. In terms of tonnage of ore the leading zinc-producing districts of the United States are the Joplin, the New Jersey, and the Colorado. The Joplin ores afford the main supply of the Kansas, Missouri, and Illinois smelters, though of recent years important amounts of ore from Colorado and smaller quantities from British Columbia have gone to Kansas for smelting. The New Jersey ore is largely burned to oxide, though some is exported crude and some is used in making spelter. The importance of the New Jersey ore production is not generally recognized. The Colorado spelter and oxide production is small as compared with its output of ore, which has been very rapidly increasing of recent years. At present it is impracticable to give complete statistics of zinc-ore production in the United States.

In the table below are estimates of the ore production of the leading districts, with the approximate content of metallic zinc. The figures are for the year 1904. In them no allowance is made for smelting losses or for the ore which is burned to oxide, the purpose being to show the ore production and the relative importance of the different districts.

Estimated zinc-ore production and metallic zinc content of ores for leading districts.

[In short tons.]

District or State.	Zinc ore.	Zinc content.
Joplin	263,243	150,048
New Jersey	250,000	58,750
Colorado	197,000	49,250
Wisconsin	19,300	10,500
New Mexico	21,000	8,400

The total production of spelter to the close of 1904 may be estimated at 2,225,000 short tons. In addition a considerable amount of ore has been burned to oxide by the direct process. Since 1880 this has amounted to 616,000 short tons, equivalent to approximately 533,000 tons of metal. Since 1897 a little more than 200,000 tons of zinc ore have been exported. This has mainly been of middle or low grade, and it will probably not be far wrong to assume a total content of 100,000 tons of metal in this export ore. On this basis the minimum figures for the total production of the United States would be as below.

Estimated total production of zinc in the United States.

	Short tons.
Spelter	2, 225, 000
Zinc content of oxide made since 1880	533, 000
Zinc content of ore exports since 1897	100, 000
Total	2, 858, 000

ORES OF THE MISSISSIPPI VALLEY.

JOPLIN DISTRICT.

The geology and the ore deposits of this district have been discussed in a preliminary way in several survey publications noted in the accompanying bibliography. The Joplin district includes an ill-defined area of approximately 1,200 square miles, lying mainly in southwestern Missouri, but extending also into Kansas and Indian Territory. It is now the leading producer of zinc ores, being credited in 1903 with a total of 227,689 short tons and an estimated production for 1904 of 267,738 short tons.[a] The ores are characterized by high grade, the ordinary sale basis being a content of 60 per cent metallic zinc. Probably an average for the recent production of the camp would be 58 per cent metallic zinc. They contain as marketed small amounts of lead and cadmium.

Mr. George Waring quotes the following analysis as the average of 2,145 recent shipments:[b]

Average analysis of Joplin ore.

	Per cent.
Zn	57. 75
Fe	2. 32
Pb	1. 07
Cu	. 042
Cd	. 388

The bulk of the ore is used for the production of spelter, and up to recent years the combined spelter production of Missouri, Kansas, and Illinois practically represented the production of blende in the Joplin district. The Kansas furnaces are now, however, drawing a considerable portion of their supplies from the West, while the furnaces of northern Illinois purchase enough ore in Wisconsin to upset the old balance of trade. The carbonate and silicate ores of the Joplin district have in part been used by local furnaces in the pro-

[a] Lead and Zinc News, January 9, 1905, p. 57.

[b] Waring, Geo. W., Jour. Am. Chem. Soc., vol. 26, 1904, p. 16.

duction of spelter and in part have gone into the manufacture of oxide. In amount they are relatively unimportant.

The Joplin ores occur in the limestones and cherts of the Boone formation, which is of Carboniferous age. They are closely associated with certain fault lines, and constitute very irregular and much modified fissure deposits. They consist for the most part of limestone and chert breccias, partly recemented by a dark-colored secondary chert and by dolomite. In the unaltered and secondarily enriched ores the ore minerals are blende and galena. With these are associated minor amounts of marcasite, pyrite, chalcopyrite, and greenockite. In the altered ores there are the silicate and carbonate of zinc, the carbonate of lead, and various carbonates, sulphates, oxides, etc., of the associated minerals. The bulk of the ore consists of limestone, chert, dolomite, blende, and galena.

The ore bodies are characterized by extreme irregularity. While the individual ore bodies are generally arranged along a more or less direct line, constituting a "run," as defined by W. P. Jenney,[a] there are many minor and puzzling irregularities. Perhaps the best illustration would be to liken the single ore body in form to a large, irregular, and very knotty potato. The ore bodies are frequently 80 to 100 feet wide and 40 to 60 feet thick, but the irregularities are so common and numerous that in mining they can be followed only with great difficulty.

A second form of ore body which is becoming increasingly important in the district is that which the miner knows as "sheet ground." In this there has been a somewhat irregular mineralization of an individual bed, forming a blanket vein. Such an ore body is frequently found on or in the top of the big flint bed known as the Grand Falls chert. In single mines as much as 15 acres, showing a face of ore 10 to 15 feet high, have been mined. These ore bodies are normally of lower grade than the runs and are more thoroughly cemented, so that they have been less mined. They constitute, however, a very important reserve.

The ores so far worked are all found near the surface, no mining having as yet been undertaken at depths greater than 250 feet, and most of the ore having been found within 150 feet of the surface. Recent development work has emphasized the importance of carrying all drill holes down at least to the Grand Falls chert. At Aurora, an important camp east of the main Joplin district, new runs have been found below the ores formerly worked and trending apparently at right angles to them. Considerable development has also been taking place along the eastern outcropping edge of the Cherokee, the overlying shale, and the conditions here seem to be not unlike those along the southern border of the Mesabi iron range, where the ponded

[a] Jenney, W. P., Trans. Am. Inst. Min. Eng., vol. 22, 1894, p. 189.

waters caught under the overlying shale make a return circuit to the surface and produce ore bodies along its edge. In the Joplin district the mines recently developed at Baxter Springs may be cited as an example.

MINOR DISTRICTS.

Outside of the Joplin district zinc is produced at a number of points in the Mississippi Valley. The lead-zinc districts of central and southeastern Missouri have already been mentioned. In northern Arkansas, principally in the Yellville district, zinc is widely distributed and some mining is being carried on. The general geology of the district has been described by Mr. Adams.[a] In 1903 not quite 1,500 tons of ore were shipped from this district; in 1904 nearly 2,000 tons were shipped. From the fluorspar district of western Kentucky, described by Messrs. Ulrich and Tangier Smith,[b] a small amount of zinc ore is shipped. Until recently carbonate formed the only output, but now from 1,000 to 2,500 tons of blende are annually marketed. The ore goes mainly to the oxide furnaces. At present several properties are being prospected, but only one or two ship with any regularity.

In the upper Mississippi district the Wisconsin mines especially are being vigorously developed. These are described in this bulletin by Messrs. Grant and Ellis. The total production of the district in 1904 amounted to approximately 19,300 tons, of which nearly all was blende. The mines of northwestern Illinois have recently been separately discussed.[c] In Iowa at present very little work is being carried on. Perhaps the most ambitious attempt is that at the Fitzpatrick mine, near Buena Vista. Here a small plant has been erected, and sinking on one of the old lead ranges is under way. No important shipments have yet been made.

ORES OF THE EASTERN AND SOUTHERN STATES.

In 1903 the States east of the Mississippi Valley are credited with a production of 12,301 tons of spelter. They should also be credited with the largest part of the oxide production of the year and with 23,722 tons of ore exported from the port of New York. Practically none of the old zinc-lead mines of the northern Appalachians are now open, though in 1903 an attempt was made to reopen the mines at Ellenville, N. Y.[d]

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[a] Adams, G. I., Purdue, A. H., and Burchard, E. F., Zinc and lead deposits of northern Arkansas: Prof. Paper U. S. Geol. Survey No. 24, 1904, 118 pages.

[b] Prof. Paper U. S. Geol. Survey No. 36 (in press).

[c] Bain, H. Foster, Zinc and lead deposits of northwestern Illinois: Bull. U. S. Geol. Survey No. 246, 1904, 51 pp.

[d] Ihlseng, A. O., The zinc mines at Ellenville, N. Y.: Eng. and Min. Jour., April 25, 1903.

New Jersey.—The principal producer of the Eastern States is the New Jersey Zinc Company, operating mines at Franklin Furnace, N. J., and reduction works near Bethlehem and Palmerton, Pa. The oxide furnaces and smelters at Newark were dismantled in 1904, the policy of the company being to eventually concentrate operations at Palmerton. The New Jersey Zinc Company also owns the mines at Sterling Hill, near Ogdensburg, N. J., which are not worked at present.

The two deposits mentioned above are notable for (*a*) the great size of the ore bodies, (*b*) the unique character of the ores, since the three principal zinc-bearing minerals are elsewhere practically unknown as ores, and (*c*) the difficulties which have been overcome in dressing and reducing the ores.

(*a*) The only available data on the size of the ore body at Franklin Furnace are those given by Mr. Nason (1894), who estimates it as equivalent to a prism 3,500 feet long, 800 feet wide, and 25 feet thick, containing 70,000,000 cubic feet. In the ten years intervening since this estimate was made development work has been continuous, so that these figures are in all probability below the truth.

(*b*) Though varying greatly in different parts of the mine, a current estimate of the average mineralogical composition of the ore at Franklin Furnace is as follows:

Average mineralogical composition of Franklin Furnace ore.

	Per cent.
Franklinite	51.92
Willemite	31.58
Calcite	12.67
Zincite	.52
Other silicates	3.31
Total	100.00

These figures are calculated from the following analysis:

Average chemical composition of Franklin Furnace ore.

	Per cent.
Iron sesquioxide	32.06
Manganese protoxide	11.06
Zinc oxide	29.35
Carbonate of lime	12.67
Silicate and insoluble matter	14.57
Total	99.71

(*c*) Prior to 1840 unsuccessful attempts had been made to use the zinc and manganese bearing ores of New Jersey for iron manufacture. In that year portions of the deposit containing much zincite were first worked for zinc alone, this material being manufactured into zinc oxide by the direct process developed by S. P. Wetherill. The ores continued to be used mainly for oxide up to the development of the process of magnetic concentration. As early as 1891 or 1892 experiments with the then existing forms of magnetic concentrators showed the possibilities of this form of ore dressing, producing ore of sufficiently high grade for spelter making. By 1896 J. P. Wetherill had developed a satisfactory form of concentrator, which was patented and installed in that year at the Franklin mines. Since then the apparatus has been improved, and an entirely new concentrating plant, completed in 1901, has a capacity of 1,000 tons of ore in twenty-four hours. In 1901 the total cost of treatment was estimated at 40 cents per ton.

The output for 1904, as stated by James B. Tonking, superintendent, was 250,000 tons. Practically everything mined is used in one way or another. The products of the mill are as follows:

(*a*) Willemite (30 to 34 per cent of total), containing also calcite, some zincite, and small amounts of other impurities. This product assays approximately 48 per cent zinc and is suitable for high-grade spelter free from lead and cadmium.

(*b*) Franklinite product (with *c* and *d* forms about 55 per cent of total), consisting of magnetite and franklinite, with other zinc minerals occurring as attached particles. This product is used for the manufacture of zinc oxide and the cinder is smelted for spiegeleisen.

(*c*) Half-and-half, containing franklinite, rhodonite, garnet, and other silicates, with attached particles of the richer zinc minerals. This product contains somewhat more zinc than *b*, but is too high in silica for the spiegel furnaces. It is used entirely for the manufacture of zinc oxide.

(*d*) The dust from the crushing and concentrating plant (about 4 per cent of the total) is collected and shipped with the other material for the manufacture of oxide.

(*e*) The tailings from the nonmagnetic portion of the ore (about 10 per cent of the total) still contain some zinc, but not enough to pay for treatment. This material is shipped for use in concrete construction.

The ore bodies occur in pre-Cambrian, coarsely crystalline, white limestone. They have no sharply defined walls as a rule, though the passage from the ore into clean limestone never occupies more than a few feet. The ore material has a structure resembling that of gneiss because of the banded arrangement of the different minerals, and this structure is cut across by dikes of granite, which are therefore evidently later than the formation of the ore. It is along these granite dikes that the majority of rare and interesting minerals from this locality occur.

The origin of the ores has never been satisfactorily explained, but studies now in progress are expected to throw new light upon this interesting problem in ore genesis.

The mines at Franklin furnace are worked in part by open pits, but the underground workings are also very extensive. The annual statements to the State geologist of New Jersey, authorized by the company, indicate that since 1896 only development work has been in progress underground, such ore as has been extracted having come from drifts and raises in the ore body. It is apparent, therefore, that the present reserves must be very large.

The suggestion has been made that the form of the Franklin ore body and its blunt underground termination indicate that its eastern side has been faulted off, but this theory has never been adequately tested by drilling.

At Sterling Hill the average grade of the ore is said to be lower than at Franklin furnace, but from surface exposures alone it is evident that large amounts of ore remain to be mined, though the extent of the deposit in depth has never been determined. The old mines are known, however, to have been 300 or 400 feet deep.

Exploration with diamond drills has been carried on by various parties in the neighborhood of Franklin furnace, but thus far no indication of valuable zinc ores has been reported.

Virginia and Tennessee.—Zinc is found in two districts in Virginia, one in Albemarle County and the other in the southwestern part of the State, adjacent to Tennessee. In the latter district zinc and lead are found at a number of points in a belt extending from Roanoke nearly to Knoxville. While few of the mines are steadily worked, there has been continuous production from the district as a whole for many years. Nearly all the ore is locally reduced. The Bertha works, at Pulaski, is the only spelter plant now in operation; though zinc oxide is burned and lead smelted at Austinville, Va., by the same company. Some ore has been shipped to the Indiana furnaces for reduction, but this movement is not important.

Between 1891 and 1897, the only years for which figures are available, the spelter production of this district averaged about 3,500 tons per year. In 1893 the district as a whole is estimated to have produced 21,000 tons of ore. In 1900 the Tennessee mines alone are estimated to have produced 3,968 tons.[a] At present the production is very small. The grade of concentrates is not high[b]—40 to 50 per cent zinc—but as the ore is of unusual purity and the furnace work very good there is produced a metal which commands a premium in the market.

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[a] The Mineral Industry for 1900, p. 665.

[b] Ingalls, W. R., Production and Properties of Zinc, 1902, pp. 197–203.

In Virginia the important producing mines of recent years have been the Bertha, situated about 30 miles southwest of Pulaski; the Wythe, at Austinville, and the Clark, at Allisonia. Of these the Wythe only is now producing zinc. The Bertha is being worked for iron. In Tennessee the mines are near Knoxville, McMillan, Mascott, Newmarket, Jefferson City, and New Tazewell. They have been described by Mr. Keith.[a]

The Virginia deposits have never been described in detail, though Boyd,[b] McCreath,[c] Kemp,[d] and Ingalls[e] have each published general notes upon the district and many briefer references are to be found. These are mainly cited by Kemp. A report upon the district is now being prepared by State Geologist Watson, who has kindly furnished in advance the following notes:

The ores occur in the Shenandoah Valley in a magnesian limestone of Cambro-Ordovician age. In Virginia from Roanoke to Scott County this formation contains scattered bodies of lead and zinc. The ores first worked were residual concentrations made up of calamine, with minor amounts of cerussite and smithsonite. At the Bertha mine they are covered by a heavy mantle of residual clay, which is now washed for the sake of the limonite which it contains. Blende is found in irregular deposits in the underlying limestones and here, as elsewhere, is presumed to represent the original mode of occurrence. The Wythe deposit is the most important of those yet developed in the sulphide zone.

In Tennessee the ore occurs in the Knox dolomite, which represents a portion of the Shenandoah, particularly near the base and at the contact with the underlying Conasauga shale.[f] It is associated with fault planes and, as in Virginia, the lean sulphides seem to have been reconcentrated in the form of carbonates and silicates.

The district as a whole has not been actively prospected, though considerable ore has been shipped and prospecting is now going on at several points. In considering its relations to possible future production its favorable situation as regards high-grade fuel, low labor cost, and ease of transportation of product to the seaboard must not be lost sight of.

The Albemarle County, Va., occurrence of lead and zinc now being exploited is particularly interesting. The deposit occurs in mica-schist of probably pre-Cambrian age and near a diorite dike of presumably more recent age. During the civil war it was worked for

[a] Keith, Arthur, Recent zinc mining in East Tennessee: Bull. U. S. Geol. Survey No. 225, pp. 208–213.

[b] Boyd, C. R., Resources of Southwest Virginia, 1881, 321 pp.

[c] McCreath, A. S., Mineral Wealth of Virginia, 1884, pp. 101–103.

[d] Kemp, J. F., Ore Deposits of the United States and Canada, 1903, pp. 247–249.

[e] Ingalls, W. R., Production and Properties of Zinc, 1902, pp. 197–203.

[f] See Morristown, Maynardsville, and Cleveland folios, U. S. Geol. Survey.

lead, which occurred as galena with a quartz gangue. More recently blende associated with fluorspar is found to come in below the galena and has been proved to a depth of about 200 feet. At present a dry concentration plant is being erected, with the expectation of being able to treat the ores.

ZINC RESOURCES OF THE ROCKY MOUNTAIN STATES.

The zinc resources of the Western States are as yet largely undeveloped. Only in the last few years has any considerable attention been devoted to them, and in 1903 for the first time spelter was locally manufactured. Prior to that ore had been shipped both abroad and to the Kansas smelters and a limited quantity had been burned to oxide at Canyon, Colo. The building of a smelting plant at Pueblo and the enlargement of the oxide plant at Canyon has greatly stimulated the Colorado production and had some influence upon that of Utah. At the same time the close affiliation of the Ozark Oxide Company with the carbonate mining companies operating in the Magdalena Mountains has resulted in an increased production from that territory. Plans are said to be under way for the utilization of the zinc found in the Alice mine at Butte, Mont., and at various other points in the West the attempt is being made to mine zinc ores.

Colorado.—The following estimates of the Colorado production for 1904 are quoted by the Lead and Zinc News:

Colorado zinc-ore production in 1904, by counties.

	Short tons.
Lake	165,000
Summit	11,000
Mineral	9,700
Clear Creek	7,000
San Juan	3,000
Dolores	1,000
Hinsdale	125
Gunnison	100
Saguache	50
Chaffee	25
Total	197,000

These figures are approximations only, but represent the best available information. The ore is of lower grade than that mined at Joplin. It would probably be safe to assume an average content of 25 per cent metallic zinc.

The zinc-producing localities in Colorado are in the main the same as those yielding lead, and have already been discussed. Pitkin County, which is second in lead production, ships no zinc. The zinc output of the Rico mines brings Dolores into the column of producers. The geology of the district has been described by Messrs. Cross and Spencer[a] and the mines by Mr. Ransome.[b]

No comprehensive study of the Colorado zinc resources has yet been made. Up to the last few years zinc has been a source of loss to the smelters and penalty to the miners, and ores high in zinc have either remained unmined or been thrown into the dump. It is therefore difficult to get a clear idea as to just how valuable they may be. The complex nature of the ores makes their treatment very difficult, but the zinc industry seems now to be making very rapid progress.

New Mexico.—In the southwestern part of this Territory, near Hanover, are some deposits of blende and smithsonite, which have been described by Blake.[c] These have yielded a considerable tonnage of zinc carbonate from surface workings. The blende, because of its intimate mixture with garnet and other heavy gangue minerals, has not proved of much value. The ore occurs in bodies of considerable size in limestones of presumably Carboniferous age and apparently in close association with igneous rocks. The carbonate mined went principally to Mineral Point, Wis., for treatment, and up to 1893 the shipments were important. At present the output of the district is approximately 1,000 tons per annum.

More recently zinc has been shipped in quantity from the Magdalena district near Socorro. The ore occurs here in the Graphic and Kelley mines, which have in the past produced important amounts of lead and silver. The occurrence is described by Mr. Keyes.[d] The zinc occurs in a great plate of Carboniferous limestone preserved on the back of a block of ancient schists thrown up by faulting. Associated with the ore bodies are intrusive and eruptive rocks of comparatively recent age. The ore occurs at four horizons:

(*a*) The "contact vein," which lies at the base of the limestone and between the latter and the schists and greenstones.

(*b*) The "Silver Pipe vein," 60 feet above the contact and developed along a bed of very pure white limestone under a cover of more siliceous rock.

(*c*) The "outer or west vein," 30 feet above the Silver Pipe vein and also in the limestone.

(*d*) The "surface vein."

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[a] Cross, Whitman, and Spencer, A. C., Geology of the Rico Mountains, Colorado: Twenty-first Ann. Rept. U. S. Geol. Survey, pt. 2, 1900, pp. 15–165.

[b] Ransome, F. L., The ore deposits of the Rico Mountains, Colorado: Twenty-second Ann. Rept. U. S. Geol. Survey, pt. 2, 1902, pp. 229–398.

[c] Blake, W. P., Zinc ore deposits of southwestern New Mexico: Trans. Am. Inst. Min. Eng., vol. 24, 1894, pp. 187–195.

[d] Keyes, C. R., Zinc carbonate ores of the Magdalena Mountains: Mining Magazine (in press).

Of these the Silver Pipe is the most important, while the outer or west vein ranks next. The ore bodies are lenticular but very irregular. They are rather large—individual stopes 25 feet wide, 100 feet high, and 300 to 800 feet long, being now open. The ore bodies represent metasomatic replacements of the limestone. The main ore shipped is carbonate of zinc carrying minor silver and copper values. It goes to the oxide works at Joplin, Mo., and Mineral Point, Wis. Mr. Keyes estimates the output for 1904 at about 20,000 tons.

Minor western production.—The large majority of the ore bodies of the West which have yielded lead and zinc contain zinc in important amounts. Coeur d'Alene affords a striking exception, and Leadville an equally noteworthy example. Apparently zinc has not been produced in quantity outside of Colorado and New Mexico, mainly because there has not been sufficient demand for it. In many of the mines of Utah, in particular, estimates of the amount of zinc available for production are now being made, and it is to be expected that this State will soon be making regular shipments. In Idaho, Montana, and other Western States much the same situation exists, and for the present there is no production to record. In the last two years the mines of British Columbia have shipped zinc concentrates to the Kansas smelters. Since, however, a smelter is soon to be built near the mines, these imports are not likely to continue. The close similarity of the ores of this district to those found at Wood River, Idaho, and various other western camps makes it altogether probable that the latter, by adopting the methods already applied in Canada, may become important producers of zinc ore.

FUTURE ZINC PRODUCTION.

Any growth of the zinc industry in this country is dependent upon future increased domestic use of zinc and upon the possibility of acquiring a part of the foreign trade. As to the first, it may be confidently affirmed that the local demand for spelter and oxide will in the future not only increase with our growth in population, but in a ratio in excess of that growth. Our per capita consumption of zinc is less than that of Europe, and we use more expensive tin and copper for many purposes for which in other countries the cheaper metal is substituted. It seems certain that in the future, unless there should be an unexpected decrease in the price of copper and tin, zinc will gain in use relatively to them, and a continued discovery of new uses is also to be anticipated.

The foreign markets offer a seemingly tempting field. The most important zinc-smelting centers of Europe import the bulk of their ore, and in recent years there have been many attempts to enter this market with American concentrates. Experience so far would seem to indicate that shipments of spelter rather than ore are more likely to be the final outcome. The foreign smelters have no advantage over the American, which are not essentially temporary and which may not be overcome, while the ore producers of America have in turn no advantages over those abroad. Under these circumstances the normal law that products will be shipped in the most concentrated form seems likely to prevail. For the present it is by no means certain but that Australia rather than America affords the largest amount of zinc ore immediately available for European furnaces.

To meet the future demands of the zinc industry in America ample ore reserves are known, no important district as yet showing any real signs of exhaustion. The ore yet to be mined, however, is of distinctly lower grade than that marketed in the past, and attempts to meet this condition are already being made by improvements in smelting and milling practice.

Probably the most important American advance in smelting practice is the development of the direct method of oxide manufacture. This process meets the situation admirably, except for the limitations imposed by the small market for oxide and the fact that the main increased demand is likely to be for spelter. Oxide burning may, however, be used as a preliminary process, becoming essentially a method of fire concentration, the oxide itself being reduced to spelter in the ordinary way. At Pulaski, Va., this combination of processes is now in successful operation. Attempts to smelt low-grade ores direct have been confined mainly to the Lanyon's work with Sadtler retorts, though this line of investigation is probably considered most hopeful. In the main the smelters have contented themselves with arranging to save by-products and with improvements directed toward greater furnace economy. They have thrown on the miners the main burden by requiring a high cleaning of the ore. Out of this condition have come many improvements in milling processes, particularly the magnetic and electrostatic separating machines, but in any large advance of the industry the smelters as well as the miners must be prepared to take a large part.

ORE DEPOSITS OF THE COEUR D'ALENE DISTRICT, IDAHO.

By Frederick Leslie Ransome.

INTRODUCTION.

Although the Coeur d'Alene region of northern Idaho produces more argentiferous lead ore than any other district in the United States, its geological features are comparatively little known. Lindgren[a] has published brief accounts of some of the mines and has described the principal mineralogical features of a few of the ores. Finlay[b] has given a good general description of the lodes and mines, mainly from the technical standpoint, and has devoted about a page to the geology of the region. These are the only important publications relating to the geology of this part of Idaho that have appeared.

The detailed investigation of the district by this Survey was begun in 1900 with the construction of a topographic map by V. H. Manning, topographer, known as the Coeur d'Alene special map. This, the first accurate map of the mining area, is on the scale of 1:62500 (approximately 1 mile to the inch), with contour intervals of 50 feet. It covers the region lying between 47° 25′ and 47° 40′ north latitude and 115° 40′ and 116° 10′ west longitude, and is the equivalent of two of the usual fifteen-minute quadrangles of the Geologic Atlas of the United States. The area mapped is about 23½ miles from west to east and about 17¼ miles from north to south. The topographic map was completed in 1902, and geological field work was begun in 1903 and finished in 1904.

The geological work has been carried on under the immediate direction of the writer, who has devoted his attention particularly to the study of the ore deposits. The exceptionally arduous labor of discriminating and mapping the geological formations over this rugged and for the most part densely wooded region has been well performed by Mr. Frank C. Calkins, who was assisted during the

[a] Lindgren, W., Metasomatic processes in fissure veins: Trans. Am. Inst. Min. Eng., vol. 30, 1901, pp. 680–682. Also A geological reconnaissance across the Bitterroot Range and Clearwater Mountains in Montana and Idaho: Prof. Paper U. S. Geol. Survey No.. 27, 1904, pp. 108–111.

[b] Finlay, J. R., The mining industry of the Coeur d'Alenes, Idaho: Trans. Am. Inst. Min. Eng., vol. 33, 1903, pp. 235–271.

season of 1903 by Mr. W. F. Williams and during both seasons by Mr. W. F. MacDonald. The brief account of the general geology included in this preliminary report is based almost entirely upon Mr. Calkins's work.

A part only of the rock and ore collections made in the field during the past two seasons has been studied, and much office work must be done before the final report on the district will be ready for publication. The present summary is nothing more than a brief statement of the progress of an uncompleted investigation and is essentially provisional in character.

GEOGRAPHY.

The area which may be conveniently called the Coeur d'Alene district (although for purposes of record and administration it has been divided into a number of local mining districts) is, so far as its productive portion is concerned, in Shoshone County, Idaho. It lies almost entirely upon the western slope of the Coeur d'Alene Mountains,[a] a broad and rather complex member of the main Rocky Mountain chain. The Coeur d'Alene Mountains extend from Pend Oreille Lake on the north to the headwaters of the North Fork of the Clearwater, or nearly to Lolo Pass, on the south. The eastern slope of the range descends in from 10 to 25 miles to the valleys of Clark Fork and the Missoula River. The western versant slopes as a broad, dissected plateau down to the basaltic plains of Spokane and eastern Washington. The breadth of this western slope is 50 or 60 miles.

The Coeur d'Alene special map, outlined in fig. 16, embraces within its eastern border part of the crest of the range, which here forms the boundary between Idaho and Montana. It includes all of the local lead-silver deposits of importance, with the exception of a few mines and prospects lying just outside its western boundary. None of these outlying mines, however, are at present active producers.

Wallace, the principal town of the region and the seat of Shoshone County, has a population of about 3,500. It is situated in the south-central part of the district, at the confluence of Ninemile and Canyon creeks with the South Fork of Coeur d'Alene River. It is essentially a supply point for the mines, the mining population being housed for the most part in the smaller towns of Wardner, Mullan, Burke, Mace, Gem, and Murray.

[a] This group of mountains is on some maps made a part of the Bitterroot Range. It seems better, however, to restrict the name Bitterroot as Lindgren has done in his recent reconnaissance paper (Prof. Paper U. S. Geol. Survey No. 27) to the range separating the drainage basins of the Bitterroot and Clearwater rivers, and forming a southern continuation of the Coeur d'Alene Mountains.

There are two railroads into the district. A branch of the Northern Pacific Railway leaves the main line at Missoula, Mont., follows the Missoula River to the mouth of the St. Regis de Borgia River and, turning up that stream, enters the district by way of Lookout Pass and Mullan. From Wallace, branches of the Northern Pacific extend up Ninemile and Canyon creeks.

From the west the district is entered by the Oregon Railway and Navigation Company, with connections at Harrison, on Coeur d'Alene Lake, with steamers operated in conjunction with the Northern Pa-

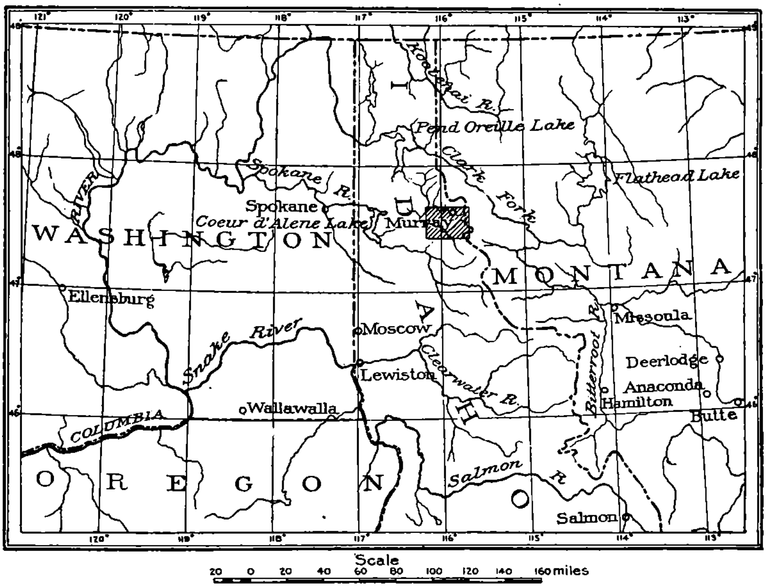


FIG. 16.—Index map showing position of Coeur d'Alene district.

cific and electric lines from Spokane. The Oregon Railway and Navigation Company also has a branch up Canyon Creek to Burke.

RELIEF AND DRAINAGE.

The elevations in the district range from 6,826 feet on the summit of Mount Stevens, near the Idaho-Montana boundary, to 2,250 feet on the South Fork of the Coeur d'Alene River, west of Kellogg. The region as a whole, seen from a commanding point, has the aspect of a deeply dissected, rolling plateau, sloping very gently westward from the divide near the eastern edge of the district. Although it is probable that the present mountainous topography has been carved by erosion from a former uneven plateau, no vestige of this old surface remains in the complex of steep ridges and deep narrow valleys and ravines that constitute the Coeur d'Alene Mountains. The ridges though steep and high, rising in places over 3,500 feet above the nearest trunk streams, are comparatively smooth of slope and not particularly rugged of crest. This general plateau-like character is not a local feature peculiar to the Coeur d'Alene Mountains, but is continuous on the south, with the great dissected plateau forming the western slope of the Bitterroot Mountains and the Clearwater Mountains.[a]

The district, with the exception of a small part along the eastern border, which is drained by the St. Regis de Borgia and other tributaries of Clark Fork, drains westward through the Coeur d'Alene River into the lake of the same name. The South Fork, which rises a few miles east of Mullan, is a comparatively feeble stream, overburdened in summer with the tailings from the concentrating mills. Its principal tributaries within the area considered are Canyon, Ninemile, and Placer creeks, which enter at Wallace, and Big Creek, which debouches from the south between Osburn and Kellogg.

The North Fork, which rises north of the district and flows out of its northwest corner, is a beautiful clear stream, navigable for light boats for many miles above Kingston, on the Oregon Railway and Navigation Company's line, where it is joined by the South Fork. Its principal tributaries within the district are Prichard and Beaver creeks, both of which enter it from the south.

Nearly all the streams of the district flow in deep V-shaped valleys, but the larger streams, such as the North and South forks and Prichard and Beaver creeks, have partially filled or aggraded their valleys—a feature which is characteristic of all the streams flowing into Coeur d'Alene Lake, and which becomes more noticeable nearer their mouths.

GENERAL GEOLOGY.

General character and distribution of the rocks.—The prevailing rocks of the Coeur d'Alene Mountains are arenaceous and argillaceous sediments of great thickness. They constitute an apparently conformable series, of which neither the stratigraphic base nor top appears in the district nor, so far as known, in the surrounding region. No fossils have been found in them, and they are probably of Algonkian age.

On the west these sediments extend to Coeur d'Alene Lake, where they are probably faulted down against the granitic and gneissic rocks forming the western shore of that picturesque body of water. On the north practically nothing is known of the extent of these Algonkian rocks. It is not unlikely that they continue northward past Pend Oreille Lake and are connected with the great series of Algonkian beds known to occur in the northwestern corner

[a] Lindgren, W., loc. cit., p. 14.

of Montana. On the east, beds of the same character as those occurring in the Coeur d'Alene district extend to the Missoula River at the mouth of the St. Regis de Borgia. Here there is apparently some change in lithological character, but quartzites and red and green siliceous argillites, probably of Algonkian age, extend at least to the town of Missoula, in Montana, and probably for some distance farther east. The area of Algonkian sediments has a width of about 80 miles between Coeur d'Alene Lake and the Missoula River, and it is probable that extensive exposures of Algonkian beds continue 100 or more miles to the eastward, connecting the Coeur d'Alene area with the known Algonkian areas of central and northern Montana.

On the south, Lindgren[a] has shown that the sedimentary rocks near Lolo Pass, which are probably part of the same series that prevails in the Coeur d'Alene Mountains, are cut off by the great granitic batholith of central Idaho.

In the Coeur d'Alene district alone, the Algonkian rocks have a thickness of at least 10,000 feet, and it is certain that by no means the entire series of rocks of this age developed in northwestern Montana is represented.

As a whole, the Algonkian sediments of the Coeur d'Alene region exhibit little lithological contrast. They are chiefly shallow-water deposits, as shown by the prevalence of ripple marks and sun cracks. They comprise dark argillites (mud rocks), graywackes (mud-sand rocks), quartzites of various degrees of coarseness, and usually sericitic, quartzitic sandstones, and impure limestones or calcareous argillites. Secondary cleavage is frequently present in all but the coarser arenaceous beds, but this slaty structure varies greatly in development in different parts of the field.

No sediments younger than the Algonkian occur in the Coeur d'Alene district, with the exception of fluviatile deposits, some of which may be of Tertiary age.

The Algonkian rocks are cut by a number of masses of syenite most of which have the form of small intrusive stocks, and by a few dikes of diabasic, dioritic, and minette-like habit, which have not yet been studied. The principal syenitic intrusions occur northeast of Wallace along a northeast-southwest line (see fig. 17). There is no means of determining the age of these intrusions. If the syenitic stocks were intruded at the same time as the great granitic batholith of central Idaho, they are of post-Triassic and pre-Miocene age.

Divisions and lithology of the sedimentary rocks.—Owing to the rather monotonous sequence of the Algonkian sediments, and the absence of fossils or unconformities, division of the group into dis-

[a] A geological reconnaissance across the Bitterroot Range and Clearwater Mountains in Montana and Idaho: Prof. Paper U. S. Geol. Survey No. 27, 1904, p. 16.

tinct formations is difficult. Sands and silts accumulated on the subsiding bottom of a shallow sea to a thickness of over 10,000 feet. So shallow was this sea that most of the sediments retain the marks of pre-Cambrian ripples and were occasionally laid bare and cracked by the sun. Throughout the entire period of deposition there was no abrupt changé in the general character of the sediments. Muddy

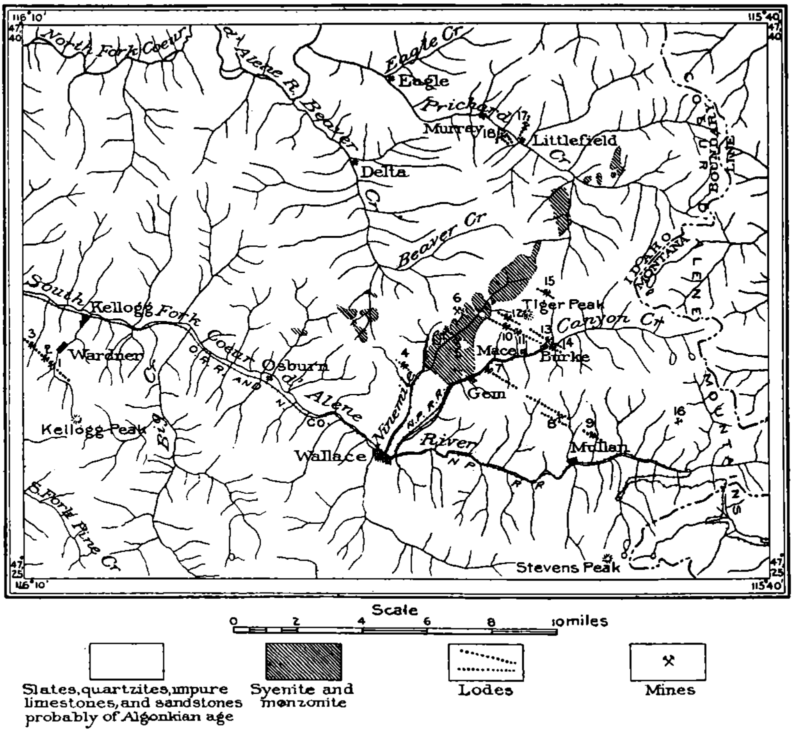


FIG. 17.—Preliminary geologic map of the Coeur d'Alene district.

silts graded into sands and these again into silts. Under such circumstances the formations recognized in the following table have more or less arbitrary upper and lower limits. The typical dark slate of the Prichard formation is very different from the sericitic quartzite of the Burke formation, but the two are connected by beds of intermediate character. In the accompanying tabular section the formations are arranged from the bottom upward in the order of their deposition:

Generalized tabular section of Algonkian rocks in the Coeur d'Alene district.

No.	Name.	Description.	Thickness.
			Feet.
6	Striped Peak formation.	Sandstones, siliceous, generally flaggy to shaly; colors mostly green and purple; characterized by shallow-water features, as ripple marks, sun cracks, etc.	1,000+
5	Wallace formation	Thin-bedded sandy shales, underlain by rapidly alternating thin beds of argillite, calcareous sandstone, impure limestone, and indurated calcareous shale; these underlain in turn by green siliceous argillites. Shallow-water features throughout. Slaty cleavage common.	2,500±
4	St. Regis formation	Sandstones, generally flaggy or shaly; usually fine-grained and much indurated; colors mostly green and purple; characterized by shallow-water features.	800±
3	Revett quartzite	White quartzites, generally rather thick-bedded; interstratified with subordinate quantities of micaceous sandstone.	1,000±
2	Burke formation	Gray, flaggy, fine-grained sandstones and shales, with interbedded purple quartzitic sandstone (the proportion varies widely in different parts of the district) and white quartzite. The formation characterized throughout by shallow-water features.	1,700±
1	Prichard slate	Mostly blue-black, blue-gray to light gray slates, generally distinctly banded. Considerable interbedded gray sandstone. Upper portion characterized by rapid alternations of argillaceous and arenaceous layers, and by shallow-water features. Base not exposed.	8,000±
	Total		15,000

The Prichard slate is the thickest and the most homogeneous of the formations in the Coeur d'Alene district and occupies the greatest area. It is also one of the most distinctive, the regularly banded bluish-gray slates being readily recognized. It can be distinguished from certain somewhat similar beds in the Wallace formation by its noncalcareous character and by the fact that it weathers in reddish-brown tints, while the weathered exposures of the Wallace formation are yellowish gray. Slaty cleavage is usually fairly well developed and of a more regular character than in the younger formations of the district. It rarely obscures the bedding, to which it is usually inclined at considerable angles. In some places cleavage and bedding coincide, as in the excellent exposures by the roadside just east of Kellogg.

This formation is the prevalent rock along the South Fork from Kellogg to Osburn and occupies almost the entire drainage basin of Prichard Creek. It is essentially the gold-bearing formation of the district, though it contains also some promising lead-silver veins, mainly in the transitional beds of its upper part.

The Burke formation consists principally of thin-bedded, often shaly, fine-grained, sericitic quartzites of prevailingly light tint. With these, however, are included some more massive quartzites, such as form the summit of Tiger Peak, and thin beds of grayish-purple argillaceous quartzite or graywacke. The latter are a more prominent feature of the Burke formation in the eastern part of the area than in the western part. Near the eastern border of the district these purplish-gray beds form the greater part of the upper portion of the Burke.

The Burke is not a very well-defined formation, as the thin-bedded sericitic quartzites and quartzitic shales that characterize it pass gradually downward into Prichard slate and gradually upward into the massive white quartzites of the Revett formation. It is, however, exceeding important from an economic standpoint as it contains the principal lead-silver deposits.

The formation is typically developed along Canyon Creek from Burke to Gem, in the vicinity of Wardner, and in many other parts of the district, particularly along its eastern border.

The Revett quartzite is fairly homogeneous and is composed almost entirely of moderately thick beds of white or pale greenish-gray quartzite. The greenish tint is due to the presence of sericite, which forms a considerable part of some of the beds, while others consist of nearly white, pure quartzite. The softer sericitic beds are characteristic of the upper and lower parts of the formation and are in reality transition beds with reference to underlying and overlying formations. The thick white medial beds of the Revett quartzite are exposed chiefly in the eastern part of the district near the Idaho-Montana divide. They contain the copper deposit of the Snowstorm mine, and surround Lake Revett, whence the formation derives its name.

The St. Regis formation consists of siliceous shales or argillites, shaly sandstones, and impure, fine-grained quartzites, characterized throughout by features indicative of shallow-water deposition, and by rather bright-green and purplish-gray tints. An irregular slaty cleavage is fairly common. The formation is far from uniform in aspect, however, and shows considerable lithological variation in different parts of the field. It contains beds not ordinarily distinguishable from certain beds in the Burke and Wallace formations, so that it is sometimes difficult to identify the formation when but small areas are exposed. The formation is thickest and best exposed in the southeastern part of the district, particularly about 3 miles northeast of Mullan and in the vicinity of St. Regis Pass.

The Wallace formation in thickness and areal extent is second only to the Prichard slate. It is the most heterogeneous of all the formations distinguished. The dominant rocks are thin-bedded, light-green shales consisting chiefly of quartz and sericite, associated with impure limestones, bluish-gray argellites, and calcareous quartzites, and characterized from top to bottom by ripple marks and other evidences of shallow-water deposition. In addition to the dominant constituents, nearly all of the beds contain more or less calcite, dolomite, and siderite (or other ferruginous carbonates), which on weathering give a yellow tint to the exposures of the formation. A slaty structure is common, the rocks often being highly fissile, though the cleavage never approaches in regularity that of ordinary clay slate. Fresh surfaces of these green-banded slates have usually a peculiar waxy luster that is very characteristic of the Wallace formation, as is also the presence of carbonates.

The formation is well exposed at the town of Wallace, particularly at the Northern Pacific Railway station. It occupies large areas all along the southern border of the district, and is the principal rock along Beaver Creek. The mines and prospects in the so-called "dry belt," between Wallace and Wardner, are mostly in the Wallace formation.

The Striped Peak formation is the least extensive in the district. The largest areas occur near the peak whence the formation derives its name. Lithologically it is almost a repetition of the St. Regis formation, with unusually abundant ripple marks.

Igneous rocks.—The most important igneous masses in the district are the irregular stock-like intrustions of syenite outlined on the accompanying map (fig. 17). The typical rock of the larger areas, as determined by Mr. Calkins, is a coarse-grained syenite with a tendency toward porphyritic development of the dominant alkali-feldspar. The other essential constituents are plagioclase, amphibole, and pyroxene. Biotite is rare, and neither quartz nor nepheline has been detected. From this central type is considerable variation, particularly near the contacts and in the smaller masses, which consist usually of syenite porphyry. In the largest mass, near Gem, are found monzonitic facies and a number of interesting peripheral modifications rich in amphibole and pyroxene.

The larger syenitic intrusions are surrounded by well-marked zones or aureoles of contact metamorphism. The quartzites are altered to hornfels. The impure quartzites and argillites are recrystallized as aggregates of andalusite, garnet, sillimanite, biotite, muscovite quartz, and feldspar, and in the calcareous Wallace beds amphibole and pyroxene are developed.

The dike rocks of the region, which seem to have no direct connection with the syenitic intrusions, are not of great structural or economic importance. They have not yet been carefully studied, but will be described by Mr. Calkins in the final report on the district.

Structural features of the district.—The sedimentary rocks of the Coeur d'Alene district have been complexly folded, the folds in several instances being overturned, so that the older formations overlie the younger. They have also been extensively faulted and so strongly compressed as to develop slaty cleavage in all but the massive quartzites. While the prevalent strike of the beds is northwesterly, it is plain that no simple compression along northeast-southwest lines can satisfactorily account for the often highly complex character of the folds and the numerous and important deviations from the dominant northwesterly strike. In the greater part of that portion of the district lying south of the South Fork the general strike is about west-northwest, and the axis of the major folds are traceable for considerable distances. In the vicinity of Kellogg Peak and Wardner, however, the strike becomes more northerly and the folds more irregular. In the region lying north of the South Fork and west of Beaver and Ninemile creeks the essential structure is that of an anticline, with a steep pitch to the north. The oldest formation exposed in this anticline is the Prichard slate, which occurs along the South Fork from Osburn westward, and in consequence of this structure forms a semicircular area north of the river.

From Mullan northward past Murray is a broad belt of close and complex folding in which north-south strikes prevail. This structure passes into a zone of more open folds to the east.

The region contains a number of important faults, of which the majority strike nearly west-northwest. Both normal and reversed faults occur, the dip of the reversed faults being usually steep. The west-northwest faults are particularly abundant in the southern part of the district, where seven important dislocations of this group have been mapped and studied by Mr. Calkins. These have throws of from 1,000 to at least 4,000 feet and observed lengths up to 18 miles. The most prominent fault of this group extends from a point east of Mullan, past Wallace, through Osburn, and for an unknown distance west of Wardner. The fault is normal, with downthrow to the south, and the dislocation brings the Wallace formation against the Prichard slate near Osburn—a relation that implies a throw of at least 4,000 feet.

The west-northwest faults have approximately the same general strike as the lead-silver lodes and were produced by the same or similar stresses. That some of the faults were formed prior to the deposition of the ore is fairly certain.

In addition to the west-northwest faults there are several dislocations of nearly north-south trend, which attain their greatest structural importance in the central part of the district. The most prominent member of this group is the Dobson Pass fault, which has been traced from a point about 3 miles north of Wallace to within 2 miles of Eagle. The fault dips to the west at an angle of 35° or less, and is normal. At Dobson Pass, 5 miles north of Murray, the fault has dropped the Striped Peak formation against the Prichard slate, indicating a throw of at least 6,000 feet.

Another great dislocation of this group is the Carpenter Gulch fault, which has been followed from the northern boundary of the district southward, past the mouths of Prichard and Beaver creeks, for 12 miles to a point about 3 miles northwest of Wallace. Its course is irregular and it dips west and southwest at a moderate angle. This fault is an overthrust of approximately 1,000 feet.

Slaty cleavage, usually of a rather irregular character, is a well-marked structural feature of the finer-grained rocks of the Cœur d'Alene region, and a distinct fissility has in some places been produced in moderately coarse quartzites. It is best developed in the Prichard slate and in the lower part of the Wallace formation. This cleavage is usually independent of bedding, and shows a marked tendency to conform in strike to the general trend of the longer folds and in both strike and dip to the major faults. Local zones of slaty cleavage are the usual accompaniments of the lead-silver lodes of Mullan and Canyon Creek. In no case does this structure attain the perfection found in roofing slate. The cleavage surfaces intersect at small angles, and the rocks split somewhat irregularly into lenticular flakes. The dip of the cleavage nearly everywhere ranges from southwestward to southward or westward.

Age of deformation.—Lindgren[a] has shown that the granitic (quartz-monzonite) batholith of the Clearwater and Bitterroot mountains is probably of post-Triassic age. That intrusion was undoubtedly associated with orogenic uplift. We know that the erosion which exposed this granite and reduced it and the surrounding rocks to a region of subdued relief must have been later than the intrusion. We know further that the whole central Idaho region must have been again uplifted, this time as a plateau, in pre-Miocene time, for the Coeur d'Alene River in its lower course had cut below its present bed before the eruption of the Columbia River basalt

[a] Loc. cit., p. 20.

flows. In this second uplift, however, the region affected appears to have been elevated as a great block without general folding. At just what period in the vast interval between Algonkian sedimentation and post-Triassic granitic intrusion the Coeur d'Alene rocks were folded, squeezed, and faulted it is impossible to say. It is probable, however, that the principal deformation was effected at the time of the granitic intrusion.

HISTORY OF MINING DEVELOPMENT.

The story of the opening of the Coeur d'Alene region to mining enterprise goes back to the year 1842, when a mission was established by the Jesuits in the beautiful valley of the St. Joseph River, a navigable stream which empties into the head of Coeur d'Alene Lake about 5 miles south of the embouchure of the Coeur d'Alene River. In 1846, however, the mission was moved to its present site on the latter stream, about 25 miles from the lake, and for many years Father J. Joset and the missionaries associated with him were the only white inhabitants in this whole region. The Coeur d'Alene Indians, about 300 in number, lived chiefly in the vicinity of the mission.

In 1854 Lieut. John Mullan, acting under instructions from the War Department, began explorations for a wagon road over the Coeur d'Alene Mountains to connect Fort Benton with Fort Walla Walla. These preparations aroused the hostility of the Indians, who, after defeating a small force of regular troops, were subjugated in 1858. In the following year work on the proposed road was begun under a Congressional appropriation, and the task seems to have been finished in 1861.[a] The new road crossed from the mouth of the St. Joseph River to the mission on the Coeur d'Alene River. Thence it followed the main stream and South Fork to a point about 3 miles east of the present town of Mullan. Here it turned south, crossed the divide through the Sohon or St. Regis Pass, and continued down the St. Regis de Borgia River, following the route later taken by the railroad to Missoula.

Roughly constructed as it was, this road, now familiarly known as the "Old Mullan road," was for many years the only line of travel into the region to whose early development it substantially contributed. It traversed what afterwards proved to be the most productive part of the district, but the discovery of the lead-silver deposits was reserved for a later date.

The first prospecting in the region appears to have been by Thomas Irwin, who in 1878 located a quartz claim near the Mullan road,

[a] Mullan, Capt. John, U. S. Army, Report on the Construction of a Military Road from Fort Walla Walla to Fort Benton, Washington, 1863.

apparently on Elk Creek. In the summer of 1879 a party, including A. J. Prichard, moving northward from the Mullan road over the Evolution trail, discovered Prichard Creek. In 1882 Gellett, another member of the party, found placer gold and located a claim on Prichard Creek. The first quartz claim on Prichard Creek was the Paymaster, near Littlefield, located by Patrick Flynn on September 21, 1883.

The discoveries of Prichard and Gillett were followed by a rush of prospectors to the North Fork early in 1884, and in May Eagle City, at the junction of Eagle and Prichard creeks, had become a bustling town connected by trail and telegraph with Belknap, 32 miles away, on the Northern Pacific Railway. It was soon found, however, that the richest placers lay higher up Prichard Creek, particularly in Dream, Buckskin, and Alder gulches, and the center of population soon shifted to the new town of Murray.

Although the chief excitement at this time centered in the rich gold placers near Murray, the lead-silver veins of the South Fork were beginning to attract attention. In 1884 Col. N. R. Wallace had a cabin and store in the dense grove of cedars that covered the future site of the town now bearing his name. His settlement was then known as Placer Center. At the same time W. B. Heyburn began work on the Polaris mine, in Polaris Gulch. The Tiger claim, on Canyon Creek, was also located in 1884 by John Carton and Almeda Seymour, who bonded it to John M. Burke. In 1885 the Tiger mine, in spite of its comparatively inaccessible position, had been opened by three tunnels and had about 3,000 tons of lead-silver ore on the dump. Other mines located in 1884 were the Gold Hunter, Morning, and You Like, near Mullan, and the Black Bear, San Francisco, and Gem of the Mountains (now comprised in the Helena-Frisco mine), near Gem.

In 1885 Murray, with a population of about 1,500, became the permanent seat of Shoshone County. In spite of the promising character of the lead-silver deposits on the South Fork, the gold placers on Prichard and Beaver creeks were still the center of attraction, and considerable work was being done on the auriferous quartz veins between Murray and Littlefield.

Communication with the mines on the South Fork was at this time difficult. Small steamers plying across the lake ascended the Coeur d'Alene River to the Mission, where passengers and freight were transferred to wagons or horses and carried over the rough Mullan road. Murray was connected by an equally poor road with Thompson Falls, on the Northern Pacific Railway, by a road down the North Fork with the Mission, and by a road with Delta. Practically the only route from the county seat to the South Fork was by way of the

Evolution trail, Evolution being a little settlement about 2 miles west of Osburn's ranch, then a well-known stopping point for travelers. It was impossible to mine and ship lead ores until better facilities for transportation were obtained.

The discovery of the Bunker Hill mine by Phil O'Rourke and N. S. Kellogg in 1885, of the Sullivan mine by Con Sullivan and Jacob Goetz, and the evident existence of large bodies of rich ore in the Tiger, Poorman, Granite, San Francisco, Morning, and other mines, removed all doubts of the future importance of the South Fork mines. The opening of the year 1886 was marked by a decided rush from the outside and from the waning placers of Murray into this new field, particularly to the settlements of Milo and Kentucky, now parts of Wardner and Kellogg. Triweekly stages ran from Mission to Wardner, and a stage road was built connecting Delta with the South Fork.

In 1886 ore from the Bunker Hill and Sullivan mines was hauled by wagons to Mission, carried by boat to the outlet of the lake, and thence shipped to Helena, Mont. The ore from Last Chance, Tyler, and Sierra Nevada mines was treated in a new smelter at Milo. This early attempt at local smelting was soon abandoned.

In the following year a narrow-gage railroad was completed by the Coeur d'Alene Railway and Navigation Company from Mission to Wardner Junction, at the mouth of Milo Creek. Wardner had now become a town of 1,500 people, while the population of Murray had fallen to about 1,000. There were about 500 inhabitants at Wallace, and Burke and Mullan were growing settlements. Probably 100,000 tons of ore were piled on the dumps of the Canyon Creek mines awaiting means of transportation. The Oregon Railway and Navigation Company and the Northern Pacific Railway were both striving at this time to secure entrance to the district.

In April, 1887, the Bunker Hill and Sullivan mines were sold to S. G. Reed, and in August the Bunker Hill and Sullivan Mining and Concentrating Company was organized, with a capital of $3,000,000. The Poorman, Granite, and Morning mines were also sold at about this time. The completion of the narrow-gage railroad to Burke in this year enabled the Canyon Creek mines to ship their ore. Probably over 50,000 tons of lead-silver ore was mined in 1887, the principal producers being the Tiger, Bunker Hill and Sullivan, Tyler and Stemwinder, Last Chance, Sierra Nevada, Poorman, and Granite. The Mammoth and Standard veins were as yet merely good prospects.

In 1888 placer mining near Murray and Delta had greatly declined. A pipe line was constructed from Raven in 1890 to hydraulic the bench gravels of the so-called Old Wash, near Murray, and some hydraulic mining is still occasionally carried on in Dream Gulch.

A hydraulic elevator was operated for some time in the bed of Prichard Creek about a mile below Murray, and some dredges were working near Delta in 1904; but the scene of activity had definitely shifted by the year 1888 to the lead-silver mines of the South Fork.

The principal events in 1890 were the completion into the district of the tracks of the Northern Pacific Railway and Oregon Railway and Navigation Company, the partial destruction by fire of Wallace and Wardner, and the first shipment of rich ore from the Mammoth mine. The old narrow-gage line was absorbed by the Oregon Railway and Navigation Company and its tracks were replaced by those of standard gage. Most of the larger mines were by this time equipped with concentrating mills.

At the beginning of 1892 most of the South Fork mines stopped work, ostensibly to secure better freight rates. Wages at this time were $3.50 a day. In the following April a reduction was made in wages, followed by a strike of the union men. The Frisco, Gem, and Bunker Hill and Sullivan mines attempted to resume work with nonunion men, and in July were attacked by armed strikers. Troops were called into the district and for a time order was partly restored. In July, 1894, a second attack was made upon the Gem mine, and in December, the Bunker Hill and Sullivan mine closed, rather than accede to union demands. In June, 1895, it resumed partial operations, paying $3 a day to miners. The Tiger and Poorman mines consolidated in this year.

In May, 1898, the Empire State Mining and Development Company was organized to control the Last Chance mine and to acquire additional territory west of Milo Gulch. This was the beginning of the process of consolidation that afterwards resulted in the formation of the Federal Mining and Smelting Company. The county seat was this year moved from Murray to Wallace, now the largest town in the district.

The opening of the year 1899 found the miners' unions still determined to enforce their demands upon the mine owners, and in a particularly bitter mood against the Bunker Hill and Sullivan Company, which maintained its right to employ nonunion labor. On April 29, a force of several hundred men attacked the buildings of the company at Kellogg. The office of the mine was rifled and both office and mill were totally destroyed by dynamite.

After this episode, 500 regular troops were sent into the district and martial law was proclaimed. The mines were closed until June, when the Standard mine reopened with men brought from Missouri. The other mines resumed work one by one as they secured nonunion miners. From that time to the present no man has been able to secure employment in the larger mines (with one exception) save through the employment bureau maintained by the principal mine owners.

In 1901 the Tiger-Poorman mine, previously acquired by the Buffalo Hump Mining Company, was consolidated with the holdings of the Empire State Company, and in September, 1903, the Empire State, Standard, and Mammoth properties were all consolidated under the Federal Mining and Smelting Company. Other notable events of the past few years were the discovery in 1901 of the rich ore body of the Hercules mine, which has produced ore of a gross value of about $2,000,000 in less than three years, and the development of the Snowstorm mine in 1903. This is the only mine in the district that ships copper ore.

PRODUCTION.

For several years the Coeur d'Alene district has been the leading lead-producing district in the United States. Out of a total of 313,553 short tons of lead produced by the mines of this country in 1904, 107,560 tons, or rather more than one-third, came from the Coeur d'Alene district. This considerably exceeds the combined product of Missouri, Kansas, Iowa, Illinois, Wisconsin, and Kentucky, and is about double the production of Utah or Colorado.

The output of Shoshone County, which is practically that of the Coeur d'Alene district, from the beginning of mining to the end of 1904, is shown in the following table. The gold there accounted for is derived almost entirely from the placers and gold-quartz veins near Murray, the lead-silver ores containing so little gold that the quantity is negligible. As no returns for gold in 1904 are yet available the probable output is roughly estimated at 7,000 ounces for that year. The silver tabulated is that obtained by smelting the lead-silver ores, no record being kept of the small amount of silver occurring with the Murray gold. The figures for the production of the precious metals, except for 1904, are taken from the reports of the Director of the Mint. Those for lead are derived partly from the same source, where the lead output for certain years is given with that of silver, and partly from the volumes of the Mineral Industry. The amounts in the columns of values are calculated in accordance with the average commercial value of lead and silver in New York for each year and the value ($20.67) of a fine ounce of gold. An allowance of 5 per cent of lead and 2 per cent of silver is usually made for loss in smelting. So far as could be determined the gross values given in the table are based upon the assay return, less this deduction.

Table showing production of lead, silver, and gold in the Coeur d'Alene district (Shoshone County) from 1884 to 1904.

Year.	Lead, in tons of 2,000 pounds.	Value of lead.	Silver, in fine ounces.	Value of silver.	Gold, in fine ounces.	Value of gold.	Value of total metallic products.	Ratio of silver to lead, by weight.	Ounces of silver to each unit of lead.[a]
1884	--------	----------	----------	----------	12,500	$258,375	$258,375	--------	--------
1885	--------	----------	----------	----------	18,220	376,607	376,607	--------	--------
1886	[b]1,500	$138,300	116,246	$115,664	8,823	182,371	436,335	1 : 384	0.77
1887	[b]5,980	538,200	340,000	332,520	7,367	152,276	1,022,996	1 : 515	.56
1888	[b]8,000	705,600	554,000	520,760	10,250	211,867	1,438,227	1 : 422	.69
1889	[b]17,500	1,333,500	1,095,265	1,025,168	8,433	174,310	2,532,978	1 : 466	.62
1890	[b]27,500	2,392,500	1,499,663	1,574,646	8,000	165,360	4,132,506	1 : 531	.54
1891	[b]33,000	2,857,800	1,825,765	1,803,856	10,000	206,700	4,868,356	1 : 626	.55
1892	[c]27,839	2,266,094	1,195,904	1,045,220	11,000	227,370	3,538,684	1 : 679	.42
1893	[c]29,563	2,424,166	1,963,561	1,529,614	14,748	304,841	4,258,621	1 : 440	.66
1894	[c]30,000	1,968,000	2,343,314	1,485,661	17,531	362,365	3,816,026	1 : 373	.78
1895	[c]31,000	2,008,800	2,471,300	1,626,115	18,439	381,134	4,016,049	1 : 366	.79
1896	[d]37,250	2,212,650	3,163,657	2,132,304	17,369	359,017	4,703,971	1 : 343	.84
1897	[d]57,777	4,159,944	3,756,212	2,264,996	16,404	339,070	6,764,010	1 : 448	.65
1898	[d]56,339	4,225,425	3,521,982	2,070,925	13,011	268,937	6,565,287	1 : 466	.62
1899	[d]50,006	4,440,533	2,737,218	1,645,068	8,602	177,803	6,263,404	1 : 533	.54
1900	[d]81,535	7,207,694	5,261,417	3,262,078	5,754	118,935	10,588,707	1 : 452	.64
1901	[d]68,953	6,026,492	4,339,296	2,603,577	4,915	101,593	8,731,662	1 : 463	.62
1902	[d]74,739	6,091,228	5,033,928	2,657,914	4,761	98,410	8,847,552	1 : 433	.67
1903	[b]103,691	8,772,258	5,471,620	2,954,674	7,651	158,146	11,885,078	1 : 552	.52
1904	[e]107,560	9,271,672	[e]6,141,426	3,512,895	[c]7,000	144,690	12,929,257	1 : 511	.57
Total and average	849,732	69,040,856	52,831,774	34,163,655	230,778	4,770,177	107,974,688	1 : 473	.64

[a] A "unit" of lead is 1 per cent to the ton of ore, or 20 pounds.
[b] Reports of the Director of the Mint upon the production of the precious metals in the United States.
[c] Estimated.
[d] The Mineral Industry: Its statistics, technology, and trade in the United States and other countries. New York.
[e] Reported to Engineering and Mining Journal of January 5, 1905, by Stanly A. Easton.

GENERAL CHARACTER AND DISTRIBUTION OF THE ORE DEPOSITS.

The ore deposits of the Coeur d'Alene district may be divided with reference to metallic contents into three classes: (1) Lead-silver deposits; (2) gold deposits, and (3) copper deposits. The lead-silver deposits are in general metasomatic fissure veins, formed in greater part by replacement of siliceous sedimentary rocks along zones of fissuring. They consist essentially of galena and siderite. The gold deposits comprise bed veins, fissure veins, and placers formed in at least two periods. The gold-bearing veins consist essentially of quartz carrying free gold and auriferous sulphides. The copper deposits include impregnations along certain quartzite beds and metasomatic fissure veins. The impregnated quartzite only has produced copper on a commercial scale.

These three classes of deposits are fairly distinct in their geographical distribution. The principal lead-silver deposits occur in the portion of the district drained by the South Fork of the Coeur d'Alene River and its tributaries. They fall into three main groups, one near Wardner, one near Mullan, and one near Burke. The principal gold deposits are found in the country drained by the North Fork, particularly by Prichard and Beaver creeks. The copper deposits are apparently confined to the corner of the district lying southeast of a northeast-southwest line drawn through the town of Mullan.

The geological distribution of the ore deposits is of a more definite character than might have been expected from the lack of lithological contrast in the thick series of the Coeur d'Alene sediments. The gold veins, so far as known, occur only in the Prichard slate, the oldest formation in the region. These slates constitute the prevailing rock along Prichard Creek from Eagle to Thompson Pass on the main divide. The principal gold-quartz veins occur in this area, the most productive being between Murray and Littlefield. Another area of Prichard slate extends along the South Fork from Osburn past Kellogg, and contains the gold-quartz veins worked in early days on Elk Creek.

The principal lead-silver deposits are in the Burke formation which overlies the Prichard, and which, as already described, is prevailingly a sericitic quartzite. Probably over 75 per cent of the lead-silver ore mined comes from this formation. The remainder is derived from the lower beds of the Revett quartzite, from the more slaty and calcareous Wallace formation, perhaps in part from the St. Regis formation, and from the upper part of the Prichard formation, which is separable merely by a rather arbitrary plane from the Burke formation into which it really grades.

The only productive copper deposit in the district occurs in the Revett quartzite, although a number of copper prospects have been opened in the Wallace and St. Regis formations.

LEAD-SILVER DEPOSITS.

Mines.—The principal companies operating in the Coeur d'Alene district on lead-silver ores are the Federal Mining and Smelting Company, owning the Tiger-Poorman mine at Burke, the Standard-Mammoth mine at Mace, and the Last Chance mine at Wardner;[a] the Bunker Hill and Sullivan Mining and Concentrating Company, owning the Bunker Hill and Sullivan mine at Wardner; Larson and

[a] These different mines are officially designated by the company as the Burke mines, the Mace mines, and the Wardner mines. It is less confusing to the reader, however, inasmuch as there are other mines at Burke and Wardner not owned by this company, to retain the old familiar names by which the mines are still known to all in the district.

Greenough, owning the Morning mine near Mullan; the Hercules Mining Company, owning the Hercules mine, and the Hecla Mining Company, owning the Hecla mine, both near Burke. Other mines which have contributed largely to the general production in the past, although they are not at present being worked on the same profitable scale as those just mentioned, are the Helena-Frisco mine near Gem, the Granite and Custer mines on the west slope of Tiger Peak, the Gold Hunter mine near Mullan, the Sierra Nevada mine, about a mile west of Wardner, and the Crown Point, owned by the Coeur d'Alene Development Company, also west of Wardner but just outside of the area mapped.

Some idea of the present relative importance of the different mines may be had from the following figures derived from a table compiled by Mr. Stanly A. Easton, manager of the Bunker Hill and Sullivan mine, for the Mineral Industry for 1903.

Gross value of product from the lead-silver mines of the Coeur d'Alene district in 1903.

Standard-Mammoth	$2,544,918
Morning	1,635,612
Bunker Hill and Sullivan	1,604,538
Last Chance	1,409,672
Hercules	850,258
Hecla	655,721
Tiger-Poorman	580,477
Helena-Frisco	465,287
Gold Hunter	166,000
Other mines	151,735
Total	[a] 10,064,218

The Bunker Hill and Sullivan and the Last Chance mines are both on the same general zone of fissuring and their workings connect at several points. The deepest level near Wardner is the Kellogg Tunnel of the Bunker Hill and Sullivan mine. This tunnel, which is a crosscut, runs southward from the mill, situated on the South Fork, about a mile west of Kellogg, for a distance of about 12,000 feet to the lode. It cuts the latter about 2,000 feet below the croppings. The Morning mine has a crosscut adit 2 miles north of Mullan, the ore being brought down to the mill on the South Fork over a narrow-gauge railway. A new adit, now being run from the mill, will cut the lodes about 800 feet below the bottom of the present workings. The Gold Hunter mine is also opened by a crosscut adit, from which two

[a] Mr. Easton's total, it may be noted, is $1,662,714 lower than the total value of the lead and silver given for 1903 on page 290. The difference is due to the fact that the average price of lead used by Mr. Easton is that received by the mining companies, which is considerably lower than the average New York price upon which the table on page 290 is based. The difference is about 0.6 cent per pound.

lower levels are worked through a winze. The Tiger-Poorman and Hecla mines are operated through shafts in the town of Burke. These workings are respectively 1,800 and 600 feet deep. The Standard-Mammoth mine has two long cross-cut adits, the Campbell tunnel, running nearly north from a point on Canyon Creek just below Mace, and the No. 6 tunnel, running nearly northeast from a point on the creek, 3,000 feet west and about 150 feet below the Campbell adit. From the end of the Campbell tunnel, an underground shaft or winze gives access to 5 levels, the lowest being 1,050 feet below the adit level, or about 2,000 feet below the apex of the vein. The main adit of the Helena-Frisco mine is a south crosscut from Canyon Creek near Gem, at the end of which is a shaft 1,400 feet deep, connecting with 7 levels. The main adit of the Hercules mine is on Tiger Peak, about 1½ miles north of Burke and about 1,500 feet above the bed of Canyon Creek. This mine as yet produces no concentrates, the crude ore being hauled by wagons to the railroads at Burke.

It appears from the foregoing that the mines working below the main canyon bottoms of the district are the Tiger-Poorman, Hecla, Standard-Mammoth, and Helena Frisco. Of these, the Tiger-Poorman, 1,800 feet, is the deepest.

The lead-silver mines as a rule are equipped with excellent machinery and are operated in a first-class and substantial manner.

Structural features of the deposits.—Most of the lead-silver deposits in the Coeur d'Alene district are metasomatic fissure veins. They are generally tabular deposits, formed partly by the filling of open spaces, but largely by replacement along zones of fissuring or of combined fissuring and shearing. The type is best exemplified by the Canyon Creek and Mullan groups of mines. The deposits worked in the mines at Wardner have different forms from those of Canyon Creek and Mullan, but, broadly regarded, fall into the same class. The ore bodies of the Granite mine also present some exceptional features, which will be adverted to later.

The general strike of the lodes is northwestward. In the Canyon Creek and Mullan groups the prevailing strike is about N. 70° W., with local variations from N. 55° W. to west. At Wardner the Bunker Hill and Sullivan–Last Chance lode strikes N. 42° to 45° W. With the exception of this lode, which dips toward the southwest at an angle of 38°, and the Sierra Nevada lode, which in places is almost horizontal, the lodes are nearly vertical. The Standard-Mammoth and Hecla dip north-northeast at an angle of about 85°. The Tiger-Poorman, Hercules, and Helena-Frisco have generally south-southwest dips ranging from 75° to nearly vertical, while the Morning and Gold Hunter lodes are practically vertical.

While the fissures appear to have been opened originally by faulting, the displacement could in no case be measured, and there is usually no observable difference in the rock on each side of the fissure. The region, as has been shown, contains many large faults that have left their marks upon the geological structure. But these structurally important faults are not ore-bearing.

The productive fissures are occasionally simple fractures. Usually, however, they exhibit complexity of various kinds.

In the Morning mine are two nearly parallel zones of fissuring about 1,000 feet apart. The northern one, known as the Morning vein, conforms approximately to the cleavage of the sericitic Burke and Revett quartzites in which it occurs, fissuring and cleavage being so closely related that the structure may be termed a shear zone. The average width of this zone is about 9 feet. The southern zone, known as the You Like vein, is similar in character but narrower, being only about 6 feet wide. In both lodes the ore occurs to some extent in small branching, irregular, or lenticular veinlets, but the ore is mainly a replacement of the country rock and as a whole has no definite walls.

In the Gold Hunter mine are three nearly parallel lodes, which, with minor intermediate ones, constitute a shear zone about 70 feet wide, of which a small part only is productive. Structurally this zone resembles the Morning and You Like veins, but is less persistent, and the productive parts of the lode, as they are followed along their strike, lose their identity in the slaty cleavage of the Wallace and probably St. Regis formations, which form the country rock of this deposit. The Gold Hunter lode is supposed to be a continuation of the You Like vein. While this is probable, the continuity has not been established. The Gold Hunter and Morning zone of shearing and fissuring probably continues west-northwest to Canyon Creek, where it seems to be represented by the fissures of the Helena-Frisco mine, which is in the Burke formation. The lodes worked in the Helena-Frisco are three in number, known as the Black Bear, Frisco, and Gem veins. They are apparently parts of a single faulted lode, as shown in fig. 18, but as the mine was only in small part accessible at the time of visit this hypothesis, which is strongly supported by the maps of the underground workings, could not be fully verified. The three veins, moreover, are not identical in structure or in character of ore, and it is possible that the transverse faults are older than the ore. The Black Bear vein is rarely over 3 feet wide and is a simple filled fissure with very little metasomatic replacement. The Frisco vein is also in the main a simple fissure, but a considerable part of the ore occurs as a replacement of the country rock. The Gem vein is much like the Frisco. It splits up and can not be followed after entering the intrusive mass of syenite on the west.

The Standard-Mammoth and Hecla mines are probably on a single fissure zone, but the actual continuity is broken by a northwest-southeast fault, dipping northeast, against which the vein abuts at the eastern end of the Standard-Mammoth mine. Between this fault and the Hecla shaft the vein is unknown. In the Standard-Mammoth and Hecla mines the general country rock, as in all of the large Canyon Creek mines, is the Burke formation. The ore occurs in a zone of combined fissuring and shearing, partly as the filling of fissures and partly as a replacement of the sericitic quartzite. The lode has no definite walls and usually ranges from 4 to 10 feet in width. In the Hecla mine the ore usually occurs on one side of a dark narrow dike, of which no microscopical examination has yet been made, but which resembles a fine-grained diorite. Very rarely a little ore occurs as a replacement in the dike. A little of the same rock, although discontinuous and much more decomposed, occurs with the Standard-Mammoth vein.

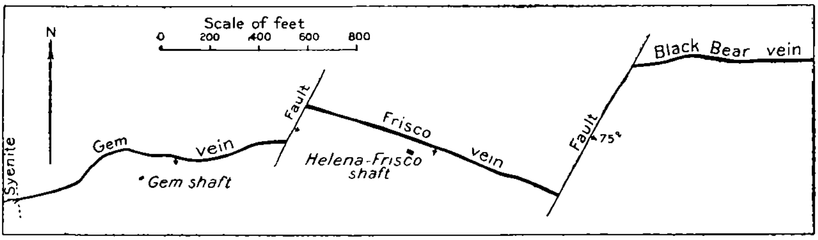


FIG. 18.—Plan of veins in the Helena-Frisco mine.

The Tiger-Poorman lode is generally similar to the Standard-Mammoth, the ore being usually from 3 to 15 feet in width. In the eastern part of the mine the lode exhibits a well-marked linked vein or imbricated structure.

In the Wardner deposits, as exemplified in the Bunker Hill and Sullivan and Last Chance mines, there is one dominant fissure, locally known as the "foot wall," which strikes northwest and dips southwestward at an angle of 38°. The rocks on both sides of this fissure are sericitic quartzites of the Burke formation. Those in the hanging wall are much more fissured than those in the foot wall, and it is in the fissured hanging-wall quartzite that the ore bodies occur. No ore of importance has yet been found in the quartzite of the foot wall in these mines. Although the main fissure was undoubtedly formed prior to the deposition of the ore, it has also been a plane of later movement, as shown by slickensided surfaces on the ore, and it is always accompanied by soft gouge.

The zone of fissured quartzite in which the ore bodies occur has a maximum width, measured perpendicularly to the foot-wall fissure, of about 300 feet. Within this zone, sometimes in contact with the foot wall, sometimes separated from it by barren quartzite, occur numerous ore bodies of very irregular shape (see fig. 19). The whole fissured zone, 300 feet in width, may be regarded as a single great lode, within which the partly overlapping and partly connected ore bodies are not uniformly distributed in the plane of the zone, but are grouped into at least four fairly distinct shoots, three of which have a general northwesterly pitch (in the plane of the lode) of 45°. The fourth, which is the most northwestern of the large pay shoots, occurs at the junction of the main foot-wall fissure, with a zone of fissures running off into the hanging wall in a southwesterly direction and dipping southeast. This is the so-called Jersey or Skookum fissure. Along this fissure zone for a horizontal distance of nearly

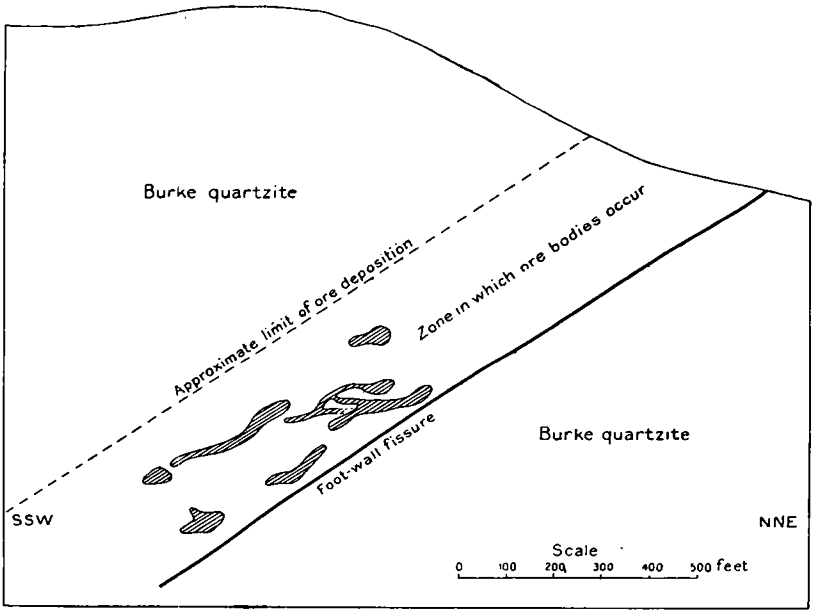


FIG. 19.—Section through Bunker Hill and Sullivan lode, showing relation of ore bodies to foot-wall fissure.

500 feet, and in the pitching trough formed by the intersection with the main foot-wall fissure, occurs some of the richest ore in the Wardner mines. The other pay shoots are also connected with distinct fissuring of the hanging-wall quartzite, but this fissuring is elsewhere of a more irregular character than in the Jersey fissure zone. The ore of the Sierra Nevada mine also occurred in a hanging-wall fissure zone connecting with the main foot wall of the Bunker Hill and Sullivan lode.

Definite walls to the ore bodies of the Wardner mines occur only where the ore rests upon the gouge seams marking the main foot wall or the foot wall of the Jersey fissure zone, or where the ore has been locally faulted. As a rule the ore passes gradually into the unmineralized quartzite.

In the Granite mine the ore occurs in extremely irregular masses in a tongue of metamorphosed and fissured quartzite which projects into the intrusive mass of syenite north of Gem.

Character of the ores.—The most characteristic minerals of the lead-silver ores are galena and siderite. Both of these minerals occur as the filling of fissures and as metasomatic replacements. In many instances the galena directly replaces sericitic quartzite. But in some large ore bodies, particularly those at Wardner, the quartzite was first replaced by siderite, which was in turn replaced by galena. All stages may be seen from siderite that is traversed by little reticulating veinlets of galena, to complete replacement by the lead sulphide. That galena was formed at more than one period is shown by the fact that masses of coarsely crystalline galena are sometimes traversed by veinlets of a more compact variety of the same mineral.

Pyrite and sphalerite are found in all the deposits. The latter is particularly abundant in the Granite mine. Elsewhere it is a minor constituent of the ore and many of the deposits are remarkably free from it. The average quantity of zinc in the concentrates from the Federal Company's mines is about 4.5 per cent. While most of the mines working above the main drainage lines of the district show no impoverishment of the ore through an increase of pyrite and sphalerite, the conditions in the lower levels of the Helena-Frisco, Tiger-Poorman, and Standard-Mammoth indicate that such a change, probably a gradual one, may be expected at considerable depths.

Tetrahedrite occurs in bunches in the galena of the Wardner and Mullan mines and in the Standard-Mammoth. It is never very abundant and always indicates ore rich in silver. It appears to be rather more abundant near the surface than at great depth.

Chalcopyrite is very rare in the mines at Wardner. In the Standard-Mammoth mine, however, it is fairly common, though never found in large masses, and it occurs also in the Tiger-Poorman, Helena-Frisco, and Granite mines. It is frequently closely associated with pyrrhotite, particularly on the bottom level of the Tiger-Poorman. Pyrrhotite was detected also in the concentrates from the Morning mine. Small quantities of stibnite occur in the Gold Hunter lode.

In addition to the prevailing siderite, quartz forms a subordinate part of the gangue in all the large mines. Barite was noted in the Standard-Mammoth, Gold Hunter, and Morning mines, and a little calcite in the Hecla mine. As a general rule, the quartz is more abundant in the low-grade portions of the ore bodies.

The minerals found in the oxidized zone are cerussite, cerargyrite, native silver, pyromorphite, and occasionally a little malachite or azurite. Limonite, of course, is always present, and results from the oxidation of the pyrite and the siderite. Plattnerite occurred in the upper tunnels of the You Like vein.

The average content of the ores in silver is a little over half an ounce to each per cent of lead per ton. During the fiscal year 1903–4 the ore of the Bunker Hill and Sullivan mine averaged 8.8 per cent of lead and 3.9 ounces of silver. The first-class concentrates from the same mine averaged 55 per cent lead and 19.5 ounces of silver to the ton. The ore of the Morning mine in 1903 had an average tenor of 7.4 per cent of lead and 2.9 ounces of silver per ton. The average contents per ton of ore in the Helena-Frisco mine in 1903 were 4.5 per cent of lead and 2.7 ounces of silver. Such ore, however, is unprofitable. In 1897 the average of the same mine was 5.5 per cent of lead and 4.2 ounces of silver. Probably the richest ore now produced on a large scale is that of the Hercules, with approximately 50 per cent of lead and 45 ounces of silver to the ton. This, however, is picked material, as this mine does not at present concentrate any of its ore.

Treatment of the ores.—The Hercules mine ships only crude ore. The Bunker Hill and Sullivan, Last Chance, and Hecla mines ship a little crude or picked ore, which in no case exceeds 2 per cent of the total tonnage mined, or 7 per cent of the total shipping product. The greater part of all the ore mined is concentrated in the district to a product containing from 50 to 60 per cent of lead. The number of tons of ore reduced to 1 ton of concentrates varies. Of the low-grade Gold Hunter ore, about 12 tons are required to make a ton of concentrates containing 50 per cent of lead and 55 to 60 ounces of silver. In the Bunker Hill and Sullivan mill 7½ tons of ore containing from 8 to 16 per cent of lead and from 3.6 to 6.8 ounces of silver to the ton are concentrated to 1 ton containing about 55 per cent of lead and 19.5 ounces of silver. From 900 to 1,000 tons of ore are treated daily in this mill, and about the same quantity in the Morning mill. The combined Standard and Mammoth mills treat from 1,000 to 1,200 tons daily. The saving effected in the best mills is about 80 per cent of the total market value of the lead and silver.

The ore and concentrates from the Bunker Hill and Sullivan mine go to the Tacoma smelter, owned by the company, where they are smelted with concentrates from the Treadmill mine, on Douglas Island. The Hercules ore also goes westward, to the Selby Smelting and Refining Company, in California. The concentrates from the Hecla are shipped to the Ohio and Colorado Smelting and Refining Company, at Salida, Colo. Most of the ore from the other mines goes to the various plants of the American Smelting and Refining Company, particularly to the smelter at East Helena, Mont., although considerable quantities are sent to Denver, Pueblo, Omaha, and El Paso.

Cost of mining and treatment.—The cost of mining and concentrating per ton of ore stoped ranges from about $2, in the Wardner mines to about $3 in the Canyon Creek mines, where the ore bodies are narrower and where pumping and hoisting are necessary. In the Bunker Hill and Sullivan mine the costs per ton of ore stoped in 1903–4 were as follows:

Costs in Bunker Hill and Sullivan mines.

Mining and concentrating	$1.97
Freight and smelter charges	2.17
Discounts for loss of lead and silver in smelting	.60
Total	4.74

The average assay value of this ore was $6.80 per ton. The freight on ores and concentrates varies from $8 to $12 a ton, according to tenor, and a uniform charge of $8 a ton is made for smelting. Ore of which more than 12 tons is required to make 1 ton of concentrates containing 50 per cent of lead, can rarely be made profitable.

THE GOLD DEPOSITS.

Veins.—The only gold-bearing veins that are now productive occur near Murray. The quartz veins on Elk Creek apparently produced some gold several years ago, but the workings upon them have long been abandoned and are not accessible. The best known veins near Murray are the Golden Chest, just north of Littlefield, and the Mother Lode group of veins on Ophir Mountain, situated on the south side of Prichard Creek, between Littlefield and Murray.

With few exceptions the veins of the Murray area belong to the class known as bed veins (Lagergänge). They usually follow the stratification planes of the Prichard formation. Occasionally they jump from one plane to another, the two parts of the vein being connected by small stringers across the intervening bed. In the Golden Chest mine there are at least six of these bed veins in a zone 150 feet in width. Their general strike is about N. 17° E., and they dip westward at angles ranging from 40° to 45°. These veins are usually a foot or two in width, but in some places a width of 10 feet is attained. They are filled with quartz, often strikingly banded, containing free gold, auriferous pyrite, galena, sphalerite, and chalcopyrite, with occasional bunches of scheelite. The best ore is said to have been worth $70 to $90 a ton and was shipped crude. The ore now worked in the 20-stamp mill is of much lower grade, probably not over $7 per ton.

On the north face of Ophir Mountain are two bed veins, one 250 to 300 feet vertically above the other. These veins have a general northeast strike, and dip northwest at angles of 18° to 20°. The veins are of the same general character as those of the Golden Chest mine, but contain rather less abundant sulphides. These were formerly worked by the Mother Lode, Occident, and Treasure Box mines by flat stopes extending from the surface into the hill. Some pockets of rich ore, containing much free gold, have been found in these mines and were treated in arrastras. The veins as a whole, however, are of rather low grade and have not been stoped for more than a few hundred feet from the surface. Their average width is probably not over 8 inches. Just west of these veins is the Mead vein which strikes about north 15° east and dips easterly at about 75°. This is a fissure vein, cutting the beds of the Prichard formation. Its relation to the bed veins east of it is unknown, as it apparently has not been considered worth while to explore the intersections or junctions of these veins. The Mead vein is said to contain a pay shoot of $25 ore. The vein consists of white quartz with sometimes a little siderite (or other ferruginous carbonate) near the walls and with auriferous pyrite, chalcopyrite, and galena in the medial portion. A number of small bed veins have been worked west of Murray, the most noted being the nearly horizontal Buckeye Boy, in Dream Gulch, which produced about $25,000 in gold from a single small pocket.

Placers.—The older placer deposits of Murray constitute what is locally called the Old Wash and are remnants of an earlier channel of Prichard Creek from 250 to 300 feet above the present stream. These gravels, which are in part derived from older gravels deposited still higher above the present valleys, have been hydraulicked near Murray, but have not proved very rich.

Most of the placer gold of the Murray region has come from the bottoms of the existing gulches and has been obtained by simple sluicing, booming, drifting, and dredging. The bed of Prichard Creek has been worked about a mile west of Murray by a hydraulic elevator, but the depth of the gravel, which averages about 30 feet, has proved in most cases an insurmountable obstacle to successful exploitation. In 1903 three dredges were at work near Delta, of which one only, at the mouth of Trail Creek, was operated at a profit, on gravel running about 10 cents to the yard.

The gravel of Trail Creek near Delta is from 18 to 20 feet deep, and was formerly worked by sinking shafts to bed rock and then drifting. At present about $6,000 a year is obtained from these gravels by booming. In this method the water is impounded in a reservoir fitted with an automatic discharge gate. When the reservoir is full the gate opens, and the whole body of water is directed against the gravel in such a manner as to wash it away. A small stream is thus rendered far more effective than if it were continuously employed. When the gravel has been removed to within 2 feet of the bed rock the remainder is shoveled into sluices.

The gold is coarse, nuggets up to 40 ounces having been reported. They are usually somewhat hackly, and often contain particles of quartz. From $15 to $18 an ounce is usually obtained for the placer gold.

THE COPPER DEPOSITS.

The only productive copper deposit in the region is that of the Snowstorm mine, east of Mullan. The deposit occurs in the Revett quartzite, and consists of an impregnated cupriferous zone, which conforms with the bedding planes. The deposit strikes N. 60° W., and dips 65° to the southwest. It has a maximum width of 40 feet. The ore consists of chalcopyrite, bornite, chalcocite, and perhaps other cupriferous sulphides disseminated in small particles through the quartzite and in part oxidized to cuprite and malachite.

The mineralization along the zone is not easily accounted for, as the quartzite is not particularly fissured and is apparently not different in character from the quartzite of the foot wall and hanging wall.

The greater part of the mineralized quartzite contains about 4 per cent of copper, 6 ounces of silver, and 0.1 of an ounce in gold to the ton. The ore shipped is worth from $9 to $10 a ton, and goes to Butte and Tacoma. Smelting and freight charges are $5 a ton, but the smelters require that the silica shall not fall below 90 per cent. In 1903 a leaching mill was being erected on the South Fork to treat the ore.

GENERAL CONDITIONS OF MINING.

Labor.—The turbulent condition that existed in the Coeur d'Alene district from 1892 to 1899, and the notoriety given the locality by the deeds of violence then perpetrated justify a brief account of the present relations of the mine owners to their employees.

Up to 1892 all men working at the mines received $3.50 a day. In the spring of that year the depression in the prices of lead and silver called for retrenchment in operating expenses, and wages were reduced to $3, except for miners, who retained the old rate. The results of this action have already been related. The men struck, but finally returned to work on the mine owners' terms. Shortly after, on the ground that further economy was necessary, wages were reduced to $2.50 a day. The men again struck, and the mines, after a period of idleness, resumed operations with wages at the original rate of $3.50 a day. For the next few years the miners' unions were dominant, and the mines were operated under their rule. The attempt of the Bunker Hill and Sullivan mine to free itself from these restrictions brought about the crisis of 1899, which put an end to the rule of the unions.

At the present time all the prominent companies, with one exception, engage their men through a central employment bureau. The wages paid in the principal mines are as follows:

Wages paid in principal mines in Coeur d'Alene district, Idaho.

Foreman	$6.00 to $7.00
Locomotive engineers (Morning mine)	6.00
Shift bosses	4.00 to 6.00
Head blacksmiths	4.50
Hoisting engineers	4.00
Blacksmiths	4.00
Timbermen	3.75 to 4.00
Miners, machine men, muckers, mill men, and blacksmiths' helpers	3.50
Yard men	3.00

These wages, all things considered, are undeniably good, for the district is readily accessible, has a moderate altitude, and an almost ideal climate. The mines, moreover, have convenient adits and are well equipped and well ventilated. The cost of living, compared with other mining districts in the Rocky Mountains, is moderate.

The present conditions in the district appear to be satisfactory to employers and to employees. Wages are as high as they were before trouble began, but lawlessness no longer exists, property is secure, and mines can be operated without improper interference. As a result, the district enjoys a prosperity which was impossible under former conditions and which is shared by all who are developing its resources.

Power.—The district is well supplied with water, very little of which is allowed to run to waste. The Bunker Hill and Sullivan, Morning, Hunter, Hecla Mammoth, and Standard mills are all run by water power for at least part of the year, usually by Pelton wheels under heads up to 900 feet. Water power is also utilized to a considerable extent for compressing air, the Morning mine having a 100-drill Rix compressor driven by Pelton wheels under heads of 1,200 to 1,500 feet. The Hecla mill and the pumps in the Tiger-Poorman mine are usually run by electricity, locally generated by water power.

Recently electric power, generated at the falls of Spokane, has been brought into the district and is used in running the Tiger-Poorman and Last Chance mills, a 40-drill compressor at the Morning mine, and other machinery. The length of the line from Burke or Mullan to Spokane is about 100 miles. In 1903 this line was carrying 45,000 volts and furnishing about 1,600 horsepower. The cost of this power at the mines is $50 per annum for each horsepower. This is cheaper than steam, though the latter power is used for hoisting at the Tiger-Poorman and Standard-Mammoth mines.

Timber.—All of the large mines require much timbering, and probably few mining regions are better supplied than the Coeur d'Alene district with abundant and cheap material suitable for this purpose. A large part of the timber used is derived from the vicinity of Coeur d'Alene Lake. Some is cut in the southeastern corner of the district, and the Hercules mine has its own timber land and sawmill on the north side of Tiger Peak.

ZINC AND LEAD DEPOSITS OF SOUTHWESTERN WISCONSIN.

By U. S. Grant.

INTRODUCTION.

The lead and zinc region of Wisconsin comprises Grant, Lafayette, and Iowa counties. It lies between the Wisconsin River on the north, the Illinois boundary on the south, and the Mississippi River on the west. Mining for lead began here about eighty years ago and has continued to the present time. Zinc mining was not undertaken until some years after lead mining began, but at the present time the zinc ores are the most important. There was a marked depression in the mining business in this region until within the last four or five years, when active operations were resumed, and the region has again become an active producer of lead, and especially of zinc.

The Wisconsin region comprises the most important part of the upper Mississippi Valley lead and zinc district, which also includes adjoining portions of Iowa and Illinois. Investigations in this district have been recently carried on by the United States Geological Survey and by the Wisconsin Geological and Natural History Survey, and some preliminary results have been published.[a] The Federal Survey has in preparation an extensive report on the ore deposits of the upper Mississippi Valley lead and zinc district and a report on the geology of the Mineral Point quadrangle, which includes the major part of the producing mines in Wisconsin. The State survey has in preparation a report which will include detailed topographic and geologic maps of several areas in which mining operations are now active.

The principal towns of the Wisconsin region are Mineral Point, Platteville, Dodgeville, Darlington, and Shullsburg. Branch lines of the Chicago and Northwestern, the Chicago, Milwaukee and St. Paul, and the Illinois Central railways reach this region and furnish an outlet for ore to the zinc smelters at Lasalle, Peru, and Wenona, Ill., at which points much of the zinc ore is reduced. Some is also

[a] Bain, H. F., Lead and zinc deposits of Illinois: Bull. U. S. Geol. Survey No. 225, 1904, pp. 202–207.

Bain, H. F., Zinc and lead deposits of northwestern Illinois: Bull. U. S. Geol. Survey No. 246, 1905.

Grant, U. S., Preliminary report on the lead and zinc deposits of southwestern Wisconsin: Bull. Wisconsin Geol. Nat. Hist. Survey No. 9, 1903.

smelted at North Chicago, and most of the zinc carbonates and the lower grades of the zinc sulphides are shipped to Mineral Point, Wis., where an extensive plant for the manufacture of zinc oxide and sulphuric acid is located. Within the last year a new railway—the Mineral Point and Northern—has been constructed. This furnishes an outlet by rail for the ores from Highland, which is the most important point in the northern part of the ore-bearing region. Recently a lead furnace has been reopened at Dodgeville, Wis., and plants for the manufacture of mining and concentrating machinery have been established at Galena, Ill., and at Platteville, Wis.

GENERAL GEOLOGY.

The outcropping strata are of early Paleozoic age. Igneous rocks are not exposed, but underlie the Paleozoic sediments. The dip of the strata is at a very low angle toward the south-southwest, averaging about 20 feet per mile. Locally the rocks have been thrown into gentle folds, whose axes have a general east-west direction and whose south limbs are long and gently sloping, while their north limbs are short and steeper. The formations represented are shown on the accompanying section, in which the approximate average thickness of each is given. The important deposits of zinc and lead occur in the Galena and Platteville limestones, which comprise the surface rocks over the larger part of the region.

Formations of the Wisconsin lead and zinc region.

	Feet.
Pleistocene: loess and soil	7
Silurian: Niagara limestone	50
Ordovician:	
Maquoketa shale	160
Galena limestone	230
Platteville limestone	55
St. Peter sandstone	70
"Lower Magnesian" limestone	200
Cambrian: "Potsdam sandstone"	700

The Platteville—known locally as the Trenton—limestone is made up largely of nonmagnesian beds, although in its lower part are certain magnesian strata. The thickness of the Platteville averages 55 feet. It ranges from 40 to nearly 70 feet, being greatest toward the eastern part of the region. A generalized section of this formation is as follows:

Generalized section of Platteville formation.

	Feet.
4. Limestone and shale	10–20
3. Thin and undulating bedded very fine-grained limestone	15–25
2. Heavy-bedded magnesian limestone or dolomite	15–25
1. Blue shale	1–5

The upper member of this section consists of both limestone and shale, commonly in alternating beds, although there is comparatively little uniformity in this respect in different parts of the region. In general it can be said that the shale layers are better developed in the west, while the limestone is more important in the east. The shale beds are usually green or blue, though some of them are white, yellow, chocolate colored, and even black. The chocolate-colored and black shales are highly carbonaceous and are locally termed "oil rock," though the main bed of chocolate-colored shale or the oil rock proper lies just at the base of the Galena. The limestone is commonly a thin-bedded, fine-grained blue rock, which is occasionally subcrystalline and usually nonmagnesian, although it becomes magnesian toward the east. The most marked part of this member of the Platteville is the "glass rock," which is a dense, very fine-grained, hard, conchoidally breaking limestone. It is light chocolate colored when fresh, but quickly weathers to light gray. The shales, and especially the limestones, of this member are rich in fossils, and among these a brachiopod—*Dalmanella subæquata* Conrad—is common.

The Galena limestone is essentially a dolomite, most of which is coarse grained and porous, and occurs in beds from 1 foot to 4 feet in thickness. The top and sometimes the bottom of this formation is thin bedded. Four divisions are recognizable, as follows:

General section of Galena limestone at Dubuque, Iowa.

	Feet.
4. Thin-bedded, nonflinty, earthy dolomite	30
3. Thick-bedded, nonflinty, coarse dolomite	60
2. Thick-bedded, flinty, coarse dolomite	90
1. Thick to thin bedded, nonflinty dolomite, with the main oil-rock horizon at the base	60

In the Wisconsin region No. 1 averages 40 feet in thickness. No. 1 of this section is not always entirely dolomitized, some of the lower part in certain localities consisting of thin-bedded, subcrystalline limestone, but the dolomitic character is the common feature in the immediate vicinity of ore deposits. At the extreme base of the Galena limestone is a chocolate-colored carbonaceous shale, or shale mixed with earthy limestone, to which the name oil rock has been applied. This varies in thickness from 1 inch to 5 feet and is a very characteristic and easily recognized horizon. It occurs at the bottom of many of the mine shafts. The bottom of this oil rock is regarded as the base of the Galena limestone. It is usually underlain by a thin bed of yellow or white clay or soft shale, which is frequently spoken of by the miners as "the pipe clay" or "the clay bed."

About 40 feet above the base of this member—No. 1—of the Galena is a layer, 1 foot to 3 feet in thickness, which carries numerous remains of *Receptaculites oweni* Hall, known locally as "the sunflower coral" or "the lead fossil." Closely connected with this horizon, which marks the top of No. 1 of the above section, are the first of the flinty nodules and layers which are so common in No. 2 of this formation.

THE ORE DEPOSITS.

The ores consist of galena, sphalerite, smithsonite, and iron sulphide; the last usually in the form of marcasite. The ore deposits occur (1) in cracks or irregular openings, (2) in apparently brecciated or very porous parts of the Galena limestone, and (3) in small particles in certain layers of rock. The first class of deposits are known as crevice deposits, the second as honeycomb deposits, and the third as disseminated deposits. These three types are frequently well defined, though at other times they grade into one another and can not be regarded as genetically distinct.

The crevice deposits are the most important. In the upper half of the Galena limestone these deposits commonly exist in vertical crevices, which are enlarged to small caves along certain beds of rock. On the walls of such caves the ore frequently passes into honeycomb deposits, which consist of apparently brecciated or semibrecciated porous rock, the fragments of which are surrounded by ore. The Hazel Green mine, near the town of Hazel Green, furnishes a good example of the crevice deposits in the upper half of the Galena limestone. Deeper down in this limestone the crevices commonly become inclined and also run horizontally along bedding planes. These inclined and horizontal crevices carrying ore form the well-known flats and pitches of the Upper Mississippi Valley lead and zinc district. The flats and pitches are especially well developed in the lower member of the Galena limestone and in the lower half of the next overlying member. At times flats of ore are found running back from the foot wall of the pitch on either side of a deposit, thus enriching large blocks of ground so much that the whole can be sent to the concentrating mill. The Hoskins and the Kennedy mines, near Hazel Green, and the Enterprise mine, at Platteville, are types of ore bodies in which the additional flats just mentioned occur. Large flats at times occur in and just above the main oil-rock horizon, such deposits consisting frequently of a combination of the crevice and the disseminated deposits. Such flats also exist in connection with another layer of oil-rock material in the upper part of the Platteville limestone just below the glass-rock horizon. About Dodgeville (Williams mine), as described on pages 313–314, and at Linden (Mason mine) these flats are well developed.

In the crevice deposits the ores have a general order of sequence of deposition as follows, beginning next to the wall rock: (1) marcasite; (2) sphalerite with at times some galena; (3) sphalerite, frequently the main mass of the ore; (4) cubes of galena; (5) calcite; (6) barite; (7) open cavity. This order, while not universal, is exceedingly common, although all members of the sequence are usually not present in any one crevice. Not uncommonly the deposits have been fissured and the cracks filled in with later marcasite, and at times there is a mixing, apparently, of all the sulphides.

The best known disseminated deposits occur along tributaries of the Little Platte River, 3 or 4 miles west and southwest of Platteville. Here this type of deposit, lying in and just above the main oil-rock layer, is less rich in marcasite than are the flats and pitches. These deposits are well shown in the Graham, the Capitola, the St. Rose, and the Klondike mines.

The ores thus far described lie below the level of ground water. In the crevices above this level are layers of smithsonite, clearly derived from the alteration of sphalerite, and galena, the latter frequently in large masses. Such ores were early mined in this region and they still continue to be mined, although now of much less relative importance than formerly.

The origin of the ore deposits will be discussed in a comprehensive report on the lead and zinc deposits of the whole Upper Mississippi Valley lead and zinc district. It is sufficient to state here that the ore deposits without question owe their origin to circulating waters which have leached the metallic substances from the surrounding limestone, mainly the Galena limestone, and deposited them in their present positions. At least one important agent in the precipitation of these metallic sulphides was the carbonaceous matter in the rocks, especially in the oil-rock horizon.

MINING AND CONCENTRATING.

In former years, and to-day in some of the smaller diggings, mining was carried on in a very primitive manner for the most part. The ores were mined and brought to the surface usually by hand and were cleaned by cobbing or by hand jigging. The present development of the region is due in considerable part to the introduction of more modern methods of mining and of concentrating the ores. The plants are, from the nature of the deposits, comparatively small, but well adapted to the needs of the region. During the last three years about thirty concentrating mills have been erected. These are similar to those used in Joplin region, and make a successful separation of the galena from the sphalerite and the marcasite, but these two, because of somewhat similar specific gravity, can not be successfully separated from each other by ordinary jigging. Still the marcasite percentage in the cleaned ore is frequently low enough to allow the ores to be used by the zinc smelters, and in cases where the marcasite percentage is higher the ores are sold to the Mineral Point Zinc Company for use in the manufacture of sulphuric acid and zinc oxide. A few of the mines have installed roasters and magnetic separators, and thus the quality of the ore is increased. The results in this work seem to be very satisfactory. In fact it is claimed that ore running 60 to 62 per cent zinc is produced in this manner, and that prices above $40 per ton—in one case as high as $47—have been obtained. The problem of the marcasite impurities in the zinc ores, which is a very important one in this region, thus appears to have been solved in a satisfactory manner, and steps are now being taken to build more roasters and magnetic separators.

Some experiments have been made on the separation of the marcasite from the sphalerite by static electricity. If this can be successfully and economically done the marcasite, which after roasting is now unsalable, can be used in acid making. In a few of the mills concentrating tables have been introduced, but their use has not become common.

PRODUCTION.

The annual zinc output of the district is probably about 20,000 tons, selling for a little less than a half million dollars. To this should be added approximately $135,000 realized from the sale of 3,000 tons of galena, and a few thousand from iron sulphide (marcasite), which has recently begun to be produced in commercial quantities in the vicinity of Montfort.

CONCLUSIONS.

In the Wisconsin region there still exist above the level of ground water considerable quantities of galena and smithsonite. Below the level of ground water are extensive bodies of sphalerite, at times mixed with galena. There is good reason to believe that such bodies of sphalerite will last for a number of years and that a considerable mining industry will be here carried on. The present high prices of lead and spelter, coupled with the fact that the lower grades of sulphide ores can be brought up to higher grades by roasting and magnetic separation, make the outlook promising.

Explorations should, in the main, be carried on by deeper work in areas which have already produced considerable quantities of galena and smithsonite above the level of ground water. While it is not to be expected that below every area which has produced these ores in the higher levels there are deposits of sulphide ores of zinc (or of zinc and lead) of economic value, still this fact has been demonstrated in so many instances that it should furnish a rule for future exploration. At the same time the actual agreement of the lower deposits with the upper ones as to value, form, and direction can not always be relied upon. In selecting an area for prospecting care should be taken to select such a one as has, below the level of ground water, a reasonable thickness of ore-bearing rock—i. e., of Galena limestone, or, in the eastern part of the region, of at least the upper member of the Platteville limestone. While it is possible that economic deposits of value may exist below the Platteville limestone, this is not considered probable, and consequently expensive explorations or deep drilling in these formations is not recommended. Attention is called to the advisability of carrying on preliminary explorations by drilling rather than by sinking deep test pits and shafts, for the expense of the latter work is considerably greater, and this expense is commonly increased by the large quantities of water encountered. Experiments are now being made as to the advisability of using the diamond drill instead of the ordinary churn drill for prospecting in this district.

ZINC AND LEAD MINES NEAR DODGEVILLE. WIS.

By E. E. Ellis.

Location.—The Dodgeville deposits lie in the extreme northeast portion of the Wisconsin lead and zinc district, which occupies about 1,500 square miles in the southwest corner of the State. This area has been chosen for discussion because of its comparative isolation from the remainder of the district and because its mines are types of the ore deposits occurring in the so-called "glass-rock opening" of the Platteville limestone. The area in which mining has been carried on is relatively small, including not more than 10 square miles, while nine-tenths of the mining has been carried on within the limits of four sections of land.

The history of this portion of the district has been similar to that of the rest of southwestern Wisconsin. Mining was first carried on for galena alone, then for galena and smithsonite, a market being found for the latter, and of late years largely for zinc blende.

Development work.—There are at present seven producing mines in the area—the Williams Brothers, producing blende and galena; the Hartford Lead and Zinc Mining Company, starting development work on an old lead range; the Snowball and Oxman mines, both yielding galena and blende; the Davy-Pengelly mine, with galena and smithsonite, and the Tyrer and McKinley mines, the former producing galena and the latter blende. In the area are a number of abandoned mines which in the past have been producers of galena and smithsonite, while there are a number of small mines that are worked only during the winter. The Williams Brothers' mine has been the heaviest producer in this locality and is the only mine equipped with a concentrating mill.

The machinery used in these mines is very simple, for in no case is the ore hoisted more than 100 feet, while in several of the mines no pumping machinery whatever is needed. In the mines not equipped with concentrating mills the ores are cleaned by hand picking and in small jigs run by horsepower or by hand.

Economic importance.—The vicinity of Dodgeville has been a steady, though never a heavy, producer of galena since 1855. About

600,000 pounds would probably be a fair estimate of the annual production before 1900. During the last five years about 150 tons of galena and 300 tons of zinc ore a year have been shipped from Dodgeville.

Dodgeville is particularly well situated in reference to markets for its ores. It is on the Illinois Central Railroad, and therefore has a direct line to the zinc works at Peru and Lasalle, Ill., which consume the higher-grade ores. The low-grade zinc ores may be shipped on the Chicago and Northwestern to the works at Waukegan, Ill., but generally find a ready market at the Mineral Point Zinc Works. These are 9 miles away by wagon road, and are also reached by railroads which gave a good rate. A smelter recently reestablished at Dodgeville gives a home market for all the galena produced.

The large horizontal extent of the flats and the small amount of pumping necessary make the working of these mines relatively cheap, and permits the development of leaner bodies of ore than would generally be profitable under the mining methods followed. The galena and smithsonite above the level of ground water occur in soft rock, as a rule, and are readily separated by hand sorting. They are relatively free from iron, and consequently are of good grade. The ores below water level are intimately associated with marcasite and are separated from it with difficulty, the grade of the blende concentrates in consequence being considerably lowered, although averaging well up with those of the Wisconsin district in general.

Physiography of the area.—Dodgeville is situated on the divide between the drainage of the Pecatonica and Wisconsin rivers, while the center of the mining district is among the small headwater streams of Dodges Branch, which flows into the Pecatonica. The country is perfectly drained, being part of the driftless area of Wisconsin; and as the streams all flow to the southeast and are nearly parallel, a series of ridges is left, with long, gentle slopes to the southeast. In the least eroded portion of the area the hills rise to an average height of 1,250 feet above tide, which marks the level of an old peneplain. The small streams have an average fall of 60 feet to the mile near their sources and have flat bottoms, while the valleys have gently rounded side slopes.

Stratigraphy.—The formations represented are all sedimentary and of early Paleozoic (Ordovician) age. Those exposed within the area are the Galena limestone, the Platteville limestone, the St. Peters sandstone, and the "Lower Magnesian" limestone.

The full thickness of the Galena limestone does not occur within the area, although at places 200 feet of this dolomite remain. In the territory where the larger proportion of the mining is carried on erosion has left not more than 100 feet of the limestone. This includes the lower 50 feet of nonflinty dolomite, above which occur the intercalated beds of flint and dolomite, which, when complete, attain a thickness of 100 feet. The base of the Galena is marked by a constant shale bed varying from 1 to 3 feet in thickness. This shale consists of blue clay and of brown carbonaceous material, which gives it the name of "oil rock." It is a very important horizon, and throughout the greater portion of the Wisconsin lead and zinc district marks the lower limit of mining operations.

The Platteville limestone has here a rather uniform thickness of 65 feet and is much less magnesian than the Galena. The upper beds, called the "glass rock," constitute the important ore horizon. The glass rock is a fine-grained, hard limestone from 4 to 12 feet in thickness. It shows considerable variation in coarseness of grain within short distances and carries varying amounts of magnesium carbonate, although not approaching a dolomite in composition. Near the base of the Platteville is a generally recognized series of beds of magnesian limestone, known as the "quarry rock."

Generalized section of the Platteville limestone near Dodgeville.

	Ft.	in.
7. Glass rock	10	0
6. Dark-brown to black, hard carbonaceous shale	0	3
5. Hard, gray limestone	10	0
4. Fossiliferous limestone, fine grained and separating into thin, irregular beds	18	0
3. Clay bed	0	2
2. Dolomite limestone in heavy beds (quarry rock)	25	0
1. Sandy shale	0	8

The St. Peter sandstone, occurring below the Platteville, varies in thickness from 50 to 150 feet and consists of pure quartz sandstone, frequently iron stained and with considerable variation in the degree of its cementation.

The "Lower Magnesian" limestone is a cherty dolomite, varying greatly in thickness and character and frequently containing sandstone layers interbedded with the limestone. Only the upper portion of this limestone occurs within the limits of the Dodgeville area and there is considerable evidence of an erosion interval between it and the St. Peter sandstone.

With the exception of this small erosion interval, the relations of the formations are those of normal sedimentation with changing littoral conditions. The strata, while in general nearly horizontal, have been subjected to stresses which locally have produced gentle though well-defined folds.

Ore deposits.—The ore bodies of this district occur in vertical crevices, in pitching crevices, and in flats, occupying a large horizontal space as compared with their vertical extent. The quantities of sphalerite and galena produced are at present nearly equal, while a small amount of smithsonite is mined in connection with them. Calcite is frequently associated with these ores, while marcasite almost invariably accompanies the blende in varying amounts.

Very little mining in this area has been done in the Galena limestone, the important ore bodies occurring in the glass rock. The ores obtained from the Galena limestone have been galena and smithsonite, which occur mainly in vertical crevices, though with a small development in flats and pitches.

The ore bodies now worked are in the so-called "glass-rock opening" of the Platteville limestone, and consist of irregular flats with occasional small vertical crevices. The beds forming the flats of the glass-rock opening range in vertical height from 1 to 7 feet, average 60 feet in width, and frequently have very considerable longitudinal extent. In another portion of the Wisconsin district deposits of the same class have been worked in individual mines for three-fourths of a mile in one direction. In the Dodgeville area these flats show no parallel arrangement, and even the individual ore bodies do not keep a single direction, but vary from place to place. This variation in direction is probably due to the position of the feeding crevices above.

Where the ore bodies are below the level of ground water the predominant ore is zinc blende, while above or near water level the important ore is galena with associated smithsonite. In the ore bodies which have been formed above ground water and which were consequently subjected to the oxidizing influences of surface waters, the limestone is generally soft and disintegrated and the ore occurs in a flat at the base of the glass rock, directly above a bed of hard, impervious, black shale 2 to 5 inches in thickness. These flats of galena and smithsonite are very irregular, varying from a solid sheet 4 inches in thickness to small, lenticular masses only a few inches in longest diameter and separated by barren rock. In the ore bodies which have escaped the oxidizing surface waters, either because of an impervious bed of oil rock above or because they were sufficiently below ground-water level, the predominant ore is zinc blende with a small proportion of intimately associated galena and with considerable iron sulphide, generally in the form of marcasite. In ore bodies of this latter type ore occurs in a flat at the base of the glass rock and above the thin shale bed, but the main body of ore is in irregular seams traversing the rocks in diverse directions, but with the majority parallel to the bedding planes of the limestone. The irregular seams represent fractures in the glass rock which have been enlarged by solution and filled with ore, and give a marked brecciated appearance to the limestone. The stratum occupied by these bedding and cross seams has a vertical height of from 1 to 5 feet and the proportion of ore varies greatly from place to place in the same mine.

Genesis of the ores.—The ore bodies of the glass-rock opening are probably all of a secondary nature, as all the evidence points toward the Galena limestone as the original source of the lead and zinc ores of the Wisconsin district. These flats are all in a deeply eroded area in which there remains a comparatively small thickness of Galena limestone, and are close to or below the level of ground water. In the deposits above ground-water level the ores are galena and smithsonite. The predominant ore below water level is blende, while crevices leading from above show the transition from the oxidized ores to the unaltered sulphides. The Galena limestone carried considerable ore, as is shown by the old lead and dry-bone diggings in this formation, but as erosion progressed and lowered the level of ground water the solution and downward transportation of the less stable sulphides—blende and marcasite—progressed equally, leaving the less soluble sulphide of lead and some of the zinc, which was reprecipitated as the carbonate. The brittle glass rock was easily fractured under the stresses which the strata have undergone, and small, irregular cracks have been formed. These, enlarged by solution and filled with ore, give the rock a brecciated appearance. The ore-bearing waters coming from above followed these comparatively open channels and, taking calcium carbonate into solution, deposited the sulphides, the precipitation being assisted by the carbonaceous shale at the base of the glass rock. The shale in this area has performed the function exercised by the "oil rock" in a considerable portion of the Wisconsin lead and zinc district, and has acted as an impervious layer, stopping the downward circulation of ore-bearing waters. Nowhere in this vicinity has ore been found below this shale bed, while in all the mines a sheet of ore occurs directly above.

The ores of the glass-rock opening constitute the most important bodies yet developed in the vicinity of Dodgeville, but in the greater part of the Wisconsin lead and zinc district the more valuable lead and zinc deposits occur above this horizon, and there is no reason to suppose that such deposits may not exist in the less eroded portions of the Dodgeville area. Considerable work has been done in the past on lead crevices at these higher elevations, and one company has recently started development work on one of these old lead ranges.

Mention should also be made of the fact that some prospecting has shown the presence of galena in the upper portion of the "Lower Magnesian" limestone near Dodgeville, although no development work has been done at that place and no definite idea can be formed of the possible extent of such bodies.

PUBLICATIONS ON LEAD AND ZINC.

Many papers relating to silver-lead deposits will be found included in the list on pages 158 to 160 of this bulletin. The principal other papers on lead and zinc, published by the United States Geological Survey, or by members of its staff, are the following:

ADAMS, G. I. Zinc and lead deposits of northern Arkansas. In Bulletin U. S. Geol. Survey No. 213, pp. 187–196. 1903.

BAIN, H. F. Lead and zinc deposits of Illinois. In Bulletin U. S. Geol. Survey No. 225, pp. 202–207. 1904.

BAIN, H. F., VAN HISE, C. R., and ADAMS, G. I. Preliminary report on the lead and zinc deposits of the Ozark region [Mo., Ark.]. In Twenty-second Ann. Rept. U. S. Geol. Survey, pt. 2, pp. 23–228. 1902.

CLERC, F. L. The mining and metallurgy of lead and zinc in the United States. In Mineral Resources U. S. for 1882, pp. 358–386. 1883.

HOFMANN, H. O. Recent improvements in desilverizing lead in the United States. In Mineral Resources U. S. for 1883–84, pp. 462–473. 1885.

ILES, M. W. Lead slags. In Mineral Resources U. S. for 1883–84, pp. 440–462. 1885.

KEITH, A. Recent zinc mining in East Tennessee. In Bulletin U. S. Geol. Survey No. 225, pp. 208–213. 1904.

SMITH, W. S. T. Lead and zinc deposits of the Joplin district, Missouri-Kansas. In Bulletin U. S. Geol. Survey No. 213, pp. 197–204. 1903.

ULRICH, E. O., and SMITH, W. S. T. Lead, zinc, and fluorspar deposits of western Kentucky. In Bulletin U. S. Geol. Survey No. 213, pp. 205–213. 1903. Professional Paper U. S. Geol. Survey No. 36. 1905.

VAN HISE, C. R. Some principles controlling deposition of ores. The association of lead, zinc, and iron compounds. Trans. Am. Inst. Min. Eng., vol. 30, pp. 102–109, 141–150.

VAN HISE, C. R., and BAIN, H. F. Lead and zinc deposits of the Mississippi Valley, U. S. A. Trans. Inst. Min. Eng. (England), vol. 23, pp. 376–434.

WINSLOW, A. The disseminated lead ores of southeastern Missouri. Bulletin U. S. Geol. Survey No. 132. 31 pp. 1896.

WOLFF, J. E. Zinc and manganese deposits of Franklin Furnace, N. J. In Bulletin U. S. Geol. Survey No. 213, pp. 214–217. 1903.

IRON AND MANGANESE.

IRON AND MANGANESE ORES OF THE UNITED STATES.

By Edwin C. Eckel.

The Survey has carried on extensive work in the principal iron districts during 1904 and preceding years, and several reports on the field work of 1904 are presented below. Detailed investigations of several important iron districts are now planned for 1905. The relations of the work done in the past and that still remaining to be done can best be shown if the iron-ore production of the United States is subjected to analysis. The figures given below are those collected by the United States Geological Survey and published in its annual volume on Mineral Resources:

Production of iron ore in the United States in 1903, by States and varieties.

[Long tons.]

State.	Red hematite.	Brown hematite.	Magnetite.	Carbonate.	Total.
Minnesota	15,371,396				15,371,396
Michigan	10,592,933		7,397		10,600,330
Alabama	2,779,691	905,269			3,684,960
Tennessee	371,189	481,515			852,704
Virginia and West Virginia	31,609	764,948	4,604		801,161
Wisconsin	646,042	29,011			675,053
Pennsylvania	15,420	202,542	426,637		644,599
New York	83,820	5,159	451,481		540,460
New Jersey			484,796		484,796
Georgia	124,648	318,804			443,452
Nevada, New Mexico, Utah, and Wyoming	235,599	13,800	142,843		392,242
Colorado	3,621	249,288			252,909
North Carolina		17,588	57,664		75,252
Missouri	49,359	14,021			63,380

Production of iron ore in the United States in 1903, etc.—Continued.

State	Red hematite.	Brown hematite.	Magnetite.	Carbonate.	Total.
Texas		34,050			34,050
Kentucky	23,327	8,900			32,227
Connecticut and Massachusetts		30,729			30,729
Ohio				29,688	29,688
Maryland		4,775		5,145	9,920
Total	30,328,654	3,080,399	1,575,422	34,833	35,019,308

These figures can be put into more serviceable form by classing the ores according to their geologic and geographic distribution. As shown below, 5 quite distinct classes can thus be formed. Taken together these five classes will account for over 99 per cent of the total iron-ore production of the United States, leaving unclassified less than 1 per cent.

Of these 5 classes the first consists of the ore from the well-known Lake Superior district. The three classes next in importance agree geographically in being all located in the eastern and southeastern United States, but differ in the character and geological association of their ores. The fifth class includes an ore district in the Rocky Mountain States of great promise but as yet slightly developed.

The relative importance of these five classes as producers is shown in the table below:

Production of iron ores in the United States in 1903, by classes.

	Long tons.	Per cent of total.
Lake Superior ores	26,617,768	76
Clinton fossil ores	3,372,557	9.6
Appalachian Valley limonites	2,731,329	7.8
Eastern magnetites	1,425,182	4.1
Rocky Mountain ores	645,151	1.8
Unclassified	227,321	.7
Total	35,019,308	100

The characteristics of these classes of iron ores and the work that has been done by this Survey in the various districts may be briefly summarized as follows:

(1) The Lake Superior ores, which consist chiefly of hematites, have been studied and mapped in great detail by the Survey. A number of monographs, by Prof. C. R. Van Hise and his assistants, have been issued, each publication taking up one of the districts or "ore ranges." The concluding monograph of this series, which is to summarize the geology of the entire lake region, is now being prepared by Professor Van Hise. The series, taken as a whole, is probably the most complete discussion of any group of ore deposits ever published. Incidentally the studies in this district have led to important generalizations in regard to the formation of ore deposits in general.

(2) The Clinton ores, which outcrop almost continuously from central New York to Alabama, occur as beds of oolitic red hematite in the Clinton group of the Silurian. At present they are exploited extensively only in the southern part of their range, in Tennessee, Georgia, and Alabama. Much of the area in which they occur has been mapped by the Survey, and the results published in geologic folios Nos. 2, 4, 6, 8, 19, 20, 25, 33, 35, 75, and 78; the locations of the areas described in the folios are given in the tables on pages 14 to 17.

The commercial importance of these Clinton ores in the southern Appalachians renders advisable a detailed economic survey of their occurrence and relationships. During the season of 1905 further work in the Clinton ores has therefore been planned by the Survey. Cooperation in this work has been arranged with the Alabama Geological Survey, the investigation being placed in charge of the writer. A detailed survey of the important Birmingham district, conducted on a cooperative basis, is already under way. During 1904 new developments in the ore region at the extreme southern end of this district were investigated by Survey parties, and a brief report on these occurrences is presented by Mr. Burchard.

Aside from their direct commercial importance, the Clinton ores present problems of great interest to the economic geologist. Unlike most other ores, they appear to have been formed simultaneously with the strata in which they are inclosed. The geographic conditions which favored this deposition, and the chemical processes by which it was brought about can not be fully stated without considerable detailed study in addition to the facts now on record. It is hoped that the investigations on the eastern iron ores, now in progress, will throw light on these questions.

(3) The ores of the Appalachian Valley are limonites (brown hematites), mostly associated with the great series of Cambro-Ordovician limestones which form the floor of this valley from Vermont to Alabama. These ores have been mapped in a number of geologic folios, while a discussion of an important Georgia district will be found in Bulletin 213, U. S. Geological Survey, pages 233-242.

In the present bulletin is presented a brief preliminary report on the brown hematites of eastern New York and western New England. It is planned to take up a detailed study of these Valley ores during 1905, commencing with their important developments in Virginia, where cooperative work has been arranged, and continuing the work as fast as possible until the entire area has been investigated. The brown hematite deposits of Alabama will, of course, be studied in connection with the cooperative survey of the Birmingham district referred to above.

(4) The magnetites of the East occur mostly in the belt of pre-Cambrian rocks which forms the Blue Ridge and its northward continuation, the New Jersey and Hudson highlands; but important outlying districts are those of Cornwall, Pa., and the Adirondacks of New York. Professor Kemp has mapped and studied the magnetites of the latter area, and his results will be published by the Survey in folio form. In North Carolina Keith has studied the important deposits of the Cranberry district (Bull. 213, pp. 243–246), while during 1904 Spencer examined a number of magnetite bodies in the New Jersey highlands. Detailed work on these ores, which present problems of unusual difficulty and interest, both in regard to stratigraphy and origin, can be taken up profitably only in connection with folio mapping in the respective areas, or after the completion of such mapping.

(5) The Rocky Mountain ores possess a certain geographic and commercial unity though differing widely in character and geologic association. The bulk of the iron ore produced west of the Mississippi comes from Colorado, Wyoming, and New Mexico, but smaller supplies are obtained from Utah and Nevada. These ores are magnetites, specular hematites, and limonites.

Until recently little attention has been paid to these deposits by either furnacemen or geologists, as the ores have been considered as useful fluxes (for precious metal and other smelters) rather than as sources of iron. The rapid manufacturing development of the Western States has, however, brought some of the iron ores into prominence.

With the practical close of detailed work in the Lake Superior region, the Survey is now free to take up the examination of the iron deposits of the Rocky Mountain States. Papers by Messrs. Boutwell and Leith, describing several Utah ore bodies, appeared in Bulletin 225.

One of the minor producing areas, not included in the above grouping, lies in northeast Texas. It is unique among American sources of iron ore in occurring in the Coastal Plain, being associated with sands, gravels, and clays of Tertiary age. A brief reconnaissance of this Texas area was made in 1904, and a report on the district is presented later.

IRON ORES IN THE BROOKWOOD QUADRANGLE, ALABAMA.

By Ernest F. Burchard.

INTRODUCTION.

In view of the present active interest in the development of the iron ores of Alabama there is presented herewith an outline of the distribution of the ore-bearing formations and a short account of the characters of the ores and their distribution and relationships in the Brookwood quadrangle. This quadrangle is west of the Bessemer quadrangle, in which mining of the Clinton red hematite ore has assumed extensive proportions. The Brookwood quadrangle is a prominent contributor to the supply of brown ore, or limonite, in the production of which Alabama ranks first among the States. The Alabama Geological Survey has already investigated this region, and has published its results in the following papers: Report on the Cahaba coal field, with map, by Joseph Squire, 1890; The iron ores of Alabama, by William B. Phillips, first edition, 1896, second edition, 1898; Report on the Valley regions of Alabama, Part II, by Henry McCalley, 1897; Report on the Warrior coal basin, with map, by Henry McCalley, 1900; and Index to the mineral resources of Alabama, by Eugene A. Smith and Henry McCalley, 1904. The Federal survey of this area is not finished, but the facts reported below either were gathered in the field during the autumn of 1904 by Mr. Charles Butts, Mr. H. S. Gale, and the writer, or have been carefully selected from the reports of the Alabama Geological Survey. In the present survey it has been the policy rather to work along lines which have received attention from members of the Alabama Geological Survey than to duplicate much of their detailed work. For this reason the records of sections published by the State Survey have been freely drawn on after verification of locations and character of the beds from notes of the past season.

GENERAL DISTRIBUTION AND AGE OF FORMATIONS.

A brief outline of the stratigraphy of the Coal Measures in the northwest half of the quadrangle has been given by Mr. Charles

Butts, on pages 359 to 365 of this bulletin. Bordering the Coal Measures of the Warrior field on the southeast and striking in a general direction N. 30° E. is a belt of earlier Paleozoic rocks that have been considerably folded and faulted. All the iron ores of importance in the quadrangle occur along this belt, either interstratified with the Paleozoic or immediately above them in later deposits. There are represented in this belt shales and shaly limestones of the Cambrian system; massive limestone, dolomite, and chert of the Ordovician; limestone, sandstone, bedded iron ore, and shale of the Silurian; thin black Devonian shale; and chert, quartzite, conglomerate, and shale of the Mississippian series of the Carboniferous system. For the most part these beds are highly inclined, and the differential weathering of the edges of the soft shales and hard quartzites and sandstones, together with solution of the limestone beds, has produced a shallow anticlinal valley bordered by quartzitic sandstone ridges and inclosing minor sandstone ridges. This valley, inclosed between Rock Mountain, on the northwest, and Sand and Red mountains, on the southeast, is a well-marked feature, which may be recognized on the topographic map of the Brookwood quadrangle, from the vicinity of Woodstock northeast to McCalla, where it passes beyond the border of the area. It has received the local name of Roups Valley, and to the northeast, in the Birmingham district, is known as Jones Valley. At McCalla, near the eastern border of the quadrangle, the width of Roups Valley is nearly 5 miles, at Green Pond it is about 3½ miles, and at Vance it is 8 miles. To the southeast the valley is bordered by the Coal Measures of the Cahaba coal field. To the northeast these so-called "valley" rocks extend beyond the border of the State, but in the southwest part of the quadrangle they pass beneath unconsolidated Cretaceous, Tertiary, and Quaternary deposits. These Cretaceous and later deposits completely mantle the Paleozoic, even in the deepest stream cuttings in the vicinity of Hagler and southward, but they become thinner and patchy to the northeast, and practically disappear between Goethite and Kimbrel. Between Green Pond, on the Alabama Great Southern Railroad, and Giles, on the Louisville and Nashville Railroad, these unconsolidated beds contain important deposits of brown iron ore. Areal mapping has been so far completed as to make it possible to outline the distribution of those "valley" formations that are of economic importance, but the details of their structure have not yet been fully worked out.

IRON ORES.

Iron ores that are being mined in the Brookwood quadrangle are (1) red ore, or hematite, and (2) brown ore, brown hematite or limonite. This is the order of their importance in the State as a whole, but in the Brookwood quadrangle at present much more brown ore is being mined than red ore.

THE RED ORE.

Distribution, geologic relations, and development.—Hematite occurs in minable quantities to the east and northeast of the Brookwood quadrangle, in the East Red Mountain ridge, which separates Jones and Shades valleys, and in West Red Mountain, which lies between Jones Valley and the Warrior coal field. The ore is in regularly stratified beds, forming a part of the Rockwood formation, which is of Silurian age and which has been termed by the Alabama Geological Survey, the " Red Mountain " or " Clinton." The Rockwood formation is somewhat variable in thickness in the quadrangle, but averages about 350 feet. It consists for the most part of reddish ferruginous sandstone interstratified with yellowish shale and clay, and in places carries limestone beds and conglomeratic sandstone in its upper part. The ore, which consists of calcareous, ferruginous sandstone, sometimes very fossiliferous, occurs near the middle of the formation, and where exploited is in from one to five seams, which vary in thickness from a few inches to 30 feet. Just beyond the border of the quadrangle, along East Red Mountain, from Birmingham to Bessemer, is a practically continuous stretch of mines and strippings on the outcrop of the ore, about 15 miles in length, constituting the most extensive development of the Clinton ore that is known. The Rockwood, or " Red Mountain," formation has been traced into the Brookwood quadrangle in strike with West Red Mountain, near Bessemer. It extends parallel to and less than a mile south of Rock Mountain, and is practically continuous from Valley Creek, in sec. 13, T. 19 N., R. 5 W., to a point in sec. 17, T. 21 N., R. 6 W., about 1 mile northwest of Bibbville. This strip of the formation, while not everywhere presenting an outcrop, doubtless passes diagonally across portions of the following sections, which are between the limits mentioned above: Secs. 13, 24, 23, 26, 35, and 34, T. 19 N., R. 5 W.; secs. 3, 10, 9, 16, 17, 20, and 19, T. 20 N., R. 5 W.; secs. 24, 25, 26, 35, and 34, T. 20 N., R. 6 W., and secs. 3, 4, 9, 8, and 17, T. 21 N., R. 6 W. It would be preferable to represent the distribution of these important beds geographically, but as maps are not to be published with this brief article the locations may be recognized by reference to the topographic map of the Brookwood quadrangle, published by the United States Geological Survey, or to the map of the Cahaba coal field, published by the Alabama Geological Survey. The strike of this strip of rocks presents a broad curve concave to the northwest, and varies from N. 45° E. to N. 25° E. In the northeast part of the strip the rocks dip generally at steep angles (60° to 80°) toward the northwest, except at a number of places where they are locally overturned and dip to the southeast. Three or four seams of ore occur in the formation in secs. 23, 26, and 34, T. 19 N., R. 5 W., but they are either too thin or too sandy to be of value. This portion of the field is comparatively well known, as its proximity to the mining activity at Bessemer has caused it to be fairly well prospected for ore. Sections of several outcrops and strippings are given by McCalley.[a] Farther southwest this strip contains ore of but little value, as is indicated by the cut through the ridge made by the Alabama Mineral division of the Louisville and Nashville Railroad as adapted from McCalley.[b]

Section on the Alabama Mineral division of the Louisville and Nashville Railroad in NE. ¼ sec. 3, T. 21 N., R. 6 W.

	Ft.	In.
18. Débris, Fort Payne chert; probably covers Devonian	--	--
17. Débris, Red Mountain (Rockwood) formation along the railroad for about	175	0
16. Limonite, stratified layer of yellowish ocher between nodules; dip 75° to 80° to the southeast	6–8	0
15. Loam (?), a yellowish ocherous color, doubtless from Clinton shales	7	0
14. Red ore, sandy, pinkish-brown color	12	0
13. Red sandy ore, loam (?), about	12	0
12. Red ore, like 14	3	0
11. Shale, yellowish and orange colors, about	60	0
10. Red ore, soft, with very small amount of pebbles or large siliceous grains, about	1	5
9. Shale, bright yellowish color	5–6	0
8. Red ore, sandy and soft or well leached	2	0
7. Sandstone, yellowish ocher color, about	4	0
6. Red ore, very good, pink, about vertical on outcrop	1	2
5. Sandstone, flaggy, yellowish ocherous color, soft	9–10	0
4. Red ore, about	0	5
3. Sandstone like 5, about	25	0
2. Débris, Red Mountain (Rockwood) formation, though it may cover some Pelham (Chickamauga) strata on northwest side of narrow depression	----	-
1. Débris, Pelham (Chickamauga) limestone	----	-

[a] McCalley, Henry, Report on valley regions of Alabama: Alabama Geol. Survey, pt. 2, 1897, pp. 353–357.

[b] McCalley, op. cit., pp. 467–468.

Seventy-five yards southwest of this cut is a test pit, in which were found two beds of ore, each about 5 feet thick, separated by about 10 feet of sandstone and débris. These beds dip about 75° toward the northwest, and the lower one, which is very sandy, is said to thin down to about one foot within a few hundred feet along the dip. Prospecting near the southwest corner of section 3 is reported to have disclosed two beds of impure ore, of 5 and 2 feet thickness. In the NE. ¼ of SW. ¼ sec. 9, T. 21 N., R. 6. W., on the south side of Gallant Creek, the formation occurs on both sides of a narrow hollow, on both sides of which test pits have been sunk. On the southeast side of the hollow about 10 feet of shaly, sandy ore is shown by one pit, while on the northwest side more than 30 feet of ore is disclosed, most of it being a dark ferruginous sandstone. A corresponding thickness of ferruginous material is indicated by a pit in the SE. ¼ of SE. ¼ sec. 8, T. 21 N., R. 6 W., but the greater part of it does not promise to be valuable. Southwest of sec. 17 the formation disappears in places, through faulting. In the NW. ¼ of NE. ¼ sec. 25, T. 21 N., R. 7 W., several deep pits have been sunk into ore-bearing strata, but thicknesses of only 2 to 5 feet were observed, and the ore was streaked and parted with clay and shale.

In the portion of the strip thus far described the showing of ore does not seem to be sufficiently valuable to encourage mining under present conditions.

At Vance the formation again outcrops, and apparently carries a workable seam of ore. A shaft sunk about 100 yards north of the station goes down 170 feet in nearly vertical ore having a limestone wall to the south. Ore has been shipped from this place to the furnace of the Central Iron and Coal Company at Holt, Ala., but in the autumn of 1904 the property was idle and the shaft was filled with water. A reported analysis of this ore, which is well leached and consequently soft, as published by McCalley,[a] is as follows:

Analysis of iron ore from Vance, Ala.

	Per cent.
Metallic iron	62.59
Silica	9.88
Sulphur	0.01
Phosphorus	0.234

The rocks in this vicinity have been much faulted, and their disturbed condition is shown in the limestone quarry at Vance. To the southwest of Vance the Rockwood formation is offset to the west by faulting, and a strip has been traced by outcrops and prospects from the Alabama Great Southern Railroad at Hurricane Creek trestle. west of Vance, southwestward for about 4 miles. There is a bed of

[a] Op. cit., p. 472.

good ore in this strip of the formation in the southern part of sec. 8, T. 22 N., R. 7 W., and a mine has been opened in it by Mr. W. P. Pinckard, of Birmingham. In November, 1904, the slope had been driven in 440 feet on a bed dipping 15° to 18° in a direction S. 65° E. The seam is reported to be about 10 feet thick, although but 6½ to 7 feet of good clean ore is removed in mining. Some ore is left at the top, since the clay shale overlying the ore body was considered an unsafe roof. Extensive development is projected here, since prospecting with a core drill has yielded results that seemed to warrant it. Limestone suitable for fluxing is exposed over an area of 25 to 30 acres, along the upper part of Big Sandy Creek, less than a mile east of the mine.

Representative samples of the leached (I) and partly leached (II) ore from this slope have been analyzed by George Steiger in the laboratory of the United States Geological Survey with the following results:

Partial analyses of ore from Pinckard's mine.

	I.	II.
	Per cent.	*Per cent.*
Metallic iron	40.26	38.82
Lime (CaO)	1.11	7.48
Phosphorus	.42	.30
Insoluble in HCl and HNO_3 (mainly silica)	32.40	21.95

Still farther to the southwest, and evidently greatly offset by faulting, are two short ridges of the Rockwood formation in sec. 2, T. 24 N., R. 7 W., on Big Sandy Creek, not far from the old Clements homestead. A sandy red ore is reported to outcrop near the base of the southeast of the two ridges, but this is of interest principally because it is the most southwesterly outcrop of the formation on the northwest side of Roups Valley.

On the southeast side of Roups Valley the Rockwood formation enters the quandrangle about 1½ miles south of McCalla, in sec. 7, T. 20 N., R. 4 W., and extends in a direction S. 45° W. along Red Mountain to sec. 7, T. 21 N., R. 5 W., about 1¼ miles southeast of Green Pond. In this vicinity the strike swings gradually around to S. 30° W., and the trend of the formation is in this direction for about 8 miles. This strip of the formation is crossed by the Alabama Mineral division of the Louisville and Nashville Railroad at Big Spring, in the SE. ¼ of SE. ¼, sec. 34, T. 21, N., R. 6 W., and is apparently about 350 feet thick. An attempt to mine the ore at Big Spring was made by Dr. G. B. Crowe, of Birmingham, but the enterprise was apparently unprofitable, since it was soon discontinued. Below is the log, furnished by the Crowe Coal and Iron Company, of a diamond-drill hole penetrating the Rockwood formation at this point. Since the rocks dip steeply, the thickness in vertical section is considerably exaggerated, and allowance should be made for this discrepancy.

Record of bore hole at Big Spring, Ala.

	Thickness of formations.		Total depth.	
	Ft.	*in.*	*Ft.*	*in.*
Clay and bowlders	22	6	22	6
"Fort Payne" chert(?):				
Chert	63	6	86	0
Blue shale	9	0	95	0
Cherty limestone	12	0	107	0
Impure limestone	3	0	110	0
Decomposed limestone, no cores and caving	41	9	151	9
Rockwood formation:				
Hard limestone	3	3	155	0
Reddish sandstone	55	0	210	0
Impure limestone, slate streak	43	6	253	6
Red mottled ore-bearing matter	3	6	257	0
Lime rock, mottled red streaks with slate	40	0	297	0
Marbleized lime rock, gray	3	0	300	0
Marbleized lime rock, gray, with fossils	13	0	313	0
Marbleized lime rock, liver-colored spots	12	0	325	0
Lime and slate mixed alternately	25	0	350	0
Dark-brown crystalline sand rock	4	0	354	0
Sandy, ferruginous, laminated sandstone	45	0	399	0
Sandy gray slate	51	0	450	0
Streaky ferruginous material	41	0	491	0
Soft ore, no core	6	0	497	0
Highly ferruginous sand, no core	7	9	504	9
Lean ore, streaked with slate	3	0	507	9
Fossiliferous ore	5	6	513	3
Impure gray limestone, streaked with flinty material	75	0	588	3
Red streaked sandstone	8	0	596	3
Chickamauga limestone:				
Limestone, with spots of hard black flinty material	109	0	705	3

The same company has furnished the following analysis of the ore from the big seam. That mining was unprofitable here is probably due in large degree to the small percentage of metallic iron in the ore.

Average analysis of red ore from Big Spring, Ala.

	Per cent.
Iron	30
Lime	40
Insoluble, silica and alumina	20

In sec. 16, T. 22 N., R. 6 W., the general trend of the outcrop again changes, becoming about S. 40° W., and thus it continues until hidden by Cretaceous and later deposits to the southwest of Schultz Creek. Between the limits indicated the formation passes diagonally across portions of the following sections: Secs. 12, 13, 14, 23, 22, 27, 28, 33, and 32, T. 20 N., R. 5 W., secs. 5, 6, 7, and 18, T. 21 N., R. 5 W.; secs. 13, 24, 23, 26, 35, and 34, T. 21 N., R. 6 W.; secs. 3, 10, 9, 16, 17, 20, 19, and 30, T. 22 N., R. 6 W.; sec. 6, T. 24 N., R. 7 W., and secs. 1, 2, and 11, T. 24 N., R. 8 W. No valuable bodies of ore seem to have been discovered in the northern part of this strip. Southwest of Roups Creek, for nearly 3 miles, or to where the Tuscaloosa-Bibb county line turns westward from the ridge, two seams of red ore have been reported by McCalley,[a] but the layer is not over 3 feet thick. Still farther to the southwest the formation is deeply buried for long stretches under Cretaceous and Tertiary deposits, so that but little prospecting has been done in this direction. Such prospects as have been made where the strata outcrop were of such remote date at the time of this survey that they would have had to be reopened in order to get good sections. McCalley,[b] however, observed several of these openings when they were fresh, and reports the following sections and analyses:

Section of cut on upper red ore seam in NW. ¼ of SW. ¼ of sec. 24, T. 21 N., R. 6 W.

	Feet.
4. Loam, Tuscaloosa formation.	
3. Ore, clay; a hard limonite-looking ore of red brick-dust color, in several solid ledges or seams, from 1 to 4 inches each in thickness, separated from each other by clayey seams.	
2. Red ore, soft or well leached, with interstratified clayey streaks	3
1. Red ore, soft or well leached, good, about	4

Section of cut on lower red ore seam NW. ¼ of SW. ¼ of sec. 24, T. 21 N., R. 6 W.

	Feet.
3. Loam, Tuscaloosa formation.	
2. Red ore, soft or well leached	2
1. Ore, clay; a hard limonite-looking ore with clayey partings	4

[a] Op. cit., p. 475. [b] Op. cit., p. 502

Analyses of red ore from cut in NW. ¼ of SW. ¼ of sec. 24, T. 21 N., R. 6 W.

	Upper seam.	Upper seam.	Lower seam.
Ferric oxide	87.088	88.385	64.138
Silica	4.280	5.160	6.485
Phosphoric acid	Trace.	.279	.192

Within the valley along McAshan Mountain occurs another strip of the Rockwood formation nearly parallel to the strip southeast of Rock Mountain. Its strike is approximately N. 40° E., and its strata dip generally to the northwest at angles of 20° to 45°. It crosses diagonally portions of the following sections: Sec. 35, T. 19 N., R. 5 W., and secs. 2, 3, 10, 9, 16, 17, 20, 19, and 30, T. 20 N., R. 5 W. It terminates apparently in the vicinity of Bucksville. This strip of the formation carries two and possibly three small seams of variable ore, which have been traced by numerous prospects as far as the NE. ¼ of sec. 10, T. 20 N., R. 5 W.

Character of the red ore.—The red hematite ores may be divided into two classes: (1) The soft ores, that contain little or no calcium carbonate, and (2) the hard ores, that contain from 12 to 20 per cent of calcium carbonate. The soft ores are usually found on the outcrop and may extend underground for 200 to 300 feet on the dip, depending on the thickness and character of the overlying material. The soft ore originally was identical with the hard ore, but it has suffered a loss of its calcium carbonate through solution. It consequently is the richer in iron, as it is poorer in calcium carbonate. Its content in metallic iron runs from 45 to 50 per cent, and its content of silica from 25 to 30 per cent. On the other hand, the hard ore has the advantage of containing almost enough, or at times sufficient, lime to flux the silica contained in it. It carries from 35 to 40 per cent of metallic iron and 12 to 18 per cent of silica. Soft and hard ores each carry on an average 0.35 per cent of phosphorus, which is so high as to preclude their use for making Bessemer steel. In the Pinckard mine the line of demarcation between the soft and hard ores is not sharp, and it does not lie parallel to the outcrop. This irregularity is shown by the fact that hard ore is encountered in the first right entry, while opposite to it the first left is in soft ore. In the ore at the Pinckard mine only a few traces of fossils were seen. This ore appears to consist chiefly of minute flattened pebbles and grains of ferric oxide having a siliceous core. In the hard ore these grains are cemented with a ferruginous calcareous cement. In the soft ore these grains often fall loosely apart, especially when dry. The hard ore contains many thin branching veins of white calcite, which contrasts strikingly with the deep red body of the ore.

THE BROWN ORE.

Distribution, geologic relations, and development.—If it should be attempted to give a general rule for the distribution of workable deposits of brown ore, it might be said that such deposits have invariably been found, in the Brookwood quadrangle at least, directly associated with two groups of rocks—the Cambro-Ordovician limestone and dolomite and the Cretaceous or Tertiary sands and clays. The brown ores occur in irregular pockets or banks in sandy clay or other unconsolidated material that overlies dolomite or limestone beds. In most cases the ore-bearing materials are clearly of Cretaceous or later age. In certain cases the ore may occur in residual clay which results from the decomposition of the underlying dolomite or limestone. The valuable brown ores are widespread in Roups Valley, from the vicinity of Bucksville southwestward to the locality where the limestones finally disappear below Cretaceous deposits along Big Sandy Creek near the old Clements place. Important brown ore deposits have been observed during this survey or reported by the Alabama Geological Survey in secs. 19, 30, and 31, T. 20 N., R. 5 W.; secs. 25 and 36, T. 20 N., R. 6 W.; secs. 1, 2, 3, 9, 10, 11, 12, 14, 15, and 17, T. 21 N., R. 6 W.; sec. 32, T. 21 N., R. 7 W.; sec. 17, T. 22 N., R. 7 W., and sec. 24, T. 22 N., R. 8 W. In this area are the well-known active open-cut mines at Goethite, Greeley, Reno, and Giles and the extensive preliminary surface stripping that is being done by the Tennessee Coal, Iron, and Railroad Company between Reno and Greenpond. In the valley between the mines near Woodstock and the most southwesterly showings of ore there is an area of approximately 40 square miles that probably has not been thoroughly tested, and there is reason to believe that rich deposits of brown ore may be found in such parts of this area as are surfaced with thin Cretaceous or later beds overlying limestone or dolomite. It is not so probable that similar deposits would be found near the contact of the limestone and the clays where the clays lie several hundred feet deep; but where these unconsolidated deposits are not more than 50 to 100 feet deep prospecting can be most conveniently and economically accomplished. The deposits are very variable, and the miner's maxim, "No one knows much about a brown-ore bank beyond the length of his pick," is repeated here for the sake of emphasizing the importance of thoroughly prospecting a piece of ground and of becoming thoroughly familiar with the local conditions before entering upon development work. It is likewise characteristic of the brown-ore or limonite deposits that surface indications rarely afford a true index of their extent or value. This is especially noticeable at the Central Iron and Coal Company's (Edwards) ore banks at Giles. Here the active workings cover, roughly estimated, 5 or 6 acres, but the ore does not reach the surface. To the west of the present openings, and across the railroad track, five or six small test pits 50 to 60 feet deep have been sunk, in all of which there is a fine showing of ore about 20 feet below the surface and continuing downward for 10 to 30 feet, although no ore whatever shows at the surface. A good typical section, and one which illustrates the position of the ore, is given by McCalley,[a] and is in substance as follows:

Section at the Edwards limonite banks.

	Ft.	in.
4. Very red loam ("Lafayette"), with small, rounded flint pebbles, about	10	0
3. Hardpan, an irregular crust of micaceous ferruginous sandstone or conglomerate, from	0 to 1	6
2. Reddish sandy loam, with some pyrolusite and manganiferous limonite as soft smutty powder and as crusts, from	0 to 4	0
1. Limonite, in a matrix of micaceous sand, with some flint and chert pebbles and irregular streaks of stiff, laminated, gray clay ("Tuscaloosa"); the clay frequently predominates, about	40	0

In the surface loams of the Tertiary and Quaternary are many irregular beds and lenses of ferruginous sandstone which have broken down into scattered bowlders. Some of this material is of a concretionary nature, and certain of its beds appear to be a low-grade siliceous hematite rather than a limonite. Although occurring in abundance over some of the hills in the pine woods in the southern part of the quadrangle, its use has not been found practicable as yet.

Character of the brown ore.—The brown ore varies considerably in physical character. No stratified seams of importance have been noted in this quadrangle, so that this description applies only to the pocket ore. This has evidently been deposited by percolating water and occurs in solid masses, or in honeycombed ramifying masses, or in loose chunks, bowlders, concretions, nodules, and gravels. The harder portions of the ore are light to dark brown in color, usually showing a dull luster on smooth, freshly broken surfaces. Cavities in the concretionary forms are usually lined with a yellow or red ocherous powder. Ore from near Gallant Creek, in sec. 9, T. 21 N., R. 6 W., is a dark-brown limonite cementing angular, weathered chert fragments into a breccia.

Two partial analyses of brown ore from the Edwards ore banks at Giles, furnished herewith, are by the Central Iron and Coal Com-

[a] Op. cit., pp. 463–464.

pany. The samples analyzed represent the average of the mine, and were taken from cars at the furnace at Holt.

Partial analyses of brown ore from Giles, Ala.

	I.	II.
	Per cent.	*Per cent.*
Iron [metallic]	47.27	47.40
Insoluble	16.20	15.92

Stock-house samples of ore from the Greeley banks, in the NW. ¼ of sec. 31, T. 20 N., R. 5 W., gave the following analysis:[a]

Analysis of stock-house sample of brown iron ore in Greeley ore banks.

	Per cent.
Metallic iron	43.08
Phosphorus	.45
Silica	21.04
Hygroscopic water	1.30
Combined water	11.30

The average composition of the cleaned and dried brown ore of the State, stock-house delivery, according to Phillips,[b] is as follows:

Average composition of Alabama brown ore, cleaned and dried.

	Per cent.
Metallic iron	51.00
Silica	9.00
Alumina	3.75
Lime	.75
Phosphorus	.40
Sulphur	.10

Brown ore is rather expensive to produce, owing to the large amount of foreign material that must be moved for every ton mined and to the necessity of cleaning the ore by washing it. There is always a good demand for this ore, however, and as its generally high quality insures for it the highest price paid for ore in the State a small margin of profit has usually been made from mining it. Fuel is near at hand, and limestone for furnace fluxing is intimately associated with the ore, in some places even being mined from the same quarry. In the autumn of 1904 strippings were being made along ore banks whose full development will nearly double the present production of the quadrangle. Under present conditions, and even more surely with prospective expansion of business, the development of the reserves of brown iron ore in this quadrangle promises well for the future.

[a] McCalley, Henry, op. cit., p. 462.
[b] Phillips, W. B., Iron making in Alabama, 2d ed.: Alabama Geol. Surv., 1898, p. 57.

Possible origin of the brown ore.—As this ore occurs near the contact of limestone or dolomite with later unconsolidated deposits, and apparently requires the presence of both classes of rock for its deposition, the question arises as to what part each class of rock has played in its origin. It has been generally considered that the iron was derived from the Cambrian or Ordovician limestone and that it has been segregated in residual clays resulting from the decomposition of the limestone. This is perhaps the case with stratified limonite that is the result of the alteration of pyrites, or of carbonate ores originally disseminated through the limestone, but this class of ore is not represented among the deposits under consideration. There are two hypotheses which may contain elements of a possible explanation of the origin of the ore. The first is that the ore may have been derived from the limestone. That the limestone or dolomite was essential to the formation of the ore is indicated by the fact that where the later unconsolidated deposits lie over other rocks—as, for instance, Coal Measures sandstone and shale—no such bodies of ore are present near the contact. Analyses show that the limestone and the dolomite of the valley both contain small percentages of iron. If the ore has come from the limestone and dolomite, an enormous mass of rock must have been involved, and, likewise, a long geologic period would have been required for the collection of the iron. This, it seems, would preclude the possibility of the ore being of post-Cretaceous age.

The second hypothesis is that the ore has been leached from post-Cretaceous beds of sand and loam by percolating water, aided by organic acids, and carried downward into the beds of sandy clay and precipitated near the clay-limestone contact. Observations have shown that all the extensive workings in Roups Valley northeastward from Woodstock to beyond Goethite are at the base of unconsolidated Cretaceous clays and later loams overlying Paleozoic limestone or dolomite. When the northeastern limit of post-Paleozoic deposits is passed no further ore deposits of the same class are found in the quadrangle, although the limestone and dolomite still floor the valley. From this it may be construed that the unconsolidated deposits are also essential factors in the formation of the ore. The ore deposits themselves are situated in the clay, in cavities, openings, and channels, which have apparently afforded passageways for waters from the overlying beds. The nature of the ore bodies and their relations to the clays suggest that they may be post-Cretaceous and, indeed, of rather recent origin; also that they have grown by accretions added by waters entering the clay from above.

It is believed that the iron could have come from post-Cretaceous deposits, for in all the unconsolidated deposits lying above the

Cretaceous clays there is a vast amount of iron distributed in the ferruginous sandstone, siliceous hematite, and beds of deep-red sand and loam. As these deposits are porous, it is entirely possible that they may have undergone comparatively rapid leaching by waters entering at the surface and passing downward through them. As the upper beds are extremely ferruginous, it seems possible that they could have furnished sufficient quantities of iron to form the richer deposits below without showing much evidence of having been leached.

If such a circulation should take place, deposition of the iron would occur wherever favorable conditions were encountered. The solution evidently could pass through the Cretaceous sands and clays along channels, cracks, and other openings, but on reaching the limestone or dolomite it would meet there a relatively impervious bed which would retard its circulation, and, if in a nearly saturated condition, the solution would tend to deposit its dissolved material; but the most important factor influencing the deposition of the iron salt probably would be the limestone itself. If the iron traveled as a carbonate in solution, contact with the limestone would tend to precipitate the iron carbonate while calcium carbonate would pass into solution. This, in principle, would be a process of replacement, but as the iron ore does not impregnate the limestone to a noticeable extent it is possible that reaction would take place by the mixing of the iron solutions with waters flowing along the limestone and containing calcium and magnesium carbonates in solution. At any rate, a nucleus of iron ore being formed, it would grow by accretion.

The nuclei of the ore masses have been deposited in the openings in the clay, and from these nuclei ramifying masses have branched into the surrounding clay. The richest deposits of ore are frequently found directly on the limestone contact, and in places where the limestone surface is an uneven one ore masses usually fill depressions or surround bowlders of the limestone that project above the old ledges. Good examples of these latter conditions are found in the workings of the Central Iron and Coal Company at Giles.

The second method of origin suggested for the ore necessarily assumes a subsequent alteration of iron carbonate to limonite, but this is a characteristic change of the first mineral and would perhaps take place through the action of oxidizing solutions very soon after precipitation of the carbonate.

The evidence afforded by the deposits herein described points most strongly to the second process outlined, and this process appears to contain the greatest number of elements of possibility; but as only a small part of the whole field has been studied this is offered merely as a suggestion at present.

LIMONITE DEPOSITS OF EASTERN NEW YORK AND WESTERN NEW ENGLAND.

By Edwin C. Eckel.

INTRODUCTION.

During the early summer of 1904 the writer visited most of the iron districts of New York and western New England. The work done was purely in the nature of a reconnaissance and was designed to supply data for comparison of these classic iron-ore deposits with those of the Southern States. It is hoped, however, that a more detailed examination can be made during the field season of 1905.

The iron deposits discussed in the present paper are the brown hematite ore bodies in New York east of the Hudson River and in the adjoining counties of New England.

Aside from the present economic importance of certain of the brown hematites of this region as sources of the famous Salisbury iron, the deposits are of widespread scientific interest as typical bodies of the so-called "Cambro-Silurian limonites" that are worked from Pennsylvania to Alabama along the Great Valley. Recent discussions of the age and origin of these ores in Pennsylvania, Virginia, Georgia, and Alabama have developed very marked points of disagreement between the various geologists and mining engineers who have studied the deposits in different localities. It is to be noted that all these recent studies have been carried on in the territory south of the glaciated region. This southern area, though of great economic importance, is unfavorable to such studies, because of the great amount of decomposed rock which must be penetrated before satisfactory exposures can be found. In New York and New England, on the other hand, the glacial sheet effected the removal of all the old land waste, and the outcrops of all rocks are comparatively fresh. To this fortunate condition is due the fact that certain determinations as to origin and occurrence of the ores can be made readily in the region in question. A partly counterbalancing disadvantage, however, is that the geologic history of the northern region precludes the possibility of procuring direct evidence as to the age of the deposits—such evidence as Hayes has been able to obtain in Alabama and Georgia.

The brown hematite deposits considered in the present paper occur in the counties of Dutchess and Columbia, N. Y., Berkshire, Mass., and Litchfield, Conn. Similar deposits occur north of this district, in Vermont, while south of it, though they are but slightly developed in southern New York and New Jersey, the limonite deposits become large and numerous in Pennsylvania, Virginia, Tennessee, Georgia, and Alabama.

GEOLOGY OF THE REGION.

The portion of New York and New England in which the brown hematite deposits are best developed is underlain by a series of highly metamorphosed and much folded rocks, varying from pre-Cambrian to late Ordovician in age.

Geologic formations.—Four geologic formations appear in the area in question and must be considered in any adequate discussion of the age and origin of the iron ores. These are—

1. Pre-Cambrian gneisses.
2. Poughquag quartzite (Georgian or lower Cambrian).
3. Stockbridge limestone (Cambro-Ordovician).
4. Hudson schists and shales (Ordovician).

Each of these rock series will be briefly described.

The pre-Cambrian rocks of the region consist mainly of gneisses, with subordinate amounts of schist. They constitute the bulk of the New York and New Jersey highlands, extending northeastward into Connecticut as Dover Mountain and being represented farther north in Connecticut and Massachusetts by a range of mountains east of the Canaan-Stockbridge-Pittsfield valley.

The Poughquag formation immediately overlies the pre-Cambrian gneisses. It is a quartzite very variable in thickness, ranging from 10 to 150 feet or more, but very constant in composition and appearance.

The Stockbridge limestone is a white to bluish, often notably crystalline, limestone. This limestone is usually highly magnesian, though it rarely carries sufficient magnesia to qualify as a true dolomite, and contains occasional beds entirely free from magnesia. Geologically the Stockbridge limestone is essentially the metamorphosed equivalent of the Cambrian, Calciferous, and Trenton series of the Mohawk and Champlain valleys.

Overlying the Stockbridge limestone is a thick series of mica schists, corresponding to the Hudson shales of the Hudson River Valley, and gradually becoming less metamorphic toward the west.

Geologic structure.—While faulting on any visible scale is decidedly uncommon in this region, the rocks are very strongly folded.

The normal type of fold for this district seems to have been a closely pressed succession of anticlines and synclines, often overturned, so as to give uniform dips on both flanks of the fold. As the tops of these folds have been subsequently beveled off by erosion, the strata now occur as monoclines, striking N. 30° E. or thereabout, and usually dipping at high angles (35° to 60°). This condition, taken in connection with the overturned character of most of the folding, often produces outcrops showing the geologically older rock apparently *overlying* conformably the newer rocks. This is well shown in the section of the National mine, where the older Stockbridge limestone apparently overlies the newer Hudson schist. The section of the Amenia mine shows several of these typical, close, overturned folds.

DESCRIPTIONS OF BROWN-HEMATITE MINES.

The time available for field work in this district was too limited to permit the writer to examine all or even the majority of the brown-hematite deposits. All the mines at present operated were visited and in addition such unworked mines as from description seemed to promise results of value in the study. The mines visited are described below, being taken up in order from those near West Stockbridge, Mass., on the north, to the Pawling, N. Y., mine on the south.

Leet mines.—The three openings known as the Leet and Goodrich mines are located about 1½ miles west of West Stockbridge, Mass. These openings were extensive, but are now filled with water. The ore body evidently lay on or in the limestone, as no schist or quartzite is exposed anywhere in its vicinity, and certainly none could have occurred in direct contact with the ore body. The limestones strike northeast-southwest and dip to the southeast, varying considerably in amount of dip—from 15° to 50°, the latter high dip being that prevailing near the ore body. The exposures near the Leet mines are very satisfactory in spite of the present condition of the mines, and prove conclusively that no schist or quartzite beds were concerned in the localization of this ore body. No carbonate ore was seen by the writer, but Dana [a] states that it occurs in the Leet mine.

The following partial analyses of ore from this group of mines are given in the Tenth Census, vol. 15, p. 86:

Analyses of iron ore from Leet mines, near West Stockbridge, Mass.

	1.	2.	3.	4.
Metallic iron	47.52	46.65	40.71	47.87
Phosphorus	.187	.174	.142	.124
Phosphorus in 100 parts iron	.394	.373	.348	.264

[a] Am. Jour. Sci., 3d ser., vol. 28, p. 398.

Davis mines.—The Davis mines are located three-fourths of a mile northeast of Lakeville, Conn. Extensive open pits are worked here now. Limestone appears at the surface at the northeast and northwest corners of the main pit, with a strike N. 55° E., and dip southeast at an angle of 15°. It is reported that limestone was struck below the ore in the main pit, but this opening is now filled up. No schist or quartzite occurs in the vicinity, and the ore body is evidently on or entirely in a flat-lying limestone. Pockets of magnesian ore occur and are said to be most common near the bottom of the deposit. The following is stated to be fairly representative of the section shown at the Davis mines, if a shaft were carried down to the underlying limestone.

Section at the Davis mines, near Lakeville, Conn.

	Feet.
Limonite and clay	15–20
Limonite with more clay (ocher)	20–40
Lenses and pockets of manganese ore	
Black ocher	1– 5
Blue limestone	

Analyses of Davis ores, from the Tenth Census Report, follow, Nos. 3 and 4 being of manganiferous ores:

Analyses of ores from Davis mines, near Lakeville, Conn.

	1.	2.	3.	4.
Metallic iron	41.55	44.59	27.46	2.24
Metallic manganese	....	....	26.60	25.81
Phosphorus	.073	.059	.045	.068
Phosphorus in 100 parts iron	.176	.132	.164	....

Orehill mines.—There is a group of mines at Orehill, on the Central New England Railroad, about 2½ miles west of Lakeville. At present these mines are being extensively worked, the product being taken by the Barnum Richardson Company, of Limerock, Conn.

The old pits show Hudson schist on the west side, striking N. 40° E. and dipping southeastward at an angle of 45°. This schist body, to judge from the appearance of the old workings and from the results shown by the slope now being sunk, was the foot wall of the ore body. The foot-wall schist contains much disseminated pyrite. On the east side of the pit the hanging wall, a schist colored deep red along its outcrop, is shown. This dips southeast at an angle of about 20°, and this flattening of the dip toward the east is corroborated by profiles of the mine workings. The ore body, at first worked as a large disintegrated mass mixed with clay, thins down to about 20 feet where it passes under the hanging wall.

Manganese ores occur apparently mostly in the lower levels of the mine. Iron carbonate occurs at the north end of the mine at a rather high level in connection with masses of limestone. A few hundred feet west of the pit a thin brecciated band of limestone appears in the schist. Analyses of the ores of this group of mines follow:

Analyses of iron ores of mines at Orehill, near Lakeville, Conn.

	1.	2.	3.	4.	5.	6.	7.
Metallic iron	35.10	40.03	44.04	44.38	48.02	50.12	44.80
Phosphorus	.128	.113	.100	.103	.120	.196	.162
Phosphorus in 100 parts iron	.364	.282	.227	.232	.250	.393	.362

In the description of this group of mines in the Tenth Census Report, volume 15, pages 84–85, it is stated that a fault occurs in the ore body in one of the pits. This can not be determined at present, and from the description and its accompanying figure it seems probable that it was merely a slip in surface material and not in any way connected with the origin of the ore body.

Mount Riga mine.—The Mount Riga mine is located one-half mile east of Mount Riga station, N. Y. It is a pit about 100 feet by 300 feet in area and is now filled with water. No solid rock is shown near it, but it is probably located not far from a contact between limestone and schist. A partial analysis of its ore is given in the Tenth Census Report, volume 15, page 134:

Analysis of iron ore from Mount Riga mine, Dutchess County, N. Y.

	Per cent.
Metallic iron	41.58
Phosphorus	.611
Phosphorus in 100 parts iron	1.470

Manhattan mine.—The Manhattan mine, located immediately west of the railroad at Sharon station, N. Y., is of interest to mining engineers because of the detailed expense accounts published by Mr. Lewis in the Transactions of the American Institute of Mining Engineers. Smock states that limestone occurs in the pit, but none is now visible. Numerous limestone outcrops occur a short distance south of the mine, however, striking N. 40° E. and dipping 30° SE. There can be no reasonable doubt that the ore body occurred entirely in or on the limestone, like that of the Leet mine, above described. No schist or quartzite could have been concerned in the localization of the ore, for no outcrops of such rocks appear within a half mile of the mine. Partial analyses of the ore follow, taken from the Tenth Census Report, volume 15, page 134, analysis No. 1 being of carload lots of washed ore and No 2 of a selected specimen of limonite:

Analyses of iron ore from the Manhattan mine, near Sharon, N. Y.

	1.	2.
Metallic iron	47.77	50.13
Phosphorus	.086	.038
Phosphorus in 100 parts iron	.180	.076
Manganese protoxide		1.93

Amenia mines.—The Amenia group of mines is located three-fourths of a mile west of Amenia station, in a narrow limestone valley between two ridges of Hudson schist. As shown in the section, all these rocks dip steeply (50°–60°) to the east and strike about N. 15° E. The hanging wall of the deposit is a dark-colored mica-schist; the foot wall is Stockbridge limestone. The principal ore worked is brown hematite, but iron carbonate occurs, being particularly common in the more southerly workings, where the limonite body is apparently widest. Little siderite now shows in the present underground workings, which are near the northern end of the old pit. In one of the old pits limestone was found nearly all the way across the opening, under the ore. The carbonate occurred at the bottom of the opening in bedded form, the beds dipping steeply eastward.[a] This carbonate ore was smelted at the Wassaic furnace, and Gridley [b] has described the rather unusual character of the iron made from it.

Analyses of Amenia ores follow, No. 3 being of the carbonate above mentioned:

Analyses of iron ore from the Amenia mines, Dutchess County, N. Y.

	1.	2.	3.
Metallic iron	48.99	48.28	42.94
Phosphorus	.413	.092	.053
Phosphorus in 100 parts iron	.843	.190	.123

National mine.—The National mine is located 2½ miles west of Pawling, N. Y. The ore body has for foot wall a body of Hudson

[a] Smock, J. C., Bull. N. Y. State Museum No. 7, p. 57.

[b] Gridley, E., Note concerning a grade of iron made from carbonate ore: Trans. Am. Inst. Min. Eng., vol. 12, pp. 520–522.

schist dipping steeply (about 60°) eastward, while limestone occurs a short distance east of the mine and probably forms the hanging wall of the deposit. The clays associated with the ore show a banding parallel to that of the adjoining mica schist. Analyses of the ores follow:

Analyses of iron ore from National mine, near Pawling, N. Y.

	1.	2.
Metallic iron	43.22	47.12
Phosphorus	.113	.137
Phosphorus in 100 parts iron	.261	.291

ORIGIN OF THE ORES.

As noted in the mine descriptions given above, iron carbonate is a fairly constant associate of the brown hematite. In several of the mines this carbonate has been found in place in the lower workings. At the Burden mines, near Hudson, N. Y., a body of practically unaltered iron carbonate appears at the surface, having been protected from oxidation by a heavy covering of Hudson shale. It seems probable, therefore, that such of the limonite deposits as show iron carbonate in depth may be fairly considered to owe their origin to the oxidation of this carbonate. In the Burden mines, as well as at other points, the weight of evidence seems to favor the idea that the iron carbonate is not an original deposit, but that it has formed by the replacement of limestone. This point will be discussed in detail in another place.

Four fairly distinct types of deposits, so far as mode of occurrence are concerned, can therefore be made out. The method of origin of the first three named can, it is believed, be stated with some certainty. The fourth type, however, is by no means so readily determined, and it is probable that it has originated at different localities in very different ways. This supposition is confirmed by the results obtained by Hayes in Alabama and Georgia. It may be further pointed out that while types 1, 2, and 3 are, on the whole, most likely to occur in a sharply folded district with steeply dipping strata, type 4 is much more likely to be found in a gently folded area. This may account for its lack of importance in the area discussed in this paper and for its great abundance both in New York and Pennsylvania, as well as farther south. The probable methods of origin of the four types noted are as follows:

Type I.—Originating in the replacement by iron carbonate of a thin bed of limestone occurring *in* the Hudson series of shales and schists. *Ore Hill mines.*

Type II.—Originating in the replacement by iron carbonate of a steeply dipping bed of limestone along the contact of the Stockbridge limestone and Hudson schist. *Amenia mines*, *National mine.*

Type III.—Originating in the replacement by iron carbonate of a steeply dipping bed of limestone entirely within the Stockbridge limestone series. *Leet mines.*

Type IV.—Originating by direct deposition, probably as limonite, in a basin *on* or a cavity or cavern *in* a flat-lying limestone. *Davis mines.*

The original iron carbonate was undoubtedly deposited from solution as a replacement of a limestone and not deposited in a basin contemporaneously with the inclosing rocks. To this extent the writer's explanation differs from that offered by Dana and certain other geologists. On the other hand, it is clear that the iron-bearing solutions did not pass freely everywhere through a mass of generally porous rock as seems to be required by the commonly accepted theory. In such a thoroughly porous mass bedding planes could not affect the shape of the deposit, the only restraining influence being the "impervious pitching trough," whose existence is so freely postulated and in the New York–New England district so rarely proved.

The presence of bedded iron carbonate in depth supports the ideas advanced by Catlett, McCallie, and Hayes as opposed to the theory that the limonite deposits are always entirely superficial, ceasing as soon as bed rock is reached.

SO-CALLED "IRON ORE" NEAR PORTLAND, OREG.

By J. S. Diller.

At the meeting of the Miners' Congress in Portland, Oreg., last August, Mr. W. A. Roberts, of that city, exhibited a series of specimens labeled as follows:

Crystallized ferrous carbonate. Twenty-five miles from Portland. Accessible by rail and water; 6,000,000 cubic yards in sight. Average composition of some 25 samples of this spathoid ore:

Fe	39.50
Al_2O_3	15.00
SiO_2	35.50
CaO	7.00
MgO	3.00
Sulph	.03
Mn	.19

According to Mr. Roberts, the analysts were Miss L. V. Hampton and Mr. J. H. Fisk.

As a part of the exhibit Mr. Roberts showed a piece of fresh iron which he said was obtained from the "iron ore" by smelting the ore in a small furnace with basalt, such as occurs abundantly in the vicinity of the ore. He stated that when the "ore" was fused alone the iron would not separate out, but when some basalt was added the molten iron sank to the bottom of the furnace and was drawn off.

The exhibit attracted much attention, and it was evidently a matter of so great importance, if the label and the statements of Mr. Roberts were wholly correct, as to deserve immediate investigation and report.

The specimens of "ore" exhibited varied somewhat, but all contained a brownish glassy substance whose nature was not evident in the samples shown. One specimen was composed wholly of the dull-brownish glass and looked like some forms of obsidian; others contained small indefinite pebbles, as if fragmental.

From the first, however, it was apparent that there was a mistake in the stated chemical composition. The summation of the analysis gives over 100 per cent, leaving no place for oxygen combined with the iron or for manganese. The absence of carbonic dioxide left no ground for calling the material a "ferrous carbonate," and the presence of so large an amount of iron as claimed was entirely inconsistent with its light weight.

Mr. Roberts very kindly arranged to conduct Mr. W. J. Sutton, of Victoria, British Columbia, and myself to the locality that we might study this material in place. We took the Oregon Railway and Navigation Company's railroad to Bridal Veil Falls on the Columbia River, 28 miles east of Portland, then walked back on the railroad about 2½ miles to near Rooster Rock, where the "ore" occurs in great abundance, forming prominent cliffs 500 feet in height overlooking the railroad and river.

The whole mass of the cliffs when seen from the railroad is more or less distinctly stratified, but the layers are large and massive, so that the stratification is not conspicuous. When examined in detail the strata are found to be made up entirely of fragmental volcanic material, forming what is technically called tuff, or, in this case, basalt tuff, on account of the basaltic character of the fragments. Such material is sometimes called palagonite tuff, from its occurrence in Palagonia, Sicily.

The layers are composed chiefly and often wholly of a substance ranging in color from light to dark brown and black, and in luster from dull glassy to pitch like and resinous. For the most part the rock is decidedly fragmental. It contains fragments of dark basalt from the size of a pea to blocks several feet in diameter. When broken, these pieces are often seen to have a black pitchy border, as if once enveloped by a molten mass.

Weathering brings out the fragmental structure on the surface of the glassy portions, but this is still more evident in a thin section of the rock where the dark brown completely isothropic glass fragments full of small lath-shaped crystals of plagioclase feldspar, with fewer crystals of augite and grains of olivine, like those of the basalt, are encompassed and bound together by a lighter brown matrix like gelatin, which has fibrous polarization.

Locally among the distinctly fragmental layers are sheets of the yellowish-brown waxy-lustered material which in thin section is found to be an altered jellylike substance containing crystal fragments of plagioclase, augite, and olivine like those in the basalt of the large fragments and flows in the cliffs, and it is evident that the whole mass is from a volcano erupting basalt. Some of it flowed out, but most of it was blown out by violent explosive eruption, giving it a wide distribution about the volcano.

In order to determine the amount of iron contained in the basalt tuff, I collected a number of samples in the field. Recognizing the character of the material, I selected for the principal sample to be analyzed 6762, which seemed to be the purest glass, collecting also sample 6764 from the overlying and 6763 from the underlying material, which appeared to be decidedly fragmental. All of these samples were taken at a point about 300 feet above the railroad and within 5 feet of one another. Mr. Roberts was with me at the time and gave from memory 46, 35, and 36, respectively, as the approximate percentages of contained iron reported by an assayer.

Mr. George Steiger, in the chemical laboratory of the Geological Survey, made a chemical analysis of 6762 with the following results:

Analysis of so-called "iron ore" from near Portland, Oreg.

SiO_2	40.89
Al_2O_3	10.41
Fe_2O_3	15.00
FeO	.07
MgO	3.76
CaO	5.18
Na_2O	.47
K_2O	.53
H_2O −	9.14
H_2O +	10.32
TiO_2	3.37
CO_2	None.
P_2O_5	.52
S	[a].03
MnO	.90
V_2O_3	.01
Total	100.60

The oxides of iron in this sample amount to 15.07 per cent and are equivalent to 10.55 per cent of metallic iron. The amount of iron in the overlying bed is 10.76 per cent and in the underlying 10.84 per cent. Although quite unlike in appearance they show a remarkable uniformity in the amount of contained iron, and it is probable that the whole mass contains approximately the same percentage.

When the foregoing analyses were completed they were sent to Mr. Roberts, who, by letter of January 3, 1905, informs me that Miss Hampton "made about 15 assays, and the lowest was 26 per cent metallic iron, the highest 46 per cent. J. H. Fisk got 21 per cent." After seeing the results of the Survey analyses he stated that "Miss Hampton assayed two samples taken from the upper level (or light-colored ore) and one at the base on the railroad, and each assayed 37 per cent metallic iron." Mr. Roberts further asserts: "I got more than 20 per cent in the blast furnace. As soon as the weather will admit I shall build another furnace and prove who is making the mistakes."

[a] It was not determined whether sulphur was present as sulphide or sulphate.

In view of the great differences in the amount of iron found in the so-called "iron ore" by the various chemists, it should be said that they did not analyze exactly the same specimens. The specimens for analysis by the Survey were collected by myself, in Mr. Roberts's presence, so as to be sure and get the right material. We have also some specimens kindly sent in later by Mr. Roberts. One of the specimens, he says, "contains about the average amount of iron." It was given to Mr. Steiger for examination, and he reports 15.26 per cent of Fe_2O_3, equivalent to 10.68 per cent of metallic iron.

When determining the amount of iron present, Mr. Steiger, in the Geological Survey laboratory, followed a well-established method of procedure, using the standard potassium-permanganate solution for titration.

No analysis was made of the basalt which Mr. Roberts said he used as a flux, but a thin section of it shows it to be a normal feldspar basalt, which is rather rich in olivine and most likely contains about 9 per cent of iron. If, therefore, the basalt can be used to flux the basalt tuff, it would add its iron to that of the tuff, but would leave the general average of the charge, ore and flux combined, not over 10 per cent of metallic iron, an amount which is below the lowest that is in general worked successfully as a source of iron, even with the most advantageous circumstances in the accessibility of ore, flux, and fuel, as well as distribution of output.

In order to get the opinion of an expert who is well qualified to judge of such matters, a letter stating the essential facts was referred by the office to Mr. John Birkinbine, of Philadelphia, whose reply is as follows:

> Acknowledging receipt of the letter of J. S. Diller concerning the so-called "iron ore" obtained along the Columbia River, I would state that it seems to be a ferruginous basalt tuff rather than an iron ore, and I doubt very much if it would be practicable for the commercial manufacture of iron by the ordinary smelting process. Its contents of magnesia and lime would assist in fluxing the necessary amount of silica, but it would undoubtedly have to have additional flux, and the percentage of metallic iron would demand that fully 10 tons of the material would be required to produce a ton of pig iron. I also notice that the titanic acid in the analyses is 3.37 per cent. This would assist in making the material refractory and demand excessive fuel.
>
> The furnace fed with material of this character would be rather a slag producer than an iron producer, and I question very seriously whether any economical value would result from treating the ore in the ordinary smelting furnace. It is also questionable, even with electricity supplied at a very low rate, if the metallic contents of this ore could be separated and made marketable. In the above reply I am treating the ore as not exceeding the analyses given by Mr. Diller.

The consideration of this ferriferous basaltic material on the Columbia recalls a discovery by Mr. S. F. Emmons while engaged on the Fortieth Parallel Survey, near Palisade Canyon.

In describing a trachyte, Volume II, page 585, Mr. Emmons remarks:

Apparently inclosed in this trachyte, on the south bank of the river at the mouth of a little side canyon, is a hill a few hundred feet in height containing a large mass of iron ore remarkably fine grained and having a thoroughly conchoidal fracture. At a little distance it might be mistaken for a basaltic rock. An analysis of this ore made by Mr. B. E. Brewster gave the following results:

Ferric oxide	84.217
Alumina	.178
Manganous oxide	1.454
Magnesia	.472
Water	1.713
Insoluble residue	12.518
Total	100.552

which would give a percentage of metallic iron 58.95. The occurrence of such a body of iron ore in the midst of volcanic rocks is an interesting phenomenon, though it is probably too far from any source of fuel supply to be of practical value. It is, however, a remarkably pure ore, being entirely free from phosphorus or sulphur, though containing a rather high percentage of silica.

The locality from which this remarkable specimen was obtained has not since been studied by any member of the Geological Survey.

THE IRON ORES OF NORTHEASTERN TEXAS.

By Edwin C. Eckel.

INTRODUCTION.

GENERAL DISTRIBUTION OF TEXAS IRON ORES.

The brown hematite iron ores of east Texas, according to the reports of the Texas Geological Survey, occur in at least 19 counties—Cass, Morris, Marion, Upshur, Wood, Harrison, Gregg, Panola, Smith, Van Zandt, Rusk, Cherokee, Henderson, Anderson, Houston, Nacogdoches, Shelby, Sabine, and San Augustine. To this list should be added Camp, which contains at least one workable area of ore, and also a number of counties farther south than those named. In the counties listed above, ore districts aggregating 1,000 square miles in area were located by the Texas survey.

Another ore region which it is necessary to consider in connection with the brown-ore district is located in Llano and adjoining counties, and contains workable deposits of magnetite and specular hematite, both of which will be important in any future development of the Texas iron industry.

GEOLOGIC WORK IN THE ORE DISTRICT.

The brown-hematite district described above has been examined and in part mapped at different times by both the State and the United States geological surveys, and the principal reports on these iron ores are noted in the list below. By far the most complete and detailed survey of the district was that executed in 1889 and 1890 by Kennedy and other assistants on the Texas survey, and their report and mapping can hardly be improved upon in default of accurate and large-scale topographic base maps. During the fall of 1904 the writer made a rapid reconnaissance of the northeastern portion of this ore district. Two ends were in view—a brief report on the present condition and future prospects of the iron industry, and an examination of the district with a view to selecting areas for more detailed work.

LIST OF REFERENCES ON TEXAS IRON ORES.

The following brief list contains practically all recent publications on the iron ores and iron industry of Texas. The two papers by Comstock deal with the Llano magnetites of central Texas; all the others describe the brown hematites of eastern and northeastern Texas. The two most important papers are those marked with an asterisk:

COMSTOCK, T. B. A preliminary report on the central mineral region of Texas. In First Ann. Rept. Texas Geol. Survey, pp. 239–391. 1890.

COMSTOCK, T. B. Report on the geology and mineral resources of the central mineral region of Texas. In Second Ann. Rept. Texas Geol. Survey, pp. 555–664. 1891.

JOHNSON, L. C. Report on the iron regions of northern Louisiana and eastern Texas. House Document No. 195, 50th Cong., 1st sess. 1888.

* KENNEDY, W., and others. Reports on the iron-ore district of eastern Texas. In Second Ann. Rept. Texas Geol. Survey, pp. 7–326. 1891.

———. The age of the iron ores of east Texas. In Science, vol. 23, pp. 22–25. 1894.

* ———. Iron ores of east Texas. In Trans. Am. Inst. Mining Engineers, vol. 24, pp. 258–288, 862–863. 1895.

PENROSE, R. A. F. A preliminary report on the geology of the Gulf Tertiaries of Texas from Red River to the Rio Grande. In First Ann. Rept. Texas Geol. Survey, pp. 3–101. 1890.

———. The Tertiary iron ores of Arkansas and Texas. In Bull. Geol. Soc. America, vol. 3, pp. 44–50. 1892.

GENERAL GEOLOGY OF THE AREA.

The area included under the heading northeastern Texas comprises a group of counties in the extreme northeastern corner of the brown-hematite district. There exists a certain definite commercial basis for this subdivision of the ore field, for the deposits occurring in these counties are so located that any iron industries based on them must be considered as tributary to two possible distributing points—Texarkana, Bowie County, and Jefferson, Marion County.

Within the area under consideration five geologic formations occur, representing the Tertiary and Quaternary periods. The five formations named, in descending order, are as follows:

Formation.	Period.
Alluvial deposits	Quaternary.
Lafayette sands and gravels	Tertiary.
Claiborne sands and greensands	
Sabine clays and sands	
Wills Point clays	

The alluvial deposits consist of mud and silt, and occupy the bottom lands along the larger streams.

The Lafayette formation consists of yellowish sands, with occasional beds of coarse gravel. These gravel beds occur at several points north of Sulphur Fork, in Bowie County and adjoining areas, but are not common south of that stream.

The Claiborne is here represented by a thin series of greensands, ferruginous sandstones, and brown to yellow sands. This series caps the highest hills of the district, and apparently includes most, if not all, of the iron-ore deposits.

Underlying the Claiborne is the Sabine, a thick series of chocolate-colored clays and various colored sands, with occasional beds of lignite or brown coal. White and reddish clays occur in places, being particularly well exposed near Queen City, Marshall County.

The Wills Point clays are a series of black, slaty clays of Midway age, which outcrop north of Sulphur Fork.

Of the five formations above noted only two—the Claiborne and the Sabine—are of importance in connection with the ore deposits of the region.

DISTRIBUTION AND OCCURRENCE OF THE IRON ORES.

The ores are present in great quantity, and cover an enormous area; but, as will be explained later, they do not occur in particularly thick beds at any given point. Their profitable development will therefore depend on their nearness to cheap transportation routes. In an agricultural and lumber district, such as northeast Texas, the ore tonnage of any railroad will form such a small percentage of the total freight that it is impracticable to build long branch lines for the sake of the ore alone. Development of the ore deposits will therefore necessarily take place only along and near railroad lines, either those at present in operation or those now under construction.

The group of iron-ore deposits tributary to Queen City is located from 4 to 6 miles north and northwest of that town. At Boyd Hill, on the Albert Emanuel headright, a heavy deposit of iron conglomerate is shown capping the hill. The streams have cut through the iron-bearing beds in this district, so that the workable deposits are to be looked for only on the hillsides and tops. In the ravines and on the slopes, however, much loose ore has been carried down and spread as a thin coating over the surface. Numerous pits and trenches have been cut to show the ore beds in this district. On the slope of Bowie Mountain a trench shows the following section:

Section on slope of Bowie Mountain.

	Ft.	In.
Iron ore	2	0
Red indurated sand	0	4
Yellow sand	0	15
White to yellowish sand	3	0
Red sandstone	0	1
White sand	0	8

This particular section, it will be noted, shows but one ore bed; but a 10-foot pit farther up the same hill shows alternate layers, one-half to 3 inches thick, of sandy ore and white clay.

The thickest single ore bed opened in any of these cuts measures about 30 inches. The aggregate thickness of all the seams may average a little less than 3 feet.

Numerous deposits of lignite occur in this area. At Stone Coal Bluff, on the Sulphur Fork, a 6-foot bed of lignite occurs at the base of the bluff, exposed only at low water. A well 1 mile west of Alamo station showed two lignite beds, the uppermost 1 foot 8 inches thick, struck at a depth of about 50 feet, while a thicker bed (4 feet 2 inches) was struck about 10 feet below the first. Most wells within a mile or two of Queen City, on the west side of the town, strike lignite beds within about 25 feet of the surface.

Should it prove practicable to utilize this lignite (either directly or as a gas-producing material) in blast-furnace practice, its occurrence near the Queen City iron-ore deposits would be of much practical interest.

Along the Missouri, Kansas and Texas Railroad, from Jefferson to Dangerfield, a series of important ore deposits occur. Many of them have been worked at different times to supply the furnace at Jefferson, so that a practical knowledge of the composition and extent of these ores can easily be obtained. The principal deposits are located between Lasater (Pyland post-office) and Veals Switch, a few miles northwest of Hughes Springs. All these deposits were examined in some detail.

The first important deposit westward of Jefferson is on Doctor McCasland's property, one-fourth mile southwest of Lasater. Here an area of about 20 acres is underlain by nodular iron ore. The iron-ore fragments are 8 to 12 inches in diameter, and occur in sands, the total thickness shown being about 2 feet. The ore is usually overlain by 2 or 3 feet of clayey sand and soil.

The Booth ore bank, formerly worked extensively by the Jefferson Iron Company, is located 1 mile west of Lasater. Here 2 feet of massive ore of excellent quality is shown in a series of shallow pits. This is overlain in places by about 6 inches of yellow indurated sands.

The principal ore banks of the Jefferson Iron Company are about 2 miles northwest of Lasater, the ore having been shipped at Orr switch, three-quarters of a mile from the mines. Several feet of bedded ore are here shown, but as much small ore occurs in the overlying dirt, the workable thickness amounts to 4 or 5 feet.

The next series of large deposits occurs at and near Hughes Springs. Excavations made on Hooten Hill, one-half mile away from the station at Hughes, shows 3 feet of massive hard ore overlain by 3 feet of wash ore, consisting of ore fragments mixed with soil, etc.

On Norwood Hill, 2½ miles northwest of Hughes, much ore is shown in bowlder form at the surface. A well at Norwood is said to have passed through 25 feet of ore, probably loose fragments, but with little intermixed sand and clay.

Veal's switch is 3 miles northwest of Hughes. Here a railroad cut shows the following section:

Section at Veal's switch, near Hughes, Tex.

Soil	inches	6 to 12
Yellow sand and sandstone	feet	3 to 8
Iron ore	do	1
Yellow sand	inches	6
Iron ore	do	6
Sand	do	4
Iron ore	do	8
Sand	feet	3 to 5
Iron ore	inches	1 to 2
Gray to chocolate-colored clays	feet	8 to 10

The clays at the base of the section probably represent the top of the Sabine or Lignitic beds. Nodules and masses of iron carbonate occur in several of the ore horizons in this cut. While the basal clays are very evenly and horizontally bedded, the sands and ore are irregular.

On the Connor property, about 4 miles southwest of Hughes and 1 mile from Veal's switch, huge bowlders of iron ore are exposed. Some of them are 8 feet in diameter. the average being about 2 to 4 feet.

COMPOSITION OF THE ORES.

In the Second Annual Report of the Texas Geological Survey are given the results of a large number of analyses of the brown hematites of northeastern Texas. These appear to have been made on good average samples, and of course give lower results than the selected samples usually quoted.

The Texas ores compare well with the average brown hematites of the Appalachian belt, both in content of metallic iron and in impurities.

The values for certain constituents given in 131 of these analyses have been averaged with the results given as No. 1 below. For comparison, the analysis of a sample of rock ore from the Ore Hill mine, of Connecticut, which is the source of the famous "Salisbury iron," in added as No. 2, being quoted from volume 15 of the Tenth Census Reports.

Analyses of iron ores.

	Average Texas ores.	Ore Hill, Connecticut.
Iron oxide (Fe_2O_3)	66.39	69.71
Silicia (SiO_2)	14.47	9.84
Alumina (Al_2O_3)	8.17	3.65
Sulphur (S)	.083	.150
Phosphorus (P)	.172	.196
Metallic iron (Fe)	46.63	50.12
Phosphorus in 100 parts iron	.371	.393

ORIGIN OF THE ORES.

Most of the ores of this district occur in approximately horizontal beds, conformable to the inclosing sands and clays; but this should not be regarded as proof that the ore deposits were formed at the same time as the sedimentary beds which now underlie and overlie them. On the other hand, the probability is that the ore deposits were formed at a much later date than the sands and clays, though the source of the iron may be looked for in the adjacent sedimentary beds.

The Claiborne beds where well exposed contain varying percentages of glauconite and frequently considerable amounts of iron pyrites. The Sabine or Lignitic beds carry in some horizons nodules and masses of iron carbonate. Penrose has consequently held the view that the brown hematites have been formed by the decomposition of these iron-bearing minerals. While there are decided difficulties in the way of extending this explanation to cover all of the deposits, it may be accepted as sufficiently satisfactory for present purposes.

To the miner the question of origin of the deposits has but one practical bearing—i. e., on the probability of finding in depth richer deposits than those now exposed at the surface or in shallow diggings. This point fortunately is not involved in any theoretical differences of opinion as to the origin of the Texas ores. Under any probable hypothesis it may as well be understood clearly by the miner that—

(*a*) As to size of deposit, there is no probability that thicker deposits will occur at deeper levels

(*b*) As to richness of ores, the richest ores are likely to be found at or near the surface.

MINING AND HANDLING THE ORES.

The two statements just made have a practical bearing on the mining prospects of the districts. If no increase in either thickness or richness is to be expected in depth, it is obvious that deep workings will not be commercially practicable. The mining of the region will be confined to working off the bowlders and other surface ores and to working the deposits nearest the surface. The whole proposition is one of shallow stripping, unlike any other mining except that of the white and brown phosphates of Tennessee.

The problem is that of economically working a deposit rarely over 2 feet in thickness, but covering great areas. This deposit will in places be exposed at the surface; at other points it will be covered by soil and sand varying from 1 to 6 feet in thickness. When the stripping becomes thicker than this the ores can not be profitably mined, for no cheap method of handling heavy stripping can be applied here. Water is too scarce to admit of hydraulicking the surface material, while the location and form of the ore bodies as well as the character of the ores will prevent the use of steam shovels or other mechanical devices.

The scarcity of water in the immediate vicinity of the ore deposits has a second disadvantage—it necessitates the working and shipment of lump ore only. At a few points washers may be installed, but for the greater part of the district this is impracticable.

All this may sound discouraging, in view of previous enthusiastic estimates of the value of these ore deposits, but the facts may as well be faced now as later. The ores are rich, and areally extensive, but the deposits are thin and located in a rugged country. So large a total amount of ore is available and competitive districts are so distant, however, that the deposits will probably be extensively worked. But the individual workings will be so small and scattered that no large concentrated mining operations can be expected.

PUBLICATIONS ON IRON AND MANGANESE.

A number of the principal papers on iron and manganese ores published by the United States Geological Survey, or by members of the Survey, are listed below:

BARNES, P. The present technical condition of the steel industry of the United States. Bulletin U. S. Geol. Survey No. 25, 85 pp. 1885. (Out of print.)

BAYLEY, W. S. The Menominee iron-bearing district of Michigan. Monograph XLVI, U. S. Geol. Survey, 513 pp. 1904.

BIRKINBINE, J. American blast-furnace progress. In Mineral Resources U. S. for 1883–84, pp. 290–311. 1885.

——— The iron ores east of the Mississippi River. In Mineral Resources U. S. for 1886, pp. 39–98. 1887.

——— The production of iron ores in various parts of the world. In Sixteenth Ann. Rept. U. S. Geol. Survey, pt. 3, pp. 21–218. 1894.

——— Iron ores. In Nineteenth Ann. Rept. U. S. Geol. Survey, pt. 6, pp. 23–63. 1898.

——— Manganese ores. In Nineteenth Ann. Rept. U. S. Geol. Survey, pt. 6, pp. 91–125. 1898.

BOUTWELL, J. M. Iron ores in the Uinta Mountains, Utah. In Bulletin U. S. Geol. Survey No. 225, pp. 221–228. 1904.

CHISOLM, F. F. Iron in the Rocky Mountain division. In Mineral Resources U. S. for 1883–84, pp. 281–286. 1885.

CLEMENTS, J. M. The Vermilion iron-bearing district of Minnesota. Monograph XLV, U. S. Geol. Survey, 463 pp. 1903.

CLEMENTS, J. M., SMYTH, H. L., BAYLEY, W. S., and VAN HISE, C. R. The Crystal Falls iron-bearing district of Michigan. Monograph XXXVI, U. S. Geol. Survey, 512 pp. 1899.

DILLER, J. S. Iron ores of the Redding quadrangle, California. In Bulletin U. S. Geol. Survey No. 213, pp. 219–220. 1903.

ECKEL, E. C. Utilization of iron and steel slags. In Bulletin U. S. Geol. Survey No. 213, pp. 221–231. 1903.

HAYES, C. W. Geological relations of the iron ores in the Cartersville district, Georgia. In Trans. Am. Inst. Min. Eng., vol. 30, pp. 403–419. 1901.

——— Manganese ores of the Cartersville district, Georgia. In Bulletin U. S. Geol. Survey No. 213, p. 232. 1903.

HAYES, C. W., and ECKEL, E. C. Iron ores of the Cartersville district, Georgia. In Bulletin U. S. Geol. Survey No. 213, pp. 233–242. 1903.

IRVING, R. D., and VAN HISE, C. R. The Penokee iron-bearing series of Michigan and Wisconsin. Monograph XIX, U. S. Geol. Survey, 534 pp. 1892.

KEITH, A. Iron-ore deposits of the Cranberry district, North Carolina-Tennessee. In Bulletin U. S. Geol. Survey No. 213, pp. 243–246. 1903.

KEMP, J. F. The titaniferous iron ores of the Adirondacks [New York]. In Nineteenth Ann. Rept. U. S. Geol. Survey, pt. 3, pp. 377–422. 1899.

LEITH, C. K. The Mesabi iron-bearing district of Minnesota. Monograph XLIII, U. S. Geol. Survey, 316 pp. 1903.

——— Geologic work in the Lake Superior iron district during 1902. In Bulletin U. S. Geol. Survey No. 213, pp. 247–250. 1903.

——— The Lake Superior mining region during 1903. In Bulletin U. S. Geol. Survey No. 225, pp. 215–220. 1904.

——— Iron ores in southern Utah. In Bulletin U. S. Geol. Survey No. 225, pp. 229–237. 1904.

SMITH, E. A. The iron ores of Alabama in their geological relations. In Mineral Resources U. S. for 1882, pp. 149–161. 1883.

SMITH, GEO. O., and WILLIS, B. The Clealum iron ores, Washington. In Trans. Am. Inst. Min. Eng., vol. 30, pp. 356–366. 1901.

SPENCER, A. C. The iron ores of Santiago, Cuba. In Eng. and Min. Jour., vol. 72, pp. 633–634. 1901.

——— Manganese deposits of Santiago, Cuba. In Bulletin U. S. Geol. Survey No. 213, pp. 251–255. 1903.

SWANK, J. M. The American iron industry from its beginning in 1619 to 1886. In Mineral Resources U. S. for 1886, pp. 23–38. 1887.

——— Iron and steel and allied industries in all countries. In Sixteenth Ann. Rept. U. S. Geol. Survey, pt. 3, pp. 219–250. 1894.

VAN HISE, C. R., BAYLEY, W. S., and SMYTH, H. L. The Marquette iron-bearing district of Michigan, with atlas. Monograph XXVIII, U. S. Geol. Survey, 608 pp. 1897.

VAN HISE, C. R. The iron-ore deposits of the Lake Superior region. In Twenty-first Ann. Rept. U. S. Geol. Survey, pt. 3, pp. 305–434. 1901.

WEEKS, J. D. Manganese. In Mineral Resources U. S. for 1885, pp. 303–356. 1886.

——— Manganese. In Mineral Resources U. S. for 1887, pp. 144–167. 1888.

——— Manganese. In Mineral Resources U. S. for 1892, pp. 169–226. 1893.

WOLFF, J. E. Zinc and manganese deposits of Franklin Furnace, N. J. In Bulletin U. S. Geol. Survey No. 213, pp. 214–217. 1903.

YALE, C. G. Iron on the Pacific coast. In Mineral Resources U. S. for 1883–84, pp. 286–290. 1885.

In addition to the papers listed above, iron deposits of more or less importance have been described in the following geologic folios (for location and further details see pp. 13–16) : Nos. 2, 4, 5, 6, 8, 10, 11, 12, 14, 18, 19, 20, 21, 22, 24, 25, 28, 32 33, 35, 36, 37, 40, 43, 44, 55, 56, 59, 61, 62, 64, 70, 72, 78, 82, 83, 84.

COAL.

THE WARRIOR COAL BASIN IN THE BROOKWOOD QUADRANGLE, ALABAMA.

By Charles Butts.

FIELD WORK.

Within the last twenty years Alabama has come into great prominence as a coal and iron producing State, standing in 1903 third among the States in the production of iron ore and fifth in the production of coal. In that year the output of iron ore reached 3,684,960 tons and of coal 11,654,324 short tons. The position of the State in this respect is due to the exploitation of the deposits of iron ore and coal in the region of which Birmingham is the business and geographic center and which is known as the Birmingham mineral district. On account of the great economic importance of this district the United States Geological Survey, in cooperation with the Alabama Geological Survey, is engaged in making a geological map of it and a report on its geology and mineral resources. In the autumn of 1904 a survey of the Brookwood quadrangle was begun by the writer, Mr. H. S. Gale, and Mr. E. F. Burchard. While the work was not completed, the portion of the area underlain by the coal seams of the Warrior basin was examined in detail, and it is the purpose of this contribution to state in a provisional way the general results of the investigation.

LOCATION.

The Brookwood quadrangle is a rectangular area of about 1,000 square miles, lying between Birmingham and Tuscaloosa, near the central part of Alabama. Its northern boundary passes just north of Oregonia post-office, or Wyndham Springs, and Toadvine. Its eastern boundary is 3 miles west of Bessemer and 6 miles east of Blockton. The southern boundary is about 1 mile south of Pratts Ferry and the same distance south of the extreme southern boundary of Tuscaloosa County. Tuscaloosa is situated 3 miles west of the western boundary.

EXTENT OF THE COAL FIELD.

About one-half, or 500 square miles, of the quadrangle lies in the Warrior coal basin. This area embraces about one-sixth of the total area of the basin and includes all of the quadrangle lying northwest of a line roughly drawn from the vicinity of Earnest southwestward along the northwestern flank of Rock Mountain to Wawah, running

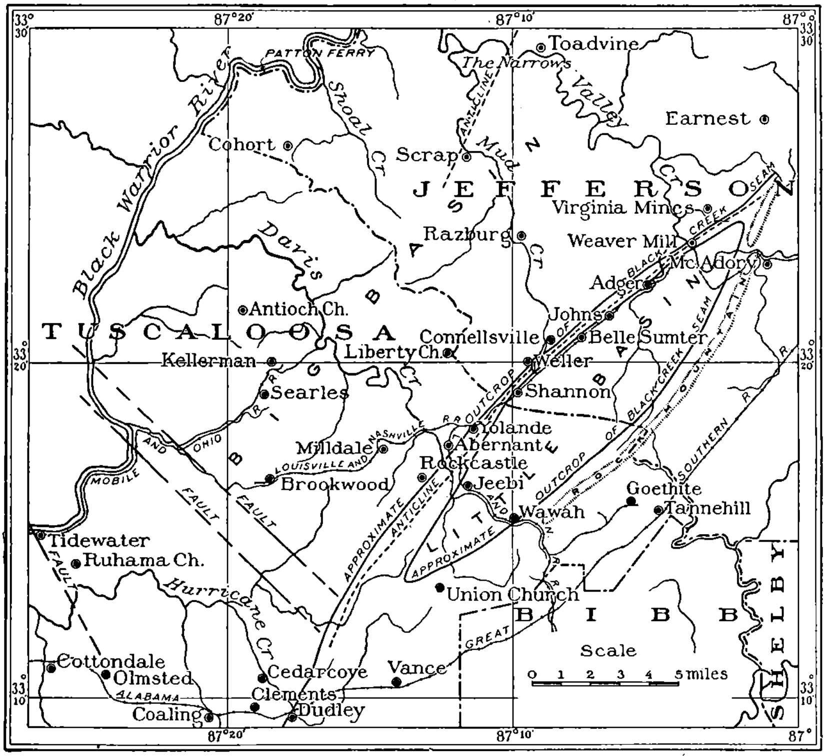


FIG. 20.—Sketch map of the Warrior coal basin, in the Brookwood quadrangle, Alabama.

thence about 2 miles northwest of Union Church, then turning more to the southwest, and reaching the Alabama Great Southern Railroad at Dudley. From Dudley the outcrop of the Carboniferous rocks follows in a general way the railroad to Cottondale; thence it follows Hurricane Creek to Black Warrior River, and the river to Tuscaloosa. South of the limit indicated above, these rocks extend below the surface and possibly underlie all the southwestern corner of the quadrangle west of a line running from Dudley through a point about 2 miles east of Pearl.

PHYSICAL FEATURES.

The surface of the Warrior basin is in large part characterized by long, narrow ridges and spurs separated by narrow valleys and ravines. The tops of these ridges have a general altitude of from 500 to 600 feet above sea level. In the northeastern corner of the quadrangle are large level tracts, which have an elevation of approximately 500 feet. These features indicate that the region formerly had a nearly level surface, the remnants of which are the areas above 500 feet. This old surface has been minutely dissected by the streams of the region and the present irregular topography produced.

Black Warrior River crosses the northwestern part of the quadrangle and drains the entire area under consideration. Its principal tributary is Valley Creek, a stream of considerable size, which has its source in the limestone valley region to the southeast, and, after crossing the northeastern part of the quadrangle, reaches Black Warrior River a short distance north of its northern boundary. Davis Creek, crossing the central part of the field, and Hurricane Creek, in the southern part, are important streams. Yellow Creek and Blue Creek are the principal streams west of the river.

These streams are of considerable importance on account of the quantity of water needed by coal washeries. Should need be in the future, Valley Creek, Hurricane Creek, and Yellow Creek will probably furnish abundance for that purpose. They were flowing a good volume well up toward their heads in the fall of 1903, even though the rainfall of the preceding season or two had been much lighter than ordinary. Davis Creek, from which water is drawn for use in the washer at the Central mine, failed in the protracted drought of last season.

Although the region in general is rather rugged, the valleys with their tributaries make most parts of the Warrior basin in the quadrangle accessible to railroads without presenting any great engineering difficulties. This makes possible the cheap transportation of the coal.

STRATIGRAPHY.

The Warrior coal basin is the southwestern end of the Appalachian coal field of the eastern United States. Its rocks are a thin superficial deposit of unconsolidated sands, clays, and gravels of Tertiary and Cretaceous age, and a great thickness of Carboniferous rocks.

In the Brookwood quadrangle the northeastern limit of the unconsolidated deposits is roughly a line extending from the northwestern corner of the quadrangle to beyond Milldale, though gravel occurs on some of the higher hills to the northeast. Generally the unconsolidated material is confined to the hilltops, ridges, and level uplands, and to the higher parts of the slopes, where it has probably been washed down from the deposits in place above, but in the southwestern third of the coal-bearing area the distribution of the unconsolidated rocks is more general. The thickness of this material varies from a few feet along the northeastern limit to probably more than 100 feet along the southwestern margin of the field.

The Carboniferous or coal-bearing rocks are shales and sandstones of Pottsville age, and are in general the equivalents of the rocks of the New River and Kanawha coal fields of West Virginia and of the anthracite coal field of Pennsylvania.

Below is a general section of these rocks compiled from measurements made at different points.

The section extends down to the top of the thick quartzitic sandstone, forming by its nearly vertical outcrop the prominent ridge of Rock Mountain, and the total thickness of the included rocks is about 3,000 feet.

Generalized section of Carboniferous rocks of Warrior field.

Character of rocks.	Thickness.		
	Average.	Minimum.	Maximum.
	Feet.	*Feet.*	*Feet.*
Shale	50	------	------
Sandstone	30	------	------
Shale, with sandstone below locally	100	------	------
Brookwood coal	5	3	7
Sandstone	35	30	40
Milldale coal	2½	1	2½
Sandstone	40	------	------
Johnson or Carter coal	2½	1	2½
Sandstone	25	------	------
Shale and sandstone	160	------	------
Gwin coal	2½	1	4
Shale	15	5	25
Sandstone	70	20	120
Thompson Mill coal	1¾	1	1½
Shale	145	70	220
Cobb upper coal	1¼	1	1½
Shale and sandstone	20	------	------
Cobb lower coal	1½	1	2
Sandstone	40	20	60
Shale	220	160	280
Pratt coal	3¼	1½	5

Generalized section of Carboniferous rocks of Warrior field—Continued.

Character of rocks.	Thickness.		
	Average.	Minimum.	Maximum.
	Feet.	*Feet.*	*Feet.*
Shale and sandstone	18	16	20
Nickel Plate coal	7	5	9
Shale and sandstone	80	60	100
American coal	5	4	6
Sandstone, with shale bands	180		
Shale	310		
Mary Lee coal	2		
Shale and sandstone	50		
Blue Creek coal	8	6	10
Shale	40		
Jagger coal	4	2	6
Shale, with sandstone beds at top	50		
Ream coal	1½	0	5
Shale and sandstone	250		
Jefferson coal	4	1	7
Shale?	50?		
Black Creek coal	2	½	4
Shale	140		
Coal (seam?)	2		
Shale	40		
Small coal	1		
Shale	60		
Small coal	1		
Sandstone	100		
Shale	300		
Shale and sandstone	350		
Sandstone of Rock Mountain			
Total	3,075½		

The highest rocks stratigraphically in this part of the Warrior basin appear to cap a high knob situated in the southeastern angle between Davis and Rockhall creeks, about 1 mile a little southeast of their junction. On this knob, above the sandstone described below, are indications of shale which may be 50 feet or more in thickness. Below this shale is about 30 feet of a somewhat shaly sandstone; what is regarded as the same sandstone caps a high knob crossed by the road 1 mile north of Liberty Church, and another knob about one-half mile north of Milldale. At these points the sandstone is rather coarse and probably at least 30 feet thick. Below this sandstone are about 100 feet of gray shale. In places this shale immediately overlies the Brookwood coal, as shown in an air shaft at the Central mine, which penetrates 60 feet of shale. The same condition prevails at Milldale. At Cedarcove, on the other hand, there is 10 to 20 feet of sandstone, separated from what is regarded as the Brookwood coal by a few feet of shale.

Below the Brookwood coal is about 100 feet of heavy sandstone, which includes the Milldale and Carter (or Johnson) coal seams. In this sandstone is a band of conglomerate which in places is 20 feet thick and is the most important Coal Measures conglomerate in the quadrangle. It immediately overlies the Milladle coal or its horizon over large areas. The conglomerate, as well as the sandstone, is especially well developed and exposed along Hurricane Creek and the upper part of Yellow Creek. The sandstone is thick east of Razburg and on the ridges between Davis Creek and Mud Creek. Its upper beds pass beneath the clays and sands of the Lafayette and Tuscaloosa formations at Tuscaloosa, Cottondale, and on Lye Branch of Big Sandy Creek about 3 miles south of Coaling. This shows that the full thickness of the Coal Measures extends for some distance south of the well-exposed rocks of the Warrior basin. This sandstone is generally underlain by about 160 feet of stiff, gray, mostly sandy shale, which, in the vicinity of Razburg, contains in its lower part many thin sandstone bands, and between Cohort and Patton Ferry, as well as between Blue Creek and Yellow Creek west of Black Warrior River, appears to be partly replaced throughout by thick-bedded sandstone.

Near the base of the shale described above lies the Gwin coal, which is generally separated by from 5 to 20 feet of shale from the next underlying sandstone. This sandstone is persistent and is generally thick-bedded or even massive. In most places it is 30 to 40 feet thick, but it reaches a thickness of 100 feet along the lower part of Davis Creek and in the bluffs along the west side of the Black Warrior below the mouth of Bone Creek. It underlies the flat land in the northeastern corner of the quadrangle for 10 miles west from Earnest. One and a half miles west of Adger it is apparently over 100 feet thick.

Below this sandstone is a shale whose thickness is 70 feet on Mud Creek, 100 feet on Rock Creek, and apparently 220 feet 1½ miles west of Adger. Below this shale is the upper Cobb coal, which is separated by 20 feet of shale or sandstone from the lower Cobb coal. It was said that the shale is *apparently* 220 feet thick west of Adger because the exact position of the Cobb coals in that section is not known to the writer. The position of a coal that is supposed to be the Pratt coal is known, however, and assuming that the interval between the upper Cobb and the Pratt coals is approximately the same in the section west of Adger as in a diamond-drill hole on Black Branch in the vicinity of Virginia mine, the interval between the Cobb upper coal and the base of the sandstone at the top of the shale would be 220 feet. This part of the section west of Adger does not show all the rocks and it is not known that it is fully occupied by shale, but shale is the only rock seen and is assumed to persist throughout. From the thicknesses given above it appears that the interval between the Gwin coal and the upper Cobb coals varies from 120 to 350 feet, according to locality.

Below the Cobb coals is a rather coarse, thick-bedded sandstone, which appears to be persistent throughout the quadrangle. It is especially prominent along Valley Creek for several miles below the mouth of Black Branch, and in places makes a long bluff 30 to 50 feet high. Its thickness varies from 20 to 60 feet, 40 feet being perhaps a fair average. In the vicinity of Toadvine this sandstone is succeeded below by a stiff sandy shale about 170 feet thick, but along Valley Creek, from Lick Creek to Blue Creek and west of Adger, the equivalent rocks appear to reach a thickness of 300 feet and to consist of shaly to laminated sandstone rather than shale.

At the base of the shale just described lies the Pratt coal. The interval between the Pratt coal and the Cobb coals varies with the thickness of the intervening shale and sandstone from 200 feet at Toadvine to 365 feet on Black Branch and at Adger. The Pratt coal is underlain by about 15 to 20 feet of shale or shale and sandstone, and just below these beds lies the Nickel Plate coal. This is succeeded by from 60 to 100 feet of shale and heavy sandstone, beneath which lies the American coal. Then follows 180 feet of sandstone containing shale bands and two small seams of coal. The upper beds of the sandstone are well displayed along Valley Creek from Toadvine to the Narrows, and along the southeastern margin of the Big basin, to be described later, it is especially conspicuous by its nearly vertical attitude along a line of outcrop which crosses Valley Creek at the mouth of Blue Creek, passes about 1½ miles west of Adger, just west of the old Connellsville mine, and probably crosses Davis Creek some distance above the Louisville and Nashville Railroad bridge. This sandstone affords a good means of locating and identifying the Pratt coals. Immediately below it is about 300 feet of shale, at the base of which lies the Mary Lee coal. Computed measurement in the vicinity of Short Creek gave about 625 feet for the interval between the Pratt and Mary Lee seams. A similar measurement west of Adger gave 650 feet, while the interval measured in the before-mentioned diamond-drill hole on Black Branch is 574 feet. The average interval is probably about 600 feet.

Below the Mary Lee coal is about 50 feet of shale and sandstone, at the bottom of which lies the Blue Creek or Big coal. This is succeeded by about 40 feet of shale, just below which lies the Jagger coal. These measurements were made along the Louisville and Nashville Railroad between Johns and Adger. Mr. McCalley describes the Ream coal seam as occurring locally below the Jagger seam. He gives no measurement of the interval in this quadrangle, however, nor did the writer secure one, but, judging from McCalley's map of the Warrior basin, it is about 50 feet.

A coal that is assumed to be the Jefferson coal is exposed along the little stream entering Blue Creek, about three-fourths of a mile southwest of Adger, and according to computed measurements it is about 300 feet below the Jagger seam, the two coals being separated by shale, with sandstone beds of greater or less thickness in the upper part. Some of these sandstone strata are conspicuous at Johns, where they make a prominent ridge. The Black Creek coal, as distinct from the Jefferson, was not seen by the writer, but is included in the section on the authority of Mr. McCalley, who maps and describes it without stating its distance below the Jefferson seam in this quadrangle. His map indicates that the distance may be 50 feet.

Below the Jefferson Creek coal is 190 feet of shale, at the base of which is a coal seam. This seam outcrops at a number of points along the road from Belle Sumpter to Adger, and on the roadside near the little stream west of Adger it is 25 inches thick. The coal seam just described is succeeded below by 100 feet, apparently of shale, which includes two or more thin coal seams. These coals may be seen in the road west from Adger to Razburg, just to the west of the point at which it crosses the little stream above mentioned.

The shale described above rests on a stratum of rather thick-bedded sandstone, which is about 100 feet thick and is well exposed at the point just mentioned, where the road crosses the stream. The sandstone makes conspicuous ridges west of Adger, but it is not known whether it is a persistent stratum. Below this sandstone is about 300 feet of dark clay shale, which is well exposed along the road about three-fourths mile west of Adger. At the base of this shale is a sandstone which is exposed on the little stream above mentioned about midway between its mouth and its intersection with the road between Adger and Mud Creek. The sandstone is the lowest stratum exposed in this part of the field.

This carries the section down 650 feet below the Black Creek coal. The interval between the Black Creek coal and the before-mentioned sandstone at the base of the general section, measured along the road through the gap in Rock Mountain northwest of Tannehill, is about 1,000 feet. This adds 350 feet to the section below the lowest beds described above near Adger. A number of good sections at various points show that the rocks in this part of the general section are mostly green shales with beds of sandstone of varying thickness.

STRUCTURE OF THE FIELD.

The rocks of the Warrior basin within the Brookwood quadrangle are generally nearly horizontal. They have a general southwesterly dip, which carries rocks that are over 600 feet above sea level in the northern part of the quadrangle to 250 feet above the sea at Cottondale and less than 150 feet above the sea at Tuscaloosa. In the vicinity of Toadvine is the southwestern extremity of the Blountsville anticline, the axis of which enters the quadrangle about 1½ miles northwest of Toadvine and extends to the vicinity of Scrap post-office. The axis pitches to the southwest and the anticline seems to die out, so that there is but slight indication of its presence southwest of Scrap. The axis of a very strongly developed anticline crosses Valley Creek one-fourth mile above Weaver Mill, extends along the ridge about one-fourth mile northwest of Adger and Johns, passes through Connellsville Junction and about 1 mile southeast of Yolande, crosses Davis Creek a short distance south of the mouth of Rockcastle Creek, and probably runs thence southwestward to the headwaters of the Middle Fork of Hurricane Creek, along which the anticline appears to die out. All of the productive coal measures have been eroded away along the crest of this anticline, and a small elliptical area of coal measures to the southeast of the anticline has been cut off from the main body of the Warrior field. This area is known as the Little basin, in contradistinction to the rest of the field, which is spoken of as the Big basin. On approaching the anticline the rocks of the Big basin rise gently at first, then in a very short distance become nearly vertical, then flatten and rise more gently again to the crest of the anticline. From the Little basin the rocks rise with gradually increasing steepness to the axis, where they become nearly vertical, thus making an unsymmetrical and nearly closed fold. From Valley Creek to Connellsville the zone of nearly vertical rocks on the west begins about one-half mile from the axis of the anticline and is 1,000 feet wide. This zone continues southwestward from Connellsville and crosses Davis Creek at the Louisville and Nashville Railroad bridge east of Milldale. At this point the dip is 60° NW. Between Connellsville and Davis Creek the distance of the zone of steeply inclined rocks from the axis of the anticline increases to 1½ miles.

At Adger the dip of the rocks from the crest of the anticline to the vertical zone on the northwest is 25°, while along the Davis Creek section the dip is first nearly vertical at the crest, but in a short distance decreases to 20°, as determined by observations on the surface and in the mines. Nearer the vertical or steeply inclined zone to the west the western dip decreases to 10°, from which it changes abruptly to 60° or more. At a cut on the Louisville and Nashville Railroad, a short distance east of the bridge across Davis Creek east of Milldale, this change of dip can be observed, and the same change can be seen in the road from Adger to Razburg about 1¼ miles west of the former place. Southwestward from the Louisville and Nashville Railroad bridge across Davis Creek east of Milldale the dip seems to diminish in the line of the western vertical zone. It is comparatively light along the headwaters of Texas Creek, and on the Middle Fork of Hurricane Creek the only vertical or highly inclined rocks are those along the axis of the anticline. The latter zone of vertical rocks extends southwestward through Dudley, and in that vicinity nearly the whole thickness of the Coal Measure rocks outcrops along a strip not over one-half mile in width. The southeastern limit of these rocks and of the Big basin is approximately indicated by occasional outcrops of vertical sandstone from Dudley southwestward to Big Sandy Creek about 2 miles east of Pearl. Southwest of this point there are no further exposures of Carboniferous rocks.

The Little basin is a canoe-shaped trough extending from the vicinity of Union Church to a point 2 miles north of McAdory. Its northwestern limit has already been defined; its southeastern limit is the vertical or overturned sandstone of Rock Mountain. From the lateral margins of the basin the rocks dip at angles of from 20° to 15°, the dip gradually decreasing toward the center. In the northeastern end the rocks of the central part are thrown into a number of minor rolls, and in the Johns and Adger mines an anticline of considerable magnitude was discovered running parallel to the longer axis of the basin. This anticline is highest at Adger and decreases southwestward, appearing as a low fold at Johns and not extending as far as Belle Sumpter. Along the Louisville and Nashville Railroad, crossing the basin along Davis Creek, the rocks are practically flat from Jeebi to Wawah, and rise from either place at first gently and then more steeply to the margins of the basin. The structure of the southern end of the basin appears to be rather complicated, and its description will not be attempted here.

Besides the structures already described the field is more or less affected by faults. Those detected run in a general way at right angles to the southeastern margin of the basin. Faulting was observed at a number of points. A fault crosses North Fork of

Hurricane Creek about one-half mile above the covered bridge on the Clements road, and another about 1¾ miles above the same point. On Daniel Creek, about one-eighth mile above the bridge on the Tuscaloosa road, is a conspicuous fault, and on Black Warrior River, in a cut of the Mobile and Ohio Railroad about 1 mile below the mouth of Daniel Creek, is another point where faulting was observed. Certain irregularities in the rocks on the west side of the river, near the mouth of Laurel Branch and also about 2½ miles higher up the river, indicate faulting. The strike of these faults is uniformly N. 45° to 50° W. It is assumed that there are two parallel faults crossing the region about 1¼ miles apart. The first crosses North Fork of Hurricane Creek at the upper point described, passes near the bridge across Daniel Creek, and crosses Black Warrior River about 2½ miles above the mouth of Laurel Branch. The second fault is 1¼ miles to the southeast of the first and passes through the points already mentioned. The strata between these faults, or the fault block, are downthrown on Hurricane Creek, so that the thick-bedded sandstone associated with the Brookwood group of coals abuts against the shale that normally underlies it. The total downthrow may equal but probably does not exceed 160 feet. On Black Warrior River the rocks between the faults are downthrown along the northeastern fault, but upthrown along the southwestern fault. These facts indicate a torsion of the fault block between the river and Hurricane Creek. In the bluff of Yellow Creek, one-half mile above its mouth, is a conspicuous fault, and what is apparently the same fault was traced southeastward to the point where the Keens Mill road crosses the little stream 1¾ miles northwest of Olmstead. At the last point there is either a fault or a sharp flexure. The rocks along this fault are apparently upthrown on the northeast side, the amount of upthrow on Yellow Creek appearing to be about 80 feet. In addition to these faults observed on the surface, faults have been encountered in mining operations at Brookwood, Milldale, and Johns. West of the Louisville and Nashville Railroad, between Adger and McAdory, the Little basin is reported to be crossed by a fault, which brings up the Black Creek coal to the level of the Blue Creek, indicating a throw of from 250 to 350 feet. It seems not unlikely that there is much more faulting of a similar nature in the field.

THE COALS.

The coals of the Warrior basin, including those in the Brookwood quadrangle, were very fully investigated by Mr. Henry McCalley, and his results were published in the Report on the Warrior Coal Basin. The present survey has added but little to the detailed knowledge of the various seams published in that report. Mr. McCalley separated the coal seams of the Warrior Basin into six groups, which, from above downward, are as follows: The Brookwood, Gwin, Cobb, Pratt, Mary Lee, and Black Creek. The seams discussed in the following pages are included in the above groups, as follows: In the Brookwood group, the Brookwood, Milldale, Carter, and Clements seams; in the Gwin group, the Gwin and Thompson Mill seams; in the Cobb group, the Cobb seams; in the Pratt group, the Pratt, Nickel Plate, and American seams; in the Mary Lee group, the Mary Lee, Blue Creek, Jagger, and Ream seams; in the Black Creek group, the Jefferson and Black Creek seams.

BROOKWOOD GROUP.

The Brookwood is the uppermost seam of any importance in the quadrangle. It is well known and developed only at Brookwood, Searles, and Central. At the last two places it is about 7 feet thick, with several partings of clay and bone. This coal was formerly mined near Cedarcove, about 2 miles north of Clements, and the old mine is being reopened. At this point the coal is about 30 inches thick.

The following sections exhibit the character of the seam in these localities:

Section of Brookwood seam at Central mine, Kellerman.

Shale roof:	Inches.
Coal	24
Bone	3
Coal	8
Bone	1
Coal	8
Bone	1½
Coal	11½
Slate	½
Coal	6
Slate	9
Coal	14
Total	86½

Section of Brookwood seam at mine No. 12 of Alabama Consolidated Coal and Iron Company, Brookwood.

	Inches.
Coal	2
Clay	4½
Coal	20
Shale	1
Coal	7½
Slate	2
Coal	11
Total	48

Section of Brookwood seam at Old De Bardeleben mine, Cedarcove.

	Inches.
Shale roof:	
Coal	7
Clay	1½
Coal	21
Total	29½

The coal is probably present over considerable territory in the vicinity of Antioch Church and also on the ridges south of Daniel Creek toward Ruhama Church, though the writer obtained but little data concerning its presence or value in those regions. It outcrops at Milldale, but is reported of little value. It is not known to the writer to be present west of Black Warrior River within this quadrangle.

The Milldale coal appears to be generally present, where not eroded, from Milldale to the head of Turkey Creek, west of the river, and southward to the southern end of the field, though probably it is not everywhere of minable thickness. Where it has been opened and mined it varies from 22 to 30 inches in thickness, with a parting of clay from one-half inch to 2 inches thick. Below are typical sections of the seam:

Section of Milldale seam at Mine No. 7 of Alabama Consolidated Coal and Iron Company, Brookwood.

	Inches.
Sandstone:	
Shale	48
Coal	4½
Bone	½
Coal	21
Total cost	26

Section of Milldale seam west of Ruhama Church.

	Inches.
Conglomerate:	
Coal	14
Clay	2½
Coal	7
Clay	
Total	23½

Section of Milldale seam near Mount Perrin Church.

	Inches.
Conglomerate:	
Coal	14
Shale	6
Coal	16
Total	36

This seam is generally overlain by a coarse, heavy sandstone, as at Milldale and Brookwood, or by a conglomerate, as along Hurricane Creek and its branches. What is regarded as this conglomerate or its equivalent—coarse sandstone, with the coal beneath—is generally present on the west side of Black Warrior River from north of Bone Creek southward and serves for the identification of the coal. At Searles and Central it is believed that the Milldale seam forms the bottom bench of the Brookwood seam, the two seams approaching within a few inches of each other by the disappearance of the sandstone that separates them elsewhere.

The Johnson, or Carter, seam, as it is locally known, is of importance in the region between Milldale and Brookwood, where it has an average thickness of 30 inches nearly solid coal. The following are sections from this region:

Sections of Johnson or Carter seam.

No. 1. Alabama Consolidated mine, Hewett.

Sandstone:	Inches.
Coal	25 to 30

No. 2. Alabama Consolidated mine No. 10, Brookwood, at pit's mouth.

Sandstone:	Inches.
Shale	48
Coal	19
Slate	1
Coal	13½
Total coal	33½

No. 3. Alabama Consolidated mine No. 10, Brookwood, at end of entry.

Sandstone:	Inches.
Shale	48
Coal	23
Slate	1
Coal	12
Total coal	36

The Johnson seam is everywhere closely overlain by a massive sandstone, from which it is in places separated by a few feet of shale. In places the coal is partly or wholly lacking, and its place is taken by the sandstone. A seam that is apparently the Johnson seam was seen at a few points on the branches of Hurricane Creek west of Ruhama Church, where it is only 1 foot or less thick and lies in the midst of heavy sandstone. The blossom of a coal, apparently small, in sandstone was noted at several points on the ridges between Davis

Creek and Shoal Creek, and what is probably the same seam was seen in the midst of sandstone near the road midway between Cohort and Patton Ferry, where it is 1 foot thick. The sandstone is that connected with the Brookwood coals, and the position of the coal in the sandstone would indicate that it is the Carter seam.

The Clements coal is a seam of some importance at Clements, in the region east of Razburg, and especially on the ridge to the west of Mud Creek northwest of Adger. Mr. McCalley states that it is from 2 to 4 feet thick in this region.

GWIN AND COBB GROUPS.

The Gwin coal has a wide distribution in the northeastern part of the quadrangle, where it is from 2 to 4 feet thick, with 2½ feet probably a fair average. It also appears to be of good thickness along the southeast margin of the field. The coal makes a good showing on Indian Creek and is reported to be 2 to 2½ feet thick in one locality near the head of Blue Creek west of Black Warrior River. So far as observed, however, the seam is thin and worthless over most of the territory west of Black Warrior River and throughout most of a strip several miles in width east of that stream. The Cobb coals are best known along the streams in the northeastern part of the quadrangle. They are generally less than 2 feet thick, but may be thicker along the southeastern margin of the Big basin. Neither the Gwin nor Cobb coals are at present commercially important in this quadrangle.

PRATT GROUP.

The Pratt coal is known only along the southeastern margin of the Big basin and on Valley Creek in the vicinity of Toadvine. Elsewhere the seam is several hundred feet below the surface. Along Valley Creek the coal is not over 2 feet thick, so far as learned. The seam is not very well known along the southeastern margin of the field. As identified it is from 3½ to 6 feet in thickness, with thick clay partings where thickest.

Below are a few sections representative of the character of the seam.

Section of Pratt seam on Valley Creek, 2 miles west of Toadvine.

	Inches.
Shale:	
Coal	12
Bone	2½
Coal	7
Bone	1
Coal	1
Total	**23½**

Section of Pratt seam at Virginia mine.

Sandstone:	Inches.
Coal	11
Slate	2
Coal	2
Slate	3
Coal	7
Slate	8
Coal	12
Total	45

Section of Pratt seam one and one-half miles west of Adger.

	Inches.
Coal	8
Clay	12
Coal	24
Clay	20
Coal	18
Total	82

The Nickel Plate seam is well known and mined only at Virginia mines and vicinity, where the following sections were obtained:

Section of Nickel Plate seam in diamond-drill hole on Black Branch.

Black shale:	Inches.
Coal	9
Slate	3
Coal	24
Slate	12
Coal	22
Slate	33
Coal	10
Total	113

Section of Nickel Plate seam in diamond-drill hole at Virginia mines.

Shale:	Inches.
Coal	33
Slate	3¼
Coal	21½
Total	57¾

Section of Nickel Plate seam at Virginia mine.

	Inches.
Coal	32
Shale	6
Coal	21
Total	59

In this quadrangle the American seam is known to the writer only in two diamond-drill holes on Black Branch in the neighborhood of Virginia mines. In these holes the seam, like all the thick seams of the field, is much broken by shale partings, as the following sections will show:

Section of American coal seam in diamond-drill hole on Black Branch.

Shale:	Inches.
Coal	2
Slate	5
Coal	2
Slate	3
Coal	31
Slate	9
Coal	2
Slate	4
Coal	3
Total	61

Section of American coal seam in diamond-drill hole at Virginia mines.

Shale:	Inches.
Coal	4
Slate	5
Coal	3
Slate	4
Coal	20
Slate	7
Coal	2
Slate	2
Coal	6
Total	57

MARY LEE GROUP.

The Mary Lee seam was noted at Johns and along the railroad between that place and Adger. It appeared to be thin and of no value. Mr. McCalley,[a] however, gives a number of measurements of what he regarded as this seam in both the Little and Big basins, a few of which are given below. These measurements show that the seam, though of considerable thickness in places, is generally much broken by shale partings, so as to be of little importance from a practical standpoint.

[a] Rept. on Warrior basin, p. 97.

Section of Mary Lee seam in Little basin northeast of Adger.

	Inches.
Shale:	
Coal, shale partings	9
Coal smut	11 to 12
Mineral charcoal	¼
Coal smut	7 to 8
Shale	4
Coal	3
Shale	½
Coal smut	6 to 7
Total	40¾ to 43¾

Section of Mary Lee seam in Little basin near Blue Creek Church.

	Inches.
Coal smut	22
Coal and shale	4
Total	26

Section of Mary Lee seam in Big basin near Connellsville.

	Inches.
Coal, called cannel coal	60
Black band ore	24
Total coal	60

The Blue Creek seam is mined in the Little basin and has a thickness of from 6 to 10 feet. It is much broken by shale partings, some of which may reach a thickness of 1 foot. This seam underlies 15 to 20 square miles of the Little basin, and probably is a thick seam along its outcrop on the margin of the Big basin.

The following sections indicate its character:

Section of Blue Creek seam in Big Basin, 1 1/2 miles west of Adger.

	Inches.
Coal	5
Clay	5
Coal	30
Clay	6
Coal	18
Clay	4
Coal	6
Total	74

Section of Blue Creek seam at Adger mine.

	Inches.
Shale:	
Coal	16
Clay	12½
Coal	17½
Clay	10¼
Coal	24
Shale	¾
Coal	15½
Slate	½
Coal	5¼
Clay	2
Coal	3¾
Clay	2
Coal	12
Clay	2
Coal	6
Total	130

Section of Blue Creek seam at Johns mine.

	Inches.
Bone	7
Shale	½
Coal	17
Shale	½
Coal	22
Shale	½
Coal	5
Shale	1¼
Coal	9¾
Shale	2
Coal	10
Shale	1½
Coal	5
Rash	1
Coal	6
Shale	1
Coal	8
Total	90¼

The Jagger seam, as observed in a railroad cut between Johns and Adger, is about 30 inches thick. According to common report it is too thin to be of value in the Little basin. In the Big basin, however, a seam that is regarded as the Jagger is mined at Yolande, Abernant, and at Rock Castle on a little branch of Davis Creek, about 2 miles southeast of Milldale. The coal at these mines is 6 to 8 feet thick, with several partings, some of which reach a thickness of 6 inches.

Following are typical sections of this seam:

Section of Jagger seam on Louisville and Nashville Railroad between Adger and Johns.

Shale:	Inches.
Coal	30

Section of Jagger seam at Davis Creek mine, Rock Castle.

Shale:	Inches.
Coal	19
Clay	6½
Coal	11
Rash	3
Coal	28
Clay	4½
Coal	12
Total	84

Section of Jagger seam at Yolande mine, Yolande.

"Coal slate:"	Inches.
Coal	2
Slate	1
Rash	6
Coal	20
Slate	5
Coal	39
Slate	4
Coal	14
Slate	
Total	97

There is a difference of opinion as to the identity of the seam mined at these points, some maintaining that it is the Blue Creek seam. There are reasons for both opinions, but the matter can not be discussed here, though the writer is inclined to favor the view that the seam is the Blue Creek.

Along the Louisville and Nashville Railroad, southeast of Valley Creek station, there is a coal seam outcropping that Mr. McCalley identifies as the Ream seam. This is generally composed of thin layers of coal and shale or clay, and only in one section appears to have a sufficient thickness of coal to be minable.

BLACK CREEK GROUP.

The Jefferson seam, as identified by the writer in the little stream west of Adger and on the Louisville and Nashville Railroad, near Jeebi, consists of several thin benches of coal and clay, the whole being from 6 to 10 feet thick. Mr. McCalley gives a number of measurements in both the Big and Little basins in which this seam runs from 16 to 42 inches. It is generally much broken by clay partings into several thin benches of coal, so that it probably could not be mined with profit under present conditions.

According to the reports of Mr. McCalley, the Black Creek coal is persistent in the quadrangle. His measurements in both the Little and Big basins show a thickness of from 16 to 54 inches for the seam, there being in many cases a clean bench of coal from 30 to 40 inches thick. If the quality of the coal in this quadrangle is as good as in other parts of the Warrior field, it would appear that it could be mined with profit in some localities.

Nothing very definite is known about the coal seams below the Black Creek seam. The writer obtained a measurement of a seam 25 inches thick, with clay partings, 190 feet below the Jefferson coal on the little stream west of Adger, but no indications of minable seams at horizons certainly below the Black Creek seam were seen.

GENERAL MINING CONDITIONS.

The Brookwood group of coals lies nearly flat. Its outspread in the quadrangle is, however, small. The Gwin and Cobb coals are not at present mined and may not be for a long time to come. Mining in the quadrangle will therefore probably be mostly confined to the lower coals of the Pratt and Mary Lee groups, which outcrop along the margins of the Big and Little basins, where the dips vary from 15° to 80°. While these coals lie nearly horizontal throughout most of the Big basin, they can only be reached by shafting to considerable depths or by following them down from their outcrop. In proceeding by the last-mentioned plan the rocks of the vertical zone, already described, would be encountered and such difficulties as they might present would have to be reckoned with. In addition to being vertical or highly inclined with normal northwest dip the rocks of this zone may be locally overturned or affected with strike faults to a greater or less extent, and such structures would be important factors in the mining problems to be solved.

The coal seams of this field are generally overlain by stiff shale or by sandstone, and these form a roof that is generally stable, so that a minimum of propping is necessary. The most important seams are, with their included partings, thick enough to give sufficient height to the entries and headings without removing any rock from the roof or floor of the mine. In the case of the Carter and Milldale seams, which are thin and overlain closely, in some places immediately, by heavy sandstone, it is necessary to remove much rock from the roof. Where sandstone immediately overlies the coal its removal adds considerably to the expense of mining, though the sandstone makes a good roof. In either of the above cases there is always a large quantity of waste material to be disposed of, and its disposal often involves considerable difficulty and expense.

CHARACTER OF THE COAL.

The coal from practically every seam mined in the quadrangle makes excellent coke, and it is equally good for steaming and domestic purposes. About one-third of the entire output of coal in the State is made into coke. To the proximity of such great deposits of coking coal and iron ore that exists in the Birmingham district, Alabama owes its prominence as an iron-producing State.

While the coal is of excellent coking quality, much of it is too dirty as it comes from the mines to be made at once into coke. It is necessary to wash it first. By "dirty" is meant that the coal is mixed with a large proportion of clay, shale, bone, etc., that would impair the quality of the coke. The presence of such material is due to the many partings, by which the coals of this region are broken into thin benches, and in many cases this mixture is so intimate that in mining it is impracticable or impossible to separate the foreign matter from the coal.

This separation is effected by washing, which consists in bringing the slack or crushed coal into water in such a way that the impurities, being heavier than the coal, settle to the bottom, leaving the coal above. The process is continuous, the particles of clay, shale, etc., being drawn off from the bottom and the coal spilling over above. The washing is done by rather elaborate mechanical contrivances, of which no description will be attempted here. By washing much coal is made suitable for coking that apparently could not otherwise be used or could only be made into an inferior grade of coke. A washer is therefore an important part of the equipment of several large mines operating in the quadrangle, of which the coal is largely coked. There is one each at Central, Searles, Brookwood, Johns, and Adger. Experiments recently made at the coal-testing plant at the Louisiana Purchase Exposition and reported in United States Geological Survey Bulletin No. 261 showed that dirty slack, otherwise of little value, could be so improved by washing as to fully equal lump coal in steam-producing power. This suggests that dirty slack to be used for steaming purposes could be profitably washed, as, in fact, has been the experience at certain western mines, and that washing might be extended with profit to other mines in the quadrangle and the slack utilized for other than coking purposes.

The chemical composition of the various seams that are now mined is exhibited by the analyses in the subjoined tables. Eleven of these analyses were made by E. E. Somermeier, under the direction of N. W. Lord, at the coal testing plant at the Louisiana Purchase Exposition. The samples were taken in the following manner: A section of uniform width and depth was cut from a working face of the coal seam from top to bottom, such portions being rejected as are rejected in mining. The coal thus obtained was crushed and thoroughly mixed, then quartered and opposite quarters rejected. This process was repeated until the sample was reduced to convenient size. It was then inclosed in a galvanized-iron can holding about one quart and sent within a few days to the laboratory for analysis. In nearly every case the sample was collected by or under the observation of one of the parties engaged in the survey of the quadrangle. It is confidently believed, therefore, that each sample fairly represents the seam at the point from which it was obtained. The samples in analyses Nos. 11, 12, and 13 were taken by an agent of the Louisville and Nashville Railroad, and presumably were impartially taken. They are published through the courtesy of Mr. J. C. Maben, jr. Analyses Nos. 3, 6, and 9 were furnished by the Tennessee Coal, Iron and Railroad Company, and analysis No. 10 by Dr. G. B. Crowe.

Analyses of coals from Warrior coal field, Alabama.

	1.	2.	3.	4.	5.	6.
Moisture	2.88	2.91	1.67	2.63	3.37	2.14
Volatile matter	25.98	24.08	27.71	26.49	25.77	26.40
Fixed carbon	60.96	53.21	60.75	59.63	61.21	66.60
Ash	.18	19.80	9.87	11.25	9.65	4.86
Sulphur	.94	.70	.66	.97	.94	.58
Phosphorus			.070			.058
Calorific value determined—calories					75.82	
Calorific value determined—B. T. U.[a]					136.48	

[a] British thermal units.

1. Blue Creek seam, Adger slope; Adger, Ala., Tennessee Coal, Iron and Railroad Company, owner; E. E. Somermeier, analyst; Chas. Butts, collector.
2. Blue Creek seam, Adger slope; Adger, Ala., Tennessee Coal, Iron and Railroad Company, owner; E. E. Somermeier, analyst; Chas. Butts, collector.
3. Blue Creek seam, Adger slope; Adger, Ala., Tennessee Coal, Iron and Railroad Company, owner; analysis furnished by the company.
4. Blue Creek seam, Johns slope; Johns, Ala., Tennessee Coal, Iron and Railroad Company, owner; E. E. Somermeier, analyst; E. F. Burchard, collector.
5. Blue Creek seam, Johns slope; Johns, Ala., Tennessee Coal, Iron and Railroad Company, owner; E. E. Somermeier, analyst; E. F. Burchard, collector.
6. Blue Creek seam, Johns slope; Johns, Ala., Tennessee Coal, Iron and Railroad Company, owner; analysis furnished by the company.

Analyses of coals from Warrior coal field, Alabama—Continued.

	7.	8.	9.	10.	11.	12.
Moisture	2.20	4.46	2.04	2.25	4.08	0.88
Volatile matter	24.62	22.30	25.00	28.00	27.47	29.30
Fixed carbon	60.51	47.98	63.41	62.00	57.39	62.19
Ash	12.67	25.26	9.55	7.00	11.06	7.65
Sulphur	.54	1.32	.64	.75	1.30	1.26
Phosphorus			.065			
Calorific value determined—calories						
Calorific value determined—B. T. U.[a]						

	13.	14.	15.	16.	17.	18.
Moisture	4.34	1.96	3.85	2.35	3.81	2.08
Volatile matter	14.09	31.55	30.80	32.36	30.19	34.68
Fixed carbon	8.70	60.96	59.70	58.15	55.99	51.68
Ash	72.87	5.53	5.65	7.14	10.01	11.56
Sulphur	2.98	1.11	.78	1.37	1.49	1.57
Phosphorus						
Calorific value determined—calories		79.80				
Calorific value determined—B. T. U.[a]		143.64				

[a] British thermal units.

7. Blue Creek seam, Belle Sumpter slope; Belle Sumpter, Ala., Tennessee Coal, Iron and Railroad Company, owner; E. E. Somermeier, analyst; E. S. Pinckard, collector.
8. Blue Creek seam, Belle Sumpter slope; Belle Sumpter, Ala., Tennessee Coal, Iron and Railroad Company, owner; E. E. Somermeier, analyst; E. S. Pinckard, collector.
9. Blue Creek seam, Belle Sumpter slope; Belle Sumpter, Ala., Tennessee Coal, Iron and Railroad Company, owner; analysis furnished by the company.
10. Jagger seam, Yolande slope; Yolande, Ala., Crowe Coal and Iron Company, owner; analysis furnished by G. B. Crowe.
11. Jagger seam (including mining seam or coal rash), Davis Creek slope; Rock Castle, Ala., Davis Creek Coal Company, owner; J. C. Long, analyst; W. W. Hughes, collector.
12. Jagger seam (without mining seam or rash), Davis Creek slope; Rock Castle, Ala., Davis Creek Coal Company, owner; J. C. Long, analyst; W. W. Hughes, collector.
13. Jagger seam (parting of coal rash, 2 to 6 inches thick), Davis Creek slope; Rock Castle, Ala., Davis Creek Coal Company, owner; J. C. Long, analyst; W. W. Hughes, collector.
14. Milldale seam, slope No. 7; Brookwood, Ala., Alabama Consolidated Coal and Iron Company, owner; E. E. Somermeier, analyst; Chas. Butts, collector.
15. Carter seam, drift No. 10; Brookwood, Ala., Alabama Consolidated Coal and Iron Company, owner; E. E. Somermeier, analyst; Chas. Butts, collector.
16. Brookwood seam; Searles, Ala., Alabama Consolidated Coal and Iron Company, owner; E. E. Somermeier, analyst; E. F. Burchard, collector.
17. Brookwood seam, Central drift; Kellerman, Ala., Central Coal and Iron Company, owner; E. E. Somermeier, analyst; Chas. Butts, collector.
18. Tidewater drift; Tidewater, Ala., Warrior Coal Company, owner; E. E. Somermeier, analyst; Chas. Butts, collector.

MINING DEVELOPMENTS.

Important mining operations within this quadrangle began about eighteen years ago with the opening of the mines at Adger, Johns, and Belle Sumpter on the Blue Creek seam in the Little basin. These extensive and important mines are owned by the Tennessee Coal, Iron and Railroad Company. They are on the northwestern side of the Little basin. There was once a mine in the Blue Creek seam in the Little basin at Shannon, but it was closed probably fifteen years ago. A mine probably on the Blue Creek seam was opened in 1887 at Connellsville in the Big basin. It was located on the southeastern margin of the zone of vertical rocks, and the slope followed the seam down at an angle of 60° to 70°. The mine was abandoned several years ago.

In 1890 the Alabama Consolidated Coal and Iron Company began operations at Brookwood and Milldale. At Brookwood several mines have been opened, some of which have been worked out and abandoned. The Brookwood, Milldale, and Carter seams are worked. New mines have been opened in the Brookwood and Carter seams within the last year. At Milldale the Milldale seam was mined. The mine was a slope and was abandoned in 1903.

About 1890 a mine was opened in the Milldale seam at Coaling. It is reported not to have been a success and was abandoned in 1900. In 1892 a shaft was sunk at Clements to a coal that is identified as the Clements seam at the bottom of the Brookwood group of coals. This operation was abandoned in 1902.

In 1897 the Tidewater mine and Blair mine were opened on the Black Warrior River by the Warrior Coal Company and the Blair Coal Company, respectively. Both mines are small. The Tidewater is on the south side of the river, nearly opposite the mouth of Yellow Creek, and the Blair mine is on the north side of the river at the mouth of Yellow Creek. They are drifts in a seam which is regarded as the Brookwood by other investigators, but which the writer has reasons to believe is a lower seam. At Searles are three large mines in the Brookwood seam. They belong to the Alabama Consolidated Coal and Iron Company, which began mining at that place in 1900. In 1900 a slope in the Blue Creek seam was opened by the Jenifer Furnace Company at Weller, southwest of Connellsville; in 1901 the Abernant slope in the Jagger seam was opened at Abernant by the Abernant Coal Company; and in 1902 the Davis Creek mine, a slope, was opened by the Davis Creek Coal Company in the same seam on a branch of Davis Creek, about 2 miles southeast of Milldale. In that year the Alabama Consolidated Coal and Iron Company opened a slope on the Carter seam at Hewett, between Milldale and Brookwood, and the Alabama Steel and Wire Company opened the Virginia mine on Black Branch of Valley Creek. It is a slope in the Nickel Plate seam. In December of 1904 a mine was opened in the Jagger seam at Yolande by the Crowe Coal and Iron Company.

PROGRESS OF COAL WORK IN INDIAN TERRITORY.

By Joseph A. Taff.

GENERAL RELATIONS OF THE COAL DEPOSITS.

Rocks in which coal may be found in Indian Territory have an area of approximately 20,000 square miles. In this report, however, only those parts will be considered which have been investigated and are known to contain beds of workable coal. Where coal beds are known to be commercially valuable and have been accurately located the outcrops are marked in solid heavy lines on the map (Pl. I). In case of question as to thickness or accuracy in location, the outcrop is shown in short dash lines.

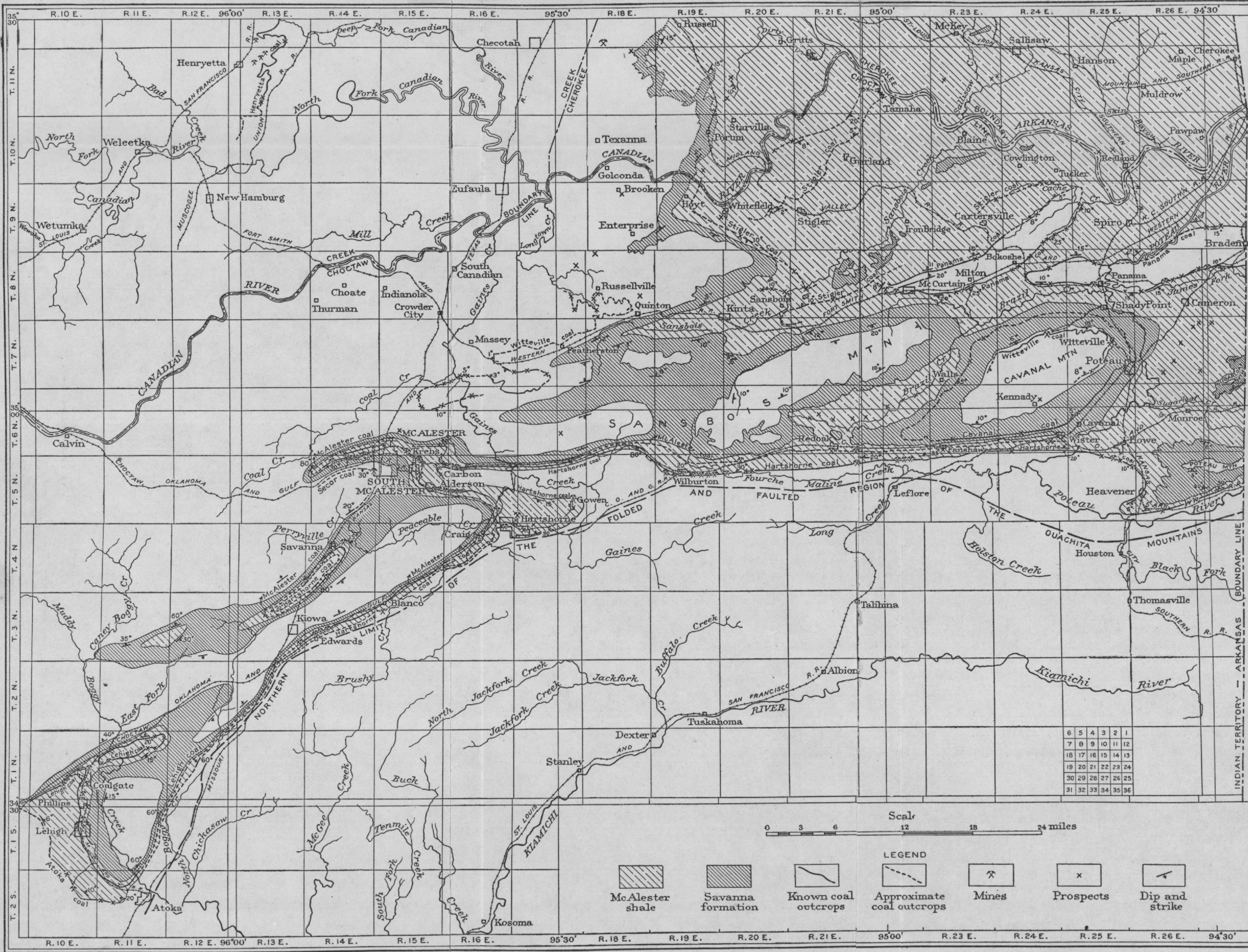
The coal in the eastern part of Indian Territory is a continuation of the deposits mined in Arkansas. The workable coal beds in the northern part of Indian Territory are stratigraphically above those in the southern part, but they occupy similar positions in the section and are probably the same as some of those in the Kansas field.

PREVIOUS WORK.

The first record of scientific investigation of coal in Indian Territory was published in 1890 by Dr. H. M. Chance.[a] In the interest of the Choctaw Coal and Railway Company, now the Choctaw, Oklahoma and Gulf Railroad Company, certain of the coal beds were traced from the vicinity of Poteau Mountain, near the Arkansas line, to McAlester, on the Missouri, Kansas and Texas Railroad.

Beginning, in 1897, in the western part of the Choctaw Nation, the United States Geological Survey has carried on detailed investigations and has completed the entire area of coal-bearing rocks of the Choctaw and Chickasaw nations and that part of the Cherokee and Creek nations south of Wagoner. Outlying areas, also, in the Creek and southern Cherokee nations, have been investigated where the coal has been mined commercially. As the surveys progressed, prelimi-

[a] Proc. Am. Inst. Min. Eng., 1890.



MAP OF CHOCTAW COAL FIELD, INDIAN TERRITORY.

nary reports[a] were made upon the coal deposits and their development. The present report will present the economic results of work since 1902, together with a brief review of the results of previous surveys.

GENERAL STATEMENT.

The coal beds of the Choctaw Nation thin out and become of no economic importance within a few miles north of Arkansas and Canadian rivers. The coals in the Creek and Cherokee nations occur much higher in the geologic section than the coals farther south. These beds thin out southward and are not known south of Canadian River. For these reasons and for convenience of description the coal field is divided into two parts, and the maps are drawn accordingly, the division line being marked by parallel of latitude 35° 30′. The southern part, which includes the Choctaw Nation, will be referred to as the Choctaw coal field and the northern part will be known as the Cherokee-Creek field.

CHOCTAW COAL FIELD.

STRATIGRAPHY.

The rocks in this coal field consist of sandstone, shale, and coal, with occasional thin limestone formations in the western and northern part. The shale succeeds sandstone and the sandstone follows upon shale repeatedly, with many coal beds interspersed, until there is a thickness of many thousand feet.

The maximum thickness of the exposed Coal Measures in the southern part of the field, south of Arkansas River, is estimated to be not less than 17,000 feet. The strata, however, between the lowest and highest workable coal beds, it is believed, will not exceed 7,000 feet in thickness. On the north side of the Arkansas Valley the thickness of the exposed part of the section is found to be reduced by nearly 6,000 feet. From the base of the Coal Measures up to the lowest productive coal the thickness does not exceed 1,200 feet, which in the south side of the field is represented by approximately 8,000 feet. On going northward from the Arkansas Valley on the east side of the field it is seen that the higher formations become thinner and more shaly, while the lower ones overlap on the Mississippian strata, at the same time becoming less sandy, so that when the northern end

[a] Geology of the McAlester and Lehigh coal fields, Indian Territory: Nineteenth Ann. Rept., pt. 3, 1899, pp. 429–593. Eastern Choctaw coal field, Indian Territory: Twenty-first Ann. Rept., pt. 2, 1900, pp. 263–311. The Southwestern coal field: Twenty-third Ann. Rept., pt. 3, 1902, pp. 373–413. Coalgate folio, No. 74. Atoka folio, No. 79. Description of unleased segregated coal lands of the McAlester, Wilburton-Stigler, Howe-Poteau, McCurtain-Massey, and Lehigh-Ardmore districts: Circulars 1, 2, 3, 4, and 5, respectively, Department of the Interior, 1904.

is reached hundreds of feet of rock section are represented by thousands in the south side of the Arkansas Valley.

Besides the remarkable thickness of the rocks as a whole and the even texture of the sandstones in the southern part of the field, there is the not less remarkable extension from east to west of many of the sandstone and coal beds. The Hartshorne sandstone and coal are examples. This sandstone, not more than 200 feet thick, extends westward from the Arkansas State line completely across the Choctaw Nation, a distance of nearly 200 miles, and one or more coal beds are found everywhere in or immediately above its top. Northward, however, both the sandstone and the coal thin out, so that in the north side of the Arkansas Valley south and west of the Ozark uplift it can not be recognized, and the coal which elsewhere lies above it is too thin to be of value or does not occur.

Only the formations which contain or are associated with coal of economic value are shown on the map. These, with the mapping of the outcrops of the coal beds and the conventional signs indicating structure, will make sufficiently clear the occurrence of the coal.

M'ALESTER FORMATION.

The McAlester formation consists chiefly of shale. A group of several sandstone beds interstratified with shale occurs near the center of the formation. These sandstones, however, are not distinctive in the southwestern part of the field. Eastward from the Missouri, Kansas and Texas Railroad they are more clearly defined, cropping out in ridges and capping flat-topped hills, which are surrounded by the valleys and plains developed on the shales. These sandstone beds vary in thickness locally, but, as a whole, are persistent from the vicinity of Krebs eastward to the Arkansas line. North of Cavanal and Sansbois mountains, where a number of upward folds bring them to the surface, the sandstone beds are seen to be much thicker. The ridges south of Bokoshe, north and south of McCurtain, south and east of Stigler, and on each side of the Canadian River near its mouth are made by these sandstones. Each of the shaly members above and below the group of sandstones is 700 to 800 feet thick, and the sandstone beds, with included shales, approximate 500 feet in thickness, making nearly 2,000 feet in all for the thickness of the formation. The McAlester formation can not be defined north of Arkansas River, since the boundary formations of sandstone above and below thin out and can not be traced. The McAlester formation contains four coal beds, which are being extensively developed, besides others reported to be locally workable. The two lowest are near together and near the base, and are known as the "Hartshorne coals." The upper ones occur immediately above the group of sandstone deposits, are also near together, and are known as the "McAlester coals."

SAVANNA FORMATION.

Next above the McAlester formation is a succession of strata, consisting of sandstone and shaly sandstone, in three groups or collections of beds, separated by deposits of shales, the whole making a thickness of 1,000 to 1,500 feet south of the Canadian and Arkansas rivers. North of the Canadian the formation becomes rapidly thinner, and is lost to view in the Cherokee Nation, 18 miles south of Muscogee. In the Choctaw Nation the outcrop of the formation is marked in the low country by many ridges and hills, and surrounding the Sansbois and Cavanal mountains the sandstone members make escarpments and benches. In the Choctaw Nation the Savanna formation contains two coal beds of workable thickness, and a third is found near the upper sandstone member in the shale of the succeeding formation. This third coal bed, which is mined in the east end of Cavanal Mountain and is known as the Witteville coal, is the highest coal known to be of economic value south of Canadian River. A coal bed having approximately the same position in the rocks has been developed for local purposes in the southern part of the Creek Nation, east of Checotah. All the formations which carry coals, and as far as known those still higher in the section in the southern part of the Indian Territory coal field, become thin northward and the sandy portions become shaly. The rocks which include the coal beds in the central part of the Creek Nation and the northern Cherokee Nation are far above the coal-bearing strata in the Choctaw Nation. They strike southwestward, approaching Canadian River near the extreme northwestern part of the Choctaw Nation.

STRUCTURE.

The southeastern part of the Indian Territory coal field lies in the Arkansas Valley, which is here a deep structural basin between the uplifts of the Ouachita Mountains on the south and the Ozark Mountains on the north. The Ozark region is a low, broad, dome-like uplift, and the rocks at its southern border in the north side of the Arkansas Valley are gently folded, with a general downward inclination southward. The rocks of the Ouachita Mountains, on the contrary, have been thrown into steep folds, overturned toward the north, and in many instances faulted. The northern border of the greatly folded belt is definitely limited a few miles south of the outcrop of the lowest coal in the field. This boundary is marked on the map by a long dashed line. The overthrusting forces of the mountain region continue northward into the southern part of the coal field, crumpling the rocks into many gently curving and lapping folds. The upward folds are, as a rule, steeper than the synclines or basins, and in a few instances are broken and faulted near their axes. The basins are, as a rule, broad, and the wider ones are occupied by the higher hills and mountains, such as Poteau, Sugar Loaf, Cavanal, and Sansbois mountains. Northward toward the center of the field the folding gradually declines until, near Canadian River, the rocks dip at low angles toward the northwest and so continue across the field. Farther northward and west of the Ozark uplift the rocks incline at an equally low grade toward the west. A number of anticlinal folds in the southern part of the field bring the coal beds up in many curving outcrops, giving large areas of available coal. In places near the southern boundary of the field the coal is steeply upturned and can not be exploited far from the outcrop, while at numerous other localities large areas occur in shallow basins and stretches of low-dipping rocks.

DESCRIPTION OF COAL BEDS.

Extent and character.—There are six beds of coal having workable thickness south of Canadian River. Besides these coal beds are others that are too thin or too poor to warrant exploitation. Many of these thinner beds have been located while prospecting for thicker coals and have been found in places of sufficient thickness to be mined profitably for local consumption. The outcrops of the known workable beds have been traced throughout their occurrence in the field, and where prospecting and mining have been sufficiently extended to assure the thickness and quality, they are marked on the map in heavy solid lines. Where there is question as to their thickness or extent the location of outcrop is indicated by short dash lines.

Hartshorne coal.—The Hartshorne coal occurs in large areas and is known to be more persistent in thickness than any other bed. It is the lowest known bed in the field. Its thickness and quality are known at short intervals along the larger part of its outcrop and at numerous localities for many hundred feet beneath the surface in mines. Through a large part of the field in the south side there are two beds, known as the upper and lower Hartshorne coals, separated by about 50 feet of sandstone and shale. The upper bed is found to be more variable in thickness than the lower, but the quality of each is practically the same. The record of analyses of the two coals is shown in the following table:

Proximate analyses of Hartshorne coals.

Location.	Moisture.	Volatile combustible matter.	Fixed carbon.	Ash.	Sulphur.	Phosphorus.
Buck, 2 miles east of Krebs	1.04	37.96	55.84	5.16	2.00	0.01
Hartshorne	1.68	41.00	51.91	5.41	2.72	.01
Wilburton, upper coal	1.43	38.15	50.76	9.66	1.38	.05
Wilburton, lower coal	1.49	37.83	53.06	7.62	1.01	.02
Mine No. 1, 1½ miles southwest of Howe	.41	18.23	76.53	3.77	1.06	....
Ozark mine, Panama	.24	15.18	80.00	4.63	1.22	....

The Hartshorne bed, though variable somewhat in composition in different parts of the field, produces a high-class bituminous coal in the McAlester district and a semibituminous coal in the eastern part of the field. It is also a successful coking coal. It has been coked with the McAlester coal at Alderson, Buck, and Krebs, and is used exclusively in a battery of 80 ovens at Howe.

The lowest coal in the Lehigh district, at the extreme southern end of the district, is presumably the same as the Hartshorne, but its exact relations are not now determinable, on account of local disturbances of the rocks in the east side of the Lehigh basin. This bed is locally known as the Atoka coal, and has been prospected at many localities, but has been mined only to a limited extent. So far as known, the coal varies between 3 feet 6 inches and 5 feet, averaging approximately 4 feet thick, and is generally clear of shaly impurities. The quality of the coal, however, is not so high as that of the Hartshorne coal at McAlester, Hartshorne, and other places along the outcrop farther east, but its value as a steaming coal is proved by its use. Between Muddy Boggy Creek and Reynolds station, on the Missouri, Kansas and Texas Railroad, the rocks in the strike of the coal are tilted at steep angles, but nothing is known of the thickness or quality of the coal.

A coal bed believed to be the lower Hartshorne has been located by prospecting between the Missouri, Kansas and Texas Railroad and Haileyville. Prospect mines and pits show the coal to be 4 feet and 4 feet 9 inches in thickness. It is believed that the coal occurs also southwestward from the vicinity of Savanna in a sharp anticlinal fold. On the sides of this fold it is for the most part steeply inclined at the outcrop, but the dips grow gradually less downward. The lower Hartshorne coal in the Hartshorne basin eastward and northward from Haileyville has been prospected extensively, and mining operations have been carried on for a number of years. The Hartshorne basin is flat, and the coal is found at a depth of 600 to 800 feet in the central part. In this basin and westward from its north side to Buck post-office the coal has an average thickness of about 4 feet. From Buck eastward on the north side of the McAlester anticline to the shallow basin 3 miles west of Wilburton the coal dips steeply northward. The outcrop has been traversed and the coal prospected in places, but not mined. Both the lower and the upper Hartshorne beds are found to be of workable thickness in the broken anticlinal fold west from McAlester. They average here 4½ and 5 feet thick, respectively, and are of the usual high grade. The coal beds are faulted down on the north side of the anticline.

In the vicinity of Wilburton, and also at Hughes, 7 miles east of Redoak, both of these beds are known to be of workable thickness. At Wilburton the lower is 5 feet, while the upper is 4 feet 6 inches. South of Hughes the lower is 4 feet 2 inches and the upper is 4 feet. Farther east, in the vicinity of Howe, only the lower coal has been worked, where it has an average thickness of about 4 feet. The upper coal is present here, but is thinner than the lower bed and has not been mined in competition with it. Both the upper and lower beds, however, were mined a number of years ago 6 miles west of Wister, where the former one was found to be 3 feet 4 inches and the latter 4 feet thick. Both coals have been penetrated by shafts and by prospecting drills in the vicinity of Howe. The upper bed is shown to be about 2 feet 6 inches thick, while the lower coal varies somewhat above and below 4½ feet, and is being mined and coked. Between Wilburton and Howe the inclination of the coal varies between 25° and 35° northward, becoming less as the coal is followed downward.

The composition of the Hartshorne coal either changes gradually westward or thins out and another is found in nearly the same position in the section, as shown in the table of analyses. These analyses indicate that the lower coal at Howe contains about 19 per cent less volatile matter and 23 per cent more fixed carbon than at Wilburton.

From the south side of the field the Hartshorne coal passes downward beneath Sansbois and Cavanal mountains and then rises to the surface in several folds farther north between these mountains and Arkansas and Canadian rivers. This coal in the northern part of Choctaw Nation, east of McCurtain, is known locally as the Panama bed. It is the westward extension of the coals mined at Bonanza, Hartford, and other places in the western part of the Arkansas field. The Panama coal varies somewhat in thickness and in structure. Near the east end in the south side of the Backbone anticline the coal is nearly 5 feet thick, but is divided into two benches by several inches of shale, while in the north side near the east end its thickness ranges between 2½ and 4 feet, and it contains a thin parting of bony coal. At the Adkins mine, northwest of Cameron, the coal averages 4 feet and contains no shaly impurities. At Panama it varies but little above and below 4 feet in thickness and is of equally high grade. Near the junction of the Kansas City Southern and the Fort Smith and Western railroads prospects show the coal to be 3 feet 10 inches thick and of good quality. Farther west, near Milton, it varies between 4 and 7 feet, but is divided into two benches by a variable parting of shale near the middle. At McCurtain the coal varies in thickness from 3½ to 5 feet, and contains usually a thin parting of shale. Near Ward, in the northwest side of the Spiro basin, the coal is 4½ feet thick and contains a thin shale near the center. In quality the coal probably varies slightly, as does the Hartshorne coal at the southern border of the field. The analyses of the coal from the Panama mine, as indicated in the table above, show it to be of a higher grade than any thus far tested in the Indian Territory field.

McAlester coal.—This coal occurs 1,200 feet stratigraphically above the Hartshorne coal, and outcrops parallel with it south of Sansbois and Cavanal mountains, west of the St. Louis and San Francisco Railroad. Being higher in the coal-bearing series, it has greater length of outcrop and is generally more advantageously disposed structurally, so that relatively larger areas can be successfully mined. The bed where estimated to be of workable thickness has an outcrop length of more than 200 miles in the southern part of the Indian Territory field. At the west end of the field, near McAlester and Lehigh, the coal will average a little above 4½ feet in thickness. Eastward the bed decreases gradually to about 3 feet at Dow and at Carbon. From Carbon eastward coal has been prospected in a number of places and has been developed in a small way at Panola Switch, 5 miles east of Wilburton, at Redoak, Hughes, and at Fanshaw. At these places there are two beds in the horizon of the McAlester coal, separated by 60 feet of shale. At Panola switch one of the beds has 4 feet 2 inches of coal, but contains thin shale partings. At Redoak the beds are 2 feet 6 inches and 3 feet in thickness and at Hughes one of the beds has been mined, showing a section of 2 feet 10 inches. At Fanshaw they are 1 foot 8 inches and 2 feet 2 inches thick. Farther east this coal is considered to be of no economic value at the present time.

The coal in the Stigler basin, near the mouth of Canadian River, occurs in the stratigraphic position of the McAlester bed and is presumed to be its northern extension. This coal is known by prospect in both sides of the basin, and has been mined for local consumption west of Tamaha, west of Stigler, and near Whitefield. The same coal has been mined for local use northeast of Cartersville, between McCurtain and Sansbois, north of Sansbois, and north of Starvilla. In this region north of Sansbois Mountain the coal bed varies in thickness from 1 foot 6 inches to 2 feet 2 inches, and all information obtainable goes to show that it is clear of shaly impurities and of high grade.

The quality of the McAlester coal in the southern part of the field east of the Missouri, Kansas and Texas Railroad is uniformly high. It is slightly harder than the Hartshorne coal, having an advantage both in mining and in shipping qualities. In the Lehigh basin the coal contains a higher percentage of sulphur and ash and is weaker structurally than the coal in the McAlester district farther east. While the coal is thinner north than it is south of Sansbois Mountain, it is of superior quality, running lower both in ash and in sulphur than in other parts of the field, so far as known. The following is a record of analyses of the McAlester coal:

Proximate analyses of Lehigh, McAlester, and Stigler coals.

Location.	Moisture.	Volatile combustible matter.	Fixed carbon.	Ash.	Sulphur.	Phosphorus.
Lehigh, Choctaw Nation	3.56	41.61	41.12	13.71	4.56	0.024
1 mile west of McAlester, Choctaw Nation	2.08	37.52	56.02	4.38	.80	.016
Krebs, Choctaw Nation	1.74	37.00	56.86	4.40	.65	.014
2 miles west of Stigler, Choctaw Nation	1.06	23.01	72.47	1.92	.91	....
1½ miles northwest of Starvilla, Cherokee Nation	1.25	22.49	62.18	7.88	6.88	....

The McAlester coal, as well as the Hartshorne, is coked successfully for commercial use, making a coke of good grade. One hundred and eighty ovens are in operation at Krebs and Alderson.

Cavanal coal.—This coal bed is situated in the Savanna formation immediately beneath the middle group of sandstone beds, and occurs in workable thickness around the east and south sides of Cavanal Mountain from the town of Poteau to a point 5 miles west of Wister. The dip of the coal at the outcrop is variable between 6° and 10°. The outcrop was traced around Cavanal Mountain and the thickness of the coal was found to vary slightly from place to place where mining and prospecting had been carried on. Between the limits where the coal is known to be workable it varies from 2 to 3 feet. But little is known of this coal in the western part of Cavanal Mountain or elsewhere farther west. Coals have been found in the Savanna formation near South McAlester and in the south side of

Sansbois Mountain northwest of Wilburton, but they have not been developed. The analysis of coal from a point north of Wister and opposite Cavanal switch is indicated in the following record:

Proximate analysis of Cavanal coal.

	Per cent.
Moisture	0.22
Volatile combustible matter	23.54
Fixed carbon	66.16
Ash	10.08
Sulphur	4.33
Phosphorus	.03

The Cavanal coal contains no shale or bony coal within the bed. Locally thin, sulphurous, bony, lenticular layers occur at the top and adhere to the coal, so that they must be removed in mining.

Witteville coals.—The two highest coal beds in the southern part of the Indian Territory field are known locally as the Witteville coals, being named for the village at which mining has been carried on for a number of years in the east end of Cavanal Mountain. The horizon of the coals has been traced completely around Cavanal Mountain, but prospecting and mining developments have shown that the coal is of workable thickness only around the north, east, and south sides of the main peak of Cavanal Mountain, which stands at the east end. Everywhere at the outcrop the dips are toward the center of the mountain, varying between 6° and 10°. The lower bed is nearly 200 feet beneath the upper, has been prospected at Witteville, and is inferior here to the upper on account of the presence of several thin layers of bony coal occurring in the bed. One of the Witteville beds, possibly the lower, has been mined rather extensively at Sutter, in the northwest base of the mountain, and the upper bed is mined at the town of Witteville, in the east end.

The upper coal at Witteville has a thickness of about 4 feet and contains a thin parting of shale or bony coal, averaging about a third of an inch in thickness. The roof of the coal is a hard fossiliferous slaty shale. The lower bed at the outcrop at Witteville contains 42 inches of coal, separated into three benches by two thin partings of shale. The bed mined at Sutter contains nearly 4 feet of coal and is separated into three benches by two thin layers of shale or bony coal.

The first of the following analyses was made by the United States Geological Survey from an average sample of the run of mine taken from the upper coal at Witteville. The second was made by the Ledoux Chemical Laboratory, of New York City, of samples selected by the Poteau Coal and Mercantile Company, operating the Witteville mines. The same coal company had samples from the Witteville mine washed and tests made to determine its coking properties. It is reported that the tests were successful, giving 65 per cent of coke.

Analyses of the Witteville coal.

Moisture.	Volatile combustible matter.	Fixed carbon.	Ash.	Sulphur.	Phosphorus.
0.48	23.82	66.69	9.01	4.64	0.02
.54	26.39	66.64	5.24	1.16	--------

A coal bed, locally known as the Secor coal, occurs in the structural basin south of South McAlester in the stratigraphic position of the Witteville bed. It has been prospected and mined at a number of places and is at present operated at Perryville switch, between South McAlester and Savanna. Its thickness here is approximately 3 feet, but it does not contain the shaly impurities found in the mines at Witteville. The roof, however, in the two localities consists of the same kind of fossiliferous shale and the quality of the coal seems to be essentially the same. The coal in this basin is well situated for mining and crops out near two lines of railway. The same coal bed crops out in an anticlinal fold which bears east from the Missouri, Kansas and Texas Railroad 4 miles northeast of McAlester. This outcrop has been traced from the railroad northeastward to Canadian River in the vicinity of Golconda. North of McAlester the coal has been extensively prospected and reports made that it is of good quality and about 4 feet thick. East of Gaines Creek, in the vicinity of Massey, and on Jones Creek southwest of Featherstone, the coal is approximately 3 feet thick. The structure of the bed varies slightly from place to place. At one prospect the face of the coal reveals two thin partings of bony shale while at others the section is clear of shaly impurities. The physical appearance of the coal indicates that it is harder and that the percentage of sulphur is probably less than at Witteville, but it is believed that the amount of ash is greater. The coal is being mined for local consumption south of Featherstone and south of Massey, and has been mined in former times between these two places.

The rocks in the region about Massey and Featherstone have been thrown into flat, low folds and the coal is well situated for exploitation. North and east of Featherstone the same coal has been exposed by prospecting and mining in a small way, but contains near the middle of the bed a shale which is thick enough to prevent its successful operation on a commercial scale. A coal bed occurs in approximately the stratigraphic position of the Witteville coal and is being mined on Elk Creek in Creek Nation, 5½ miles east of Checotah. The bed here is 2 feet 6 inches thick and the coal is of good quality. No information has been obtained concerning the occurrence of this coal farther north.

CHEROKEE-CREEK COAL FIELDS.

LOCATION.

The northern part of the Indian Territory coal field, included in the area mapped as Pl. II, has not been surveyed in detail, except an area of nearly 1,000 square miles in the southeastern portion, within the Muscogee quadrangle. The Muscogee quadrangle is included between parallels of latitude 35° and 35° 30′ and meridians of longitude 94° 30′ and 95°. In other parts of the field investigations of coals have been made and certain sandstone and limestone formations traced as an aid to the interpretation of the rock structure and the location of the coal beds with which they are related. The outcrops of the limestone beds and coal prospects in northern Cherokee Nation were traced and mapped by George I. Adams, of the United States Geological Survey, and John Bennett. The locations of limestone, sandstone, and coal beds in the Creek Nation were made by M. K. Shaler in the progress of coal-land surveys for the Commission to the Five Civilized Tribes. The continuous lines on the map show the locations of outcrops of limestones and coal, and the dotted lines indicate only approximately accurate locations made by reconnaissance surveys.

As stated in the description of the rocks of the Choctaw coal field, the coal beds and formations in which they occur south of Canadian River can not be traced north of the vicinity of Muscogee. The detailed surveys, therefore, of the Muscogee quadrangle have little economic bearing on the coal in northern Indian Territory, and the general geology will not be discussed separately from the remainder of the Cherokee-Creek field.

STRATIGRAPHY.

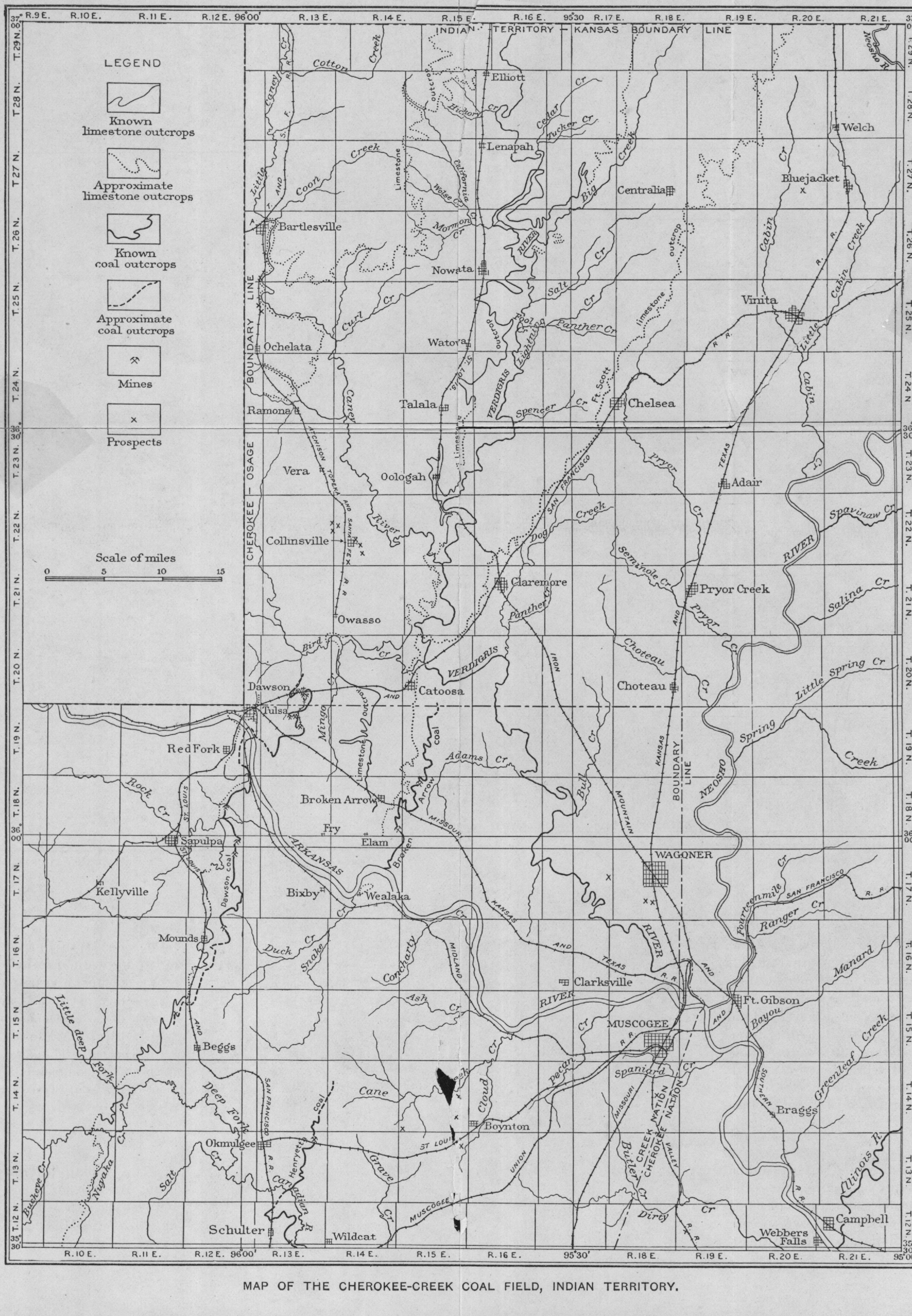
The rocks of the Indian Territory coal field, especially the lower part of the section, decrease in thickness northward, and with this decrease goes a change in the character of the sediments. On approaching Arkansas River in northern Creek Nation the thick section of coal-bearing rocks of southern Indian Territory is found to be greatly reduced in thickness, and the numerous sandstone beds are too thin or shaly to be recognized. With the dying out of the sandstone deposits there is an increase in lime in the rocks, indicated by the presence of thin limestone beds found interstratified with the shales and thin sandstones. The belt of country so characterized in the northern part of the Indian Territory coal field lies between Neosho River and a line drawn through Schulter, Wealaka, Broken Arrow, Catoosa, Claremore, Chelsea, and thence northward to the Kansas line a few miles west of the Missouri, Kansas and Texas Railroad. This belt of country might well be classed within a single formation. In southeastern Kansas it is included within the Cherokee shales, a formation of shale with local thin sandstones and limestones interstratified, and containing two workable coal beds in the upper part, known as the Wier-Pittsburg coals.

The Cherokee shale is succeeded by the Fort Scott limestone, which has been traced southwestward across Cherokee Nation, passing near Chelsea, Claremore, and to Arkansas River near Wealaka. Its approximate outcrop is shown on the map. The Fort Scott limestone becomes thin southward, but has not been traced south of the immediate valley of Arkansas River. In northern Indian Territory a coal bed occurs at Broken Arrow beneath the limestone and near the horizon of the Wier-Pittsburg coal in Kansas. In the vicinity of Henryetta a commercially valuable coal bed, known locally as the Henryetta coal, occurs below the horizon of the Fort Scott limestone. Its outcrop has been traced northward beyond Okmulgee, and it is presumably the same as that at Broken Arrow. A number of thin coal beds are known to occur lower in the shales in northern Indian Territory.

The coal measures rocks which lie above the horizon of the Fort Scott limestone crop out in northwestern Cherokee Nation and western Creek Nation. In the Creek Nation they consist of an alternating succession of sandstone and shale formations with occasional beds of limestone and one or more coal beds of economic importance. The sandstone formations become gradually thinner northward and the limestone, as a whole, thicker. Two or more of the limestones become thick enough to be classed as formations north of Arkansas River, and the outcrops of those best known are mapped. The outcrops of a deposit of yellow limestone that lies above the commercially valuable Dawson coal have been traced from Tulsa southwestward, and its mapping will aid in locating the outcrop of the coal.

STRUCTURE.

The structure of the northern part of the Indian Territory coal field is simply monoclinal, the rocks being tilted about N. 65° W. at locally variable inclinations of 60 to 100 feet per mile. This applies more particularly to the rocks occurring west of the Missouri, Kansas and Texas Railroad. East of this railroad the rocks are involved in



MAP OF THE CHEROKEE-CREEK COAL FIELD, INDIAN TERRITORY.

the local warping, and are probably to some extent affected by faulting connected with the Ozark uplift. These structures do not affect any of the coal beds of economic value and do not require description.

DESCRIPTION OF COAL BEDS.

Thin unnamed coals.—A coal bed of locally workable thickness has been opened in the hilly country 12 miles east of Wagoner and mined by stripping for local consumption. It is not known to be thick enough to mine, however, except in the immediate vicinity of the workings. It occurs in local deposits of shale a few feet above limestone of the Morrow formation, the lowest Pennsylvanian (upper Carboniferous) formation in the western border of the Ozark Mountain region. A thin variable coal was noted in the sandstone at about the same position in the section near the mouth of Greenbrier Creek, southeast of Fort Gibson. Some prospects have been made on the coals south of Muscogee and in the vicinity of Wagoner. Those south of Muscogee are probably in the same bed which occurs in or near the stratigraphic position of the McAlester coal. The coal located by prospect 4 miles west of Wagoner is presumably the same, while the thin bed 2 miles south of Wagoner is doubtless lower in the rocks, but in the northward extension of the McAlester shale. These beds so prospected have shown that they are too thin to be worked profitably. Four openings have been made on two coal beds in the vicinity of and 6 miles west of Boynton. The crop of the one is within a mile west of the town, and the prospects upon it show the thickness to range from 8 to 18 inches. The other bed, which occurs higher in the rocks, has been opened near the southwest corner of T. 14 N., R. 15 E. It is reported to crop out also on a branch of Cane Creek 2½ miles farther north. The coal in the prospect is 23 inches thick. It deserves further investigation, and may prove to be a valuable deposit. This coal and the one near Boynton have been mined by stripping to a considerable extent for local use.

Henryetta coal.—The next coal in stratigraphic order, and the one that will most likely prove on further development to be the most valuable in the northern part of the Indian Territory field, is being mined at Henryetta and Broken Arrow. It occurs 100 to 200 feet beneath the Fort Scott limestone. Mr. G. I. Adams, who traced the limestone southward through northern Cherokee Nation, reports that a sandstone formation gradually develops between the two limestone members of the formation and that near Arkansas River the lower limestone member thins out, while the sandstone continues southward, gaining in thickness. At Broken Arrow a heavy sandstone occurs between the limestone and the coal. East and south of Okmulgee and at Henryetta the limestone is not known, but the sandstone outcrop is a prominent feature of the landscape and will serve as a guide in locating the position of the coal. The crop of the Henryetta coal has been traversed from the vicinity of Henryetta northward beyond Okmulgee. No trace of the coal, however, was obtained from a point northeast of Okmulgee to Arkansas River. At the river south of Broken Arrow it was taken up again and traced to the Creek-Cherokee Nation line. Workable coal 4 feet thick is reported to outcrop 4 to 5 miles west of Bluejacket in northern Cherokee Nation, and it is not improbable that it will prove to be the northward continuation of the Henryetta bed.

This coal bed has received the greatest attention near Henryetta, where three mines have been in operation during the last year, producing 35,600 tons. The bed is 3 feet thick and mines in block, separating into two or three benches along stratification lines of distinct cleavage. In the southernmost strip pits east of the town a shale parting was discernible near the middle of the coal. Three and one-half miles southeast of Henryetta an outcrop of the coal shows that the shale parting has increased to 10 inches, separating the bed into two branches, the upper 12 to 15 inches and the lower 15 to 20 inches in thickness. At the mines 2 miles north of Henryetta, 2 miles southeast of Schulter, and east of Okmulgee, the Henryetta coal maintains its thickness of 3 feet to 3 feet 4 inches, and shows no appreciable change in character except the presence of a thin shale in the openings near Okmulgee. The outcrop has been traced between these localities and to a point 6 miles east of Okmulgee. No openings are known to have been made on the coal between Okmulgee and Arkansas River. Southeast of Broken Arrow, however, the coal is shown in workings to be 3 feet thick. Northeast of this town, in sec. 5, T. 18 N., R. 15 E., it is seen in the mines to be 30 inches to 3 feet thick. The coal in the vicinity of Broken Arrow is essentially the same as that found between Okmulgee and Henryetta.

Dawson coal.—The highest coal bed of known workable thickness is found in northwest Creek Nation, where its outcrop has been mapped from Dawson, on the St. Louis and San Francisco Railway, near the edge of the Creek Nation, southward to the vicinity of Mounds. Outcropping in association with the coal on the west and occurring nearly 90 feet above it is a thin bed of light-blue limestone which weathers to a bright yellow color. The outcrop of this limestone has been mapped from Tulsa southwestward nearly 50 miles and beyond the known occurrence of the coal. This peculiar limestone is easily recognized and its outcrop is a ready reference in locating the coal. The Dawson coal is here unusually clean for a bituminous coal. It mines in block separating near the middle along a distinct bedding plane, and resembles very closely the Henryetta coal in physical characteristics. A very thin parting of bony coal occurs near the center, separating the bed into two benches. The shale gradually grows thicker southward, reaching about 4 inches near Mounds. It continues to increase southward beyond Mounds at the expense of the coal until the latter has decreased to 8 inches northwest of Beggs. South of Mounds the Dawson coal is not known to be of any commercial value. Three miles south of Dawson it is 2 feet 8 inches thick, and is being exploited in a strip pit and a slope mine. At points 6 and 9 miles south of Red Fork the coal is 2 feet 6 inches to 3 feet 4 inches thick, and 3 feet 4 inches, respectively, where strippings have been made. Two miles northeast of Mounds the Dawson coal is 2 feet 2 inches to 2 feet 6 inches thick and contains a parting of shale near the middle.

A coal bed very near, if not in, the stratigraphic position of the Dawson coal has been mined rather extensively by stripping in the vicinity of Collinsville, in the Cherokee Nation. The coal here is 1 foot 6 inches thick, and 28,900 tons have been removed by strip mining during the last fiscal year.

Coal has been prospected near Caney River, south of Bartlesville, but no definite information has been obtained concerning its thickness or quality. Its surface location indicates that it is stratigraphically above the Dawson coal bed.

DEVELOPMENT.

Coal mining on a commercial scale in Indian Territory began near McAlester in 1872, immediately following the construction of the Missouri, Kansas and Texas Railroad. Nearly ten years later mining operations began at Savanna, on the main line, and at Lehigh, on a branch road extending from Atoka.

The building of the Choctaw, Oklahoma and Gulf Railroad along the strike of the coal beds from South McAlester eastward gave great impetus to coal mining. Mines were opened at Alderson, Hartshorne, Wilburton, and Howe, and more recently at Dow, Haileyville, and Hughes. This road was finally extended eastward to Memphis and westward across Oklahoma, increasing the market for its coal.

The construction of the St. Louis and San Francisco Railroad, and still later of the Kansas City Southern, across the east end of the field gave additional impetus to coal development, though they did not take part in mining operations.

These four railroads were the only lines in operation in the Indian Territory coal field when detailed investigations by the United States Geological Survey were begun on the coal in 1897. At that time 18 companies and individuals were mining coal on a commercial scale, and the output during the preceding year was slightly more than 1,235,300 tons. With the exception of a sudden decline in the production in 1894 on account of labor troubles, there was a gradual advance in output from nearly 394,000 tons in 1885, when the first authentic record of output was obtained, to 1,350,000 tons in 1897. Previous to this time mining operations in Indian Territory were controlled by tribal laws and royalty was required to be paid by the operator to both the Indian citizen holding the land and to the tribal government.

Soon after the publication of the report on the McAlester-Lehigh coal field, a branch of the Choctaw, Oklahoma and Gulf Railroad was extended from the main line, 2 miles west of Hartshorne, to Ardmore, following the outcrop of the coal for nearly 50 miles. Several important mines have been opened along this line and extended means for transportation given to the large product from the mines at Coalgate and Lehign. Also branches of the Choctaw, Oklahoma and Gulf and the Missouri, Kansas and Texas roads have been extended, paralleling the coal outcrop from Dow and Carbon to Wilburton and adding 40 miles of line convenient for future mining operations.

As surveys progressed, and following the publication of the report on the eastern Choctaw coal field, the Fort Smith and Western and the Midland Valley railroads have been built adjacent to the coal outcrops in the northern part of the Choctaw Nation, adding nearly 100 miles of road accessible to present and future development and requiring but little additional track expense in connection with mining operations. Both of these roads are building westward, connecting with through lines of the St. Louis and San Francisco and the Chicago, Rock Island and Pacific roads north and south through Oklahoma.

A new branch of the St. Louis and San Francisco road has been constructed within the past few years in northern Cherokee and western Creek nations through the productive parts of the Cherokee-Creek coal field, inducing increased development of the coals at Dawson and Henryetta.

The large additional means of transportation, opening the field to new markets since 1897, together with improved regulations concerning leasing and mining of coal, are in a large measure responsible for the rapid development of the field. During the fiscal year ending June 30, 1904, fifty companies were operating 117 mines, producing 3,320,000 tons of coal. When the recently enacted law providing for the sale of the commercially valuable coal lands in the Choctaw and Chickasaw nations is carried into effect and the Territory is organized into a new State, still more rapid advance in the development of the coal is to be expected.

The information contained in the following tables, setting forth the mining operations and present development of the Indian Territory coals, is furnished by the very valuable report of Mr. William Cameron, United States mine inspector for Indian Territory:

Summary of coal development in Indian Territory during the year ending June 30, 1904.

Operator.	Shipping point.	Coal bed.	Mine number.	Thickness of coal.	Depth of shaft.	Length of slope.	Output.
				Ft. in.	*Feet.*	*Feet.*	*Tons.*
Ardmore Coal and Power Co.	Ardmore	Ardmore				1,000	828
Bache & Denman Coal Co.	Red Oak	Lower Hartshorne.	1	4 6		240	5,930
Blackstone Coal and Mining Co.	Henryetta	Henryetta	1	3 0		250	2,151
Bolen-Darnall Coal Co	McAlester	McAlester	3	4 0		2,500	63,948
Do	Craig	do	4	3 4		1,100	
Brewer Coal and Mining Co.	Savanna	do	1	4 0		320	12,305
Do	do	do	2	4 0		150	
Cameron Coal and Mercantile Co.	Cameron	Panama	1	3 10		800	
Canadian Coal Co	Dawson	Dawson		3 0			13,461
Central Coal and Coke Co.	Henryetta	Henryetta	22	3 0		600	81,641
Do	Carbon	McAlester	77	3 6		2,600	
Chambers Coal and Mining Co.	Chambers	Secor	1	3 0		490	1,962
Coalgate Co., The	Coalgate	Lehigh	1	3 6		3,000	131,042
Do	do	do	2	3 6		2,200	
Do	do	do	3	3 6		2,000	
Do	do	do	4	3 8		1,500	
Do	do	do	5	4 6	633	450	
Edwards & Son	Edwards	McAlester	1	4 0		500	12,647
Do	do	do	2	4 0		350	
Folsom-Morris Coal and Mining Co.	Midway	Lehigh	1	3 4	122	920	34,362
Great Western Coal and Coke Co.	Wilburton	Lower Hartshorne.	1	6 0		1,100	196,978
Do	do	Upper Hartshorne.	2	4 0		1,000	
Do	do	do	3	4 0		1,100	
Do	do	Lower Hartshorne.	4	4 5		800	
Do	do	do	6	5 0		1,200	
Do	do	do	7	6 0		300	
Do	Baker	do	8	4 0		1,080	
Do	do	McAlester	9	4 8		400	
Hailey-Ola Coal Co.	Haileyville	Lower Hartshorne.	1	4 9	320	700	169,713
Do	do	do	3	5 0		500	
Do	Wilburton	do	1	5 0		950	
Do	do	do	1½	5 0		600	
Do	do	do	3	5 0		750	
Do	do	do	4	6 0		300	
Henderson Smokeless Coal Co.	Bokoshe	Panama	1	4 6		270	2,036
Do	do	do	2	4 6		100	
Henryetta Coal and Mining Co.	Henryetta	Henryetta	1	3 0		60	30,255
Indian Coal and Mining Co.	Buck	Lower Hartshorne.	1	3 0		240	122
Kali-Inla Coal Co.	Gowen	do	1	4 6		300	

Summary of coal development in Indian Territory, etc.—Continued.

Operator.	Shipping point.	Coal bed.	Mine number.	Thickness of coal.		Depth of shaft.	Length of slope.	Output.
				Ft.	*in.*	*Feet.*	*Feet.*	*Tons.*
Le Bosquet Coal and Mining Co.	Hughes	Lower Hartshorne	1	4	8		385	4,612
McAlester and Galveston Coal Mining Co.	McAlester	do	1	3	4		800	
Do	do	do	2	4	0		250	4,936
Do	do	do	3	4	0		125	
McAlester-Choctaw Coal Co.	do	do	1	4	3		450	
Do	do	McAlester	2	4	6		250	27,084
Do	do	do	3	4	3		250	
McAlester Coal and Mineral Co.	Wilburton	Upper Hartshorne	4	4	0		2,800	
Do	do	do	5	4	0		2,600	
Do	do	Lower Hartshorne	6	4	0		2,600	
Do	do	do	7	4	0		2,900	193,378
Do	do	Upper Hartshorne	8	4	0		600	
Do	do	Lower Hartshorne	9	4	0	130	800	
Do	do	Upper Hartshorne	10	4	0		2,500	
McAlester Coal Mining Co.	Buck	Lower Hartshorne	2	4	0		2,900	
Do	do	do	12	3	0	118	1,600	63,189
Do	do	do	6	4	0	525	450	
McEvers Coal Co	McAlester	do	1	4	6		300	12,954
McKenna, Terry	Poteau	Lower Cavanal	1	2	0		300	557
Markley, Geo. J	Sutter	Lower Witteville	1	4	2			34,984
Do	do	do	2	4	2			
Mexican Gulf Coal and Transportation Co.	Howe	Arkansas (Hartshorne).	1	4	0	110	700	
Do	do	do	2	4	0		1,320	68,535
Do	do	do	3	4	0		400	
Do	do	do	4	4	0	365		
Milby & Dow Coal and Mining Co.	Dow	McAlester	1	2	10	228	2,425	
Do	do	do	2	3	0	328	1,900	162,525
Do	do	do	3	3	0			
Missouri, Kansas and Texas Coal Co.	Wilburton	Upper Hartshorne	15	4	0		1,400	
Do	do	Lower Hartshorne	16	4	0		1,000	18,748
Do	do	do	18	4	0		1,000	
Do	do	do	19	4	0	300		
Osage Coal and Mining Co	Krebs	McAlester	5	4	0	482	2,000	
Do	do	do	7	3	10		1,150	
Do	do	do	8	3	7	272	1,000	338,867
Do	do	do	11	4	2	470	3,100	
Do	do	do	11½	4	2	238		
Do	do	do	14	3	6		750	
Ozark Coal and Railway Co.	Panama	Panama	1	4	0		1,000	4,000
Poteau Coal and Mercantile Co.	Poteau	Witteville	4	4	0		700	
Do	do	do	5	3	8		1,500	72,827
Do	do	do	6	3	8		900	

Summary of coal development in Indian Territory, etc.—Continued.

Operator.	Shipping point.	Coal bed.	Mine number.	Thickness of coal.		Depth of shaft.	Length of slope.	Output.
				Ft.	*in.*	*Feet.*	*Feet.*	*Tons.*
Rock Island Coal Co	Hartshorne	Lower Hartshorne	7	3	6	527		
Do	do	do	8	3	6	254	1,000	
Do	do	do	18	3	8		900	
Do	Alderson	McAlester	5	3	6	535	350	
Do	do	do	6	3	6	505		
Do	do	do	32	3	6		1,100	
Do	do	do	33	3	6		1,150	
Do	do	do	34	3	6		1,150	473,166
Do	do	do	35	3	6		975	
Do	do	do	36	3	6		1,050	
Do	do	do	37	3	6		725	
Do	do	do	38	3	6		1,400	
Do	do	do	15	3	6		1,800	
Do	Gowen	Lower Hartshorne	3	4	0	256	3,270	
Do	do	do	12	4	0		3,270	
Samples Coal and Mining Co.	McAlester	McAlester	1	4	0		1,150	60,390
Do	do	do	2	4	0		750	
Sansbois Coal Co	McCurtain	Panama	1	5	0		1,732	
Do	do	do	2	6	5		1,372	130,968
Do	do	do	3	4	5		1,355	
Savanna Coal Co	Savanna	McAlester	2	4	0		210	5,927
Do	do	do	3	4	0		140	
Southwestern Development Co.	Coalgate	Lehigh	4	4	8	158	2,500	
Do	do	do	9	4	8	325	1,300	362,629
Do	do	do	10	4	8	84	1,800	
Do	do	do	12	5	0	653		
Turkey Creek Coal Co	Hughes	McAlester	1	2	10		650	
Do	do	Lower Hartshorne	2	4	2		450	34,184
Do	do	do	4	4	2		300	
Valley Coal Co	McAlester	do	1	3	0		320	4,121
Warden Coal Co	Henryetta	Henryetta	1	3	0	70		3,266
Western Coal and Mining Co.	Lehigh	Lehigh	5	4	4	202	2,800	
Do	do	do	5½	4	6	152		
Do	do	do	6	4	6	239	2,400	426,905
Do	do	do	6½	4	6	249		
Do	do	do	7	4	6	110	1,200	
Do	do	do	8					
Whitehead Coal and Mining Co.	Henryetta	Henryetta	1	3	0	88		825
Sundry small slopes and drifts in Creek and Cherokee nations.								21,375

PITTSBURG COAL IN THE BURGETTSTOWN QUADRANGLE, PENNSYLVANIA.

By W. T. Griswold.

METHODS OF WORK.

The geologic work on the Burgettstown quadrangle has been carried on in what might be called an instrumental way. The combination of topographic and geologic work by one party made it possible to do the geologic work with a much greater degree of accuracy than is ordinarily attained in such work. Important outcrops were located on the map with the same accuracy as the topographic features by the traverse party when the map of the roads was made. Spirit-level lines were run over all the roads of the quadrangle with a degree of precision that insured the closing of circuits within an error of 1 foot. As this work proceeded the elevation of each outcrop that could be identified was determined, and the name of the formation was marked upon the map. Profiles were then made of all the roads which gave sections of the geologic formations. Above and below the outcrop of a stratum of economic importance, such as the Pittsburg coal, the hillsides were examined for good reference strata, such as solid limestone ledges and coal seams, and the elevations of these determined by spirit level. The profiles of the roads and the special sections were then critically examined for the purpose of determining the interval between easily recognized beds, which might serve as key rocks. Only those outcrops were selected that were horizontally near together or were in such a position that the elevation of the outcrop of one stratum could be compared with the elevations of two outcrops of the other occurring upon different sides of the first outcrop. This method was used to eliminate any error which might enter into the results from the dip of the rocks. By thus determining the distance between the Pittsburg coal and other well-known beds in different parts of the quadrangle the relation which this well-known bed bears to others was determined. Throughout the quadrangle some beds were found to be in almost all places parallel with the Pittsburg coal, and were therefore adopted as key horizons. The most important of these are a thin bed of limestone near the center of the Benwood limestone and the Uniontown coal. The limestone mentioned is a solid brown rock a foot or two in thickness, breaking with uneven fracture and showing a number of small crystals of calcite. This bed is underlain persistently by green shale, and it is at a constant distance of about 150 feet above the Pittsburg coal.

The Uniontown coal is about 1 foot in thickness. It is of no commercial importance in the Burgettstown quadrangle, but it is generally present, and is valuable as a geologic marker. It is only a few feet above the upper ledge of the Benwood limestone, and, owing to this fact, it can be readily identified. It is 206 feet above the Pittsburg bed. This interval was found to be very constant throughout the quadrangle.

The depth of the Pittsburg coal below other beds, such as the Waynesburg coal, Washington coal, and Washington limestone, was determined, but, as these strata are farther away from the coal, not so many good comparisons could be obtained. Whenever possible the limestone beds and Uniontown coal were used in determining the position of the Pittsburg seam where the latter lies below the surface and is inaccessible.

If the intervals between the different strata are well determined, the mapping of an underground seam, such as the Pittsburg coal, is very simple. The distance from a particular outcropping stratum to the coal is subtracted from the elevation of the outcrop and the remainder is the elevation of the Pittsburg coal at that point. When this method was applied to all known outcrops occurring in the region where the Pittsburg coal is not exposed, the altitude of the coal was known at a great many points, and by connecting the points of equal altitude by lines the accompanying contour map of the coal seam (Pl. III) was formed.

GENERAL DESCRIPTION.

Location of the quadrangle.—The territory represented by this map is rectangular and has a width of about 13 miles from east to west and a length of 17 miles from north to south. It lies in southwestern Pennsylvania, south of Ohio River, and includes parts of Beaver, Allegheny, and Washington counties. Burgettstown is situated on the Pennsylvania Railroad, 27 miles west of Pittsburg, approximately in the center of the area, and from this village the quadrangle takes its name.

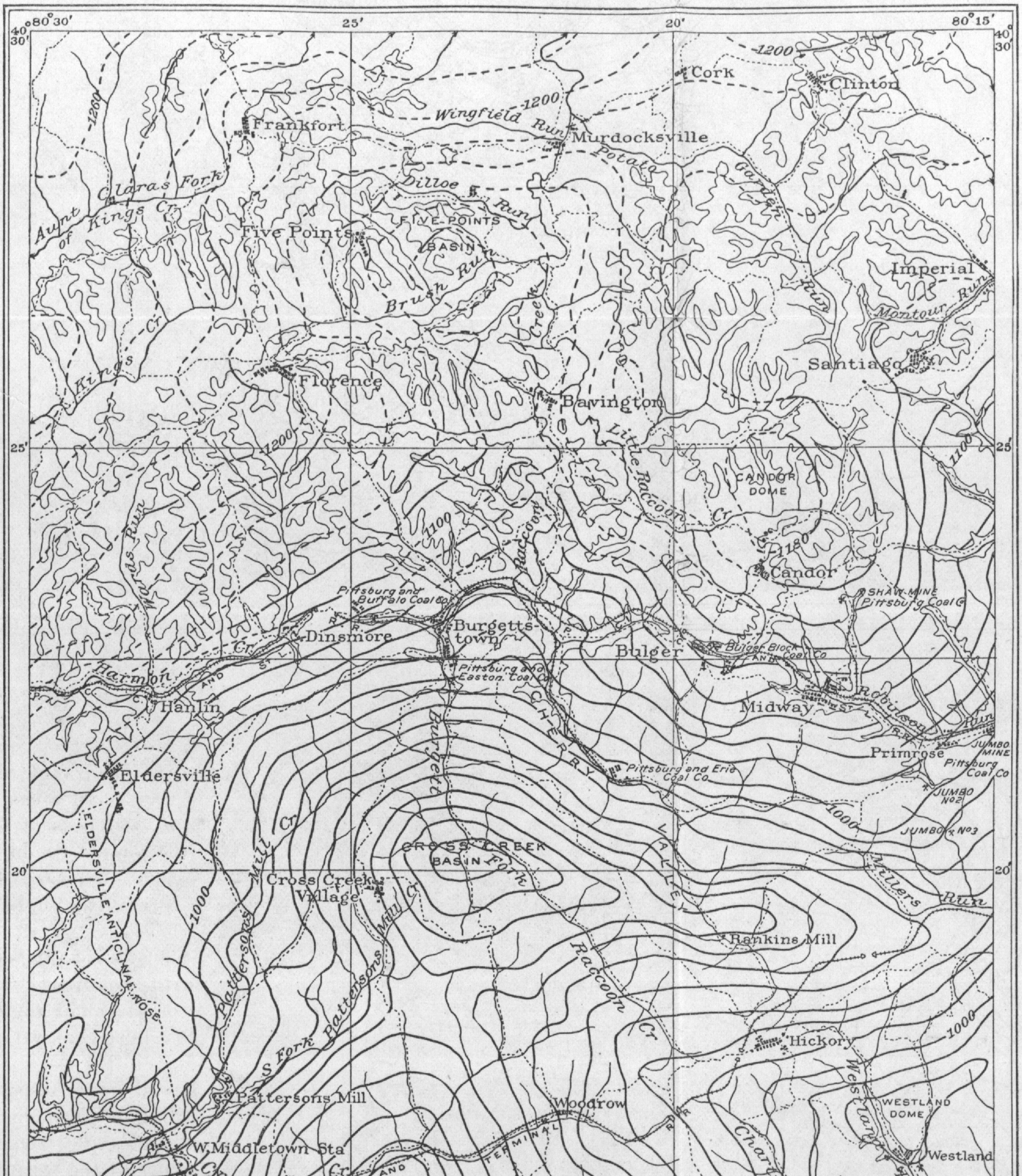
Topography.—There are no striking topographic features. The region is made up of hills and valleys without definite arrangement, except that the principal valleys coincide with the major streams. The topography is typical of that of much of western Pennsylvania, West Virginia, and southeastern Ohio. The altitude of the surface ranges from 800 to 1,500 feet above sea level. The topography is that of an elevated plateau which has been deeply dissected by the short rapid streams flowing into Ohio River. Two watersheds, lying roughly parallel, divide the quadrangle from north to south into three secondary drainage basins of approximately equal size.

GENERAL GEOLOGY.

Stratigraphy.—The rocks of this area are all of Carboniferous age, and they have been divided into three formations—Conemaugh, Monongahela, and Dunkard. In the northern part of the quadrangle the lowest member of the group, the Conemaugh, is most widely exposed, its lowest recognizable member being the Ames limestone. The overlying Monongahela formation caps only the highest hills. Toward the south the Conemaugh gradually decreases in area, while the Monongahela shows a corresponding increase in the extent of its outcrop. A little south of the middle of the quadrangle the Conemaugh disappears with the exception of two small areas. At the same place the characteristic limestone and coal beds of the lower Dunkard make their first appearance in the tops of the hills. This formation in turn gradually widens in extent southward, superseding the Monongahela, as the latter passes beneath the surface with a gentle dip toward the center of the basin.

Geologic structure.—Taken as a whole the rocks of this section dip slightly, but by no means constantly, to the southeast. From the northwestern to the southeastern corner of the quadrangle careful leveling shows a drop of 280 feet in the Pittsburg coal, yet along the line joining these points there are differences in the elevation of this coal of as much as 300 feet in 3 miles. The structure responsible for this variation in dip is a broad, shallow, irregular, synclinal trough, which passes through the center of the quadrangle from south to north. Its axis intersects the southern border of the territory about 5 miles from the southwest corner, which is about 1 mile east of West Middletown. The axis trends a little east of north, passing east of Burgettstown west of Bavington, and thence with a more easterly direction into the southeast corner of the Beaver quadrangle, which lies directly north of the Burgettstown quadrangle.

This syncline is in reality a chain of oval-shaped basins of different sizes and depths, linked together by low structural divides. The center of the one farthest to the south is near Wilsons Mill, from which locality it has received its name. At this point the Pittsburg coal is at an elevation of only 720 feet above sea level. The center of the next basin to the north lies beneath Raccoon Creek at a point about 3 miles south of Burgettstown and 1½ miles east of the village of Cross Creek, from which place it derives the name of the Cross



MAP OF BURGETTSTOWN QUADRANGLE, PENNSYLVANIA, SHOWING ELEVATION OF PITTSBURG COAL.

Creek basin. In the center of this basin the Pittsburg coal is 800 feet above sea level and about 80 feet lower than upon the divide which separates this basin from Wilsons Mill basin.

The major axis of the Cross Creek basin lies at right angles to the axis of the general synclinal depression. From the center of the basin westward the rocks rise in a broad amphitheater, but gradually flatten to the normal rise to the northwest. Toward the east the strata rise much more slowly, forming a long, narrow, canoe-shaped basin 4 or 5 miles in length. From the center of the Cross Creek basin the rocks rise rapidly to the north, and only slight indications of the general synclinal trough are found in the steep dip which passes from east to west across most of the quadrangle on the north side of this basin. This east-west slope terminates near the town of Florence on the west and that of Candor on the east.

The next synclinal basin to the north lies about midway between the towns of Bavington, Florence, Frankfort, and Murdocksville, and close to the cross-roads known as the "Five Points," from which it derives its name.

East of the synclinal basins above described are two pronounced anticlinal domes; one occurs just north of the town of Candor, and is named from that place; the other occurs in the southeast section of the quadrangle near Westland, from which it derives its name. From Eldersville an anticlinal ridge extends southward, decreasing in elevation, but maintaining its crest somewhat higher than the adjacent structures. This is called the "Eldersville anticlinal nose."

LINES OF TRANSPORTATION.

Three railroad systems enter the Burgettstown quadrangle. From the south side of Ohio River, west of Pittsburg, a branch line has been built from the Pittsburg and Lake Erie Railroad (Vanderbilt system) to the mining towns of Imperial and Santiago, in the northeast section of the quadrangle. No serious topographic feature would be encountered in extending this line to Clinton, and, in case that were done, this road would receive the full coal output of that place and also that of an extensive area to the south.

The Pittsburg, Cincinnati, Chicago and St. Louis Railroad (Pennsylvania system) crosses the middle of the quadrangle in an east-west direction. Within the quadrangle this line crosses two summits, one at Bulger, separating the valley of Robinsons Run from the valley of Raccoon Creek, and the other at Dinsmore, separating the valley of Raccoon Creek on the east from that of Harmon Creek on the west. West of Dinsmore the railroad follows Harmon Creek to Ohio River, in the vicinity of Steubenville. At Burgettstown branches have been started from the main line up the two forks of

Raccoon Creek. The branch up Cherry Valley Fork extends a distance of 4 miles to the mines of the Pittsburg and Eastern Coal Company. The branch up Burgetts Fork runs only a short distance to the mines of the Pittsburg and Erie Coal Company at the south end of Burgettstown. These two forks of Raccoon Creek have smooth, open valleys, up which railroads may be constructed to near the headwaters of the streams at a small expense per mile. The Pennsylvania system is again represented in the quadrangle by a branch line up Chartiers Creek and Westland Run from Cannonsburg to the mining town of Westland and also by a short spur up Chartiers Run.

Across the southern part of the quadrangle the Wabash-Pittsburg Terminal Railway Company (Wabash system) has lately built a line of road. This crosses one main summit near Hickory, where the railroad attains an elevation of 1,223 feet above sea level. From this summit the road follows down Cross Creek to Ohio River. A spur from the main line of the Wabash, east of Hickory, could easily be built down Cherry Valley, reaching the general valley level in a distance of 1½ miles with a total descent of only 100 feet. Owing to the high altitude of the Wabash road as it swings around the head of the stream the valley of Burgetts Fork of Raccoon Creek is hardly accessible to branch lines, as the grade would be too steep to reach the valley bottom from the high summit. The valley of the South Fork of Cross Creek is easily accessible from the main line of the Wabash, and it affords an opportunity for the building of a branch line along the southern edge of the quadrangle. The valley of Pattersons Mill Creek could be utilized also by a railroad line at slight expense, except for a short distance near the village of Patterson Mill, where the stream runs through a narrow, crooked canyon, which probably would require the construction of a short tunnel or of a high bridge.

In addition to the routes already described, where short and inexpensive railroad lines could be built in order to develop the mineral resources of the region, the Burgettstown quadrangle also affords another easy route for an east-west line of railroad that has not heretofore been utilized. This route has the advantage of lower summits than those crossed by the existing lines, and also of open and direct stream valleys in an east-west direction. This course extends from a point about half a mile below Santiago, near the eastern margin of the quadrangle, to a low divide at the head of Potato Garden Run, and passes down this run to Raccoon Creek, which it crosses just below the village of Murdocksville. From this place the course lies up Wingfields Run and across a low summit three-fourths of a mile east of Frankfort. From this summit it passes by easy grades into the headwaters of Kings Creek, down which it would proceed to Ohio River. Probably the most expensive part of the line would be the tunnel near the mouth of the creek, since the grade of the stream at this point is too great to be followed by a railroad line.

PITTSBURG COAL.

In all that portion of the area in which the Monongahela formation has not been eroded the Pittsburg coal is present. Within this area the coal is remarkably regular in thickness and quality, not attaining the maximum thickness found in the Monongahela Valley to the east, but averaging over 54 inches of workable coal. In fact, this coal bed is so constant in thickness and quality that large sums have been expended in the purchase of coal lands in localities where the outcrop is several miles away without the previous precaution of test wells to determine the presence and thickness of the coal. Space does not permit the presentation of detailed sections of the coal and of particular descriptions of the mines. Only a short description of the coal can be given with reference to its slopes and the most advantageous points from which to develop the territory so that the coal may be delivered by gravity to the mouth of the mine or to the foot of a shaft.

In the northeast corner of the quadrangle the coal shows in many places in outcrop. All of the large streams and most of their principal tributaries have cut their channels below the horizon of this bed, exposing it in the hillsides. The dip of the coal is not pronounced except to the southeast and the southwest of the Candor dome, where it dips advantageously for mining and delivery to the Pennsylvania Railroad. North of the summit of the dome the coal is nearly flat, but it has been dissected to such an extent by the streams that mines can be located in almost any ravine, so as to have natural drainage and down grade for hauling the coal to the mouth of the mine. Similar conditions exist throughout the region from the Candor dome to the town of Clinton.

The only coal area in the northwest corner of the quadrangle that is large enough to support commercial mines lies along Florence Ridge and the high spurs which extend toward the south. In this territory the coal has a southeast dip, and it can be brought to the Pennsylvania Railroad at or near Burgettstown by a long downgrade underground haul or to tipples overlooking the Pennsylvania Railroad on the ends of the spurs which extend south from the main ridge toward Harmons Creek.

A short distance south of the Pennsylvania Railroad the coal goes under cover and does not appear again except along the valley of Cross Creek, near the western edge of the quadrangle, and on Westland Run in the southeast corner.

In the southern half of the quadrangle the Pittsburg coal lies in an unbroken and almost untouched sheet, except in the few places noted above, where it has been eroded by the streams. This unbroken field offers the best opportunities for future work, and a careful study of the geologic structure of this field should be made by anyone contemplating the establishment of mines, so as to obtain the full benefit of the dip of the coal.

Along the Pennsylvania Railroad from Jumbo to Bulger a considerable body of coal has already been taken out by the different mines operating on the south side of the railroad. On account of the southern dip of the coal, these mines have been working at a great disadvantage, having to lift both coal and water to the mouth of the mines. In order to obtain better drainage conditions, Shaft No. 2 of the Jumbo mine has been sunk in the hollow south of Primrose, and Shaft No. 3 is now being constructed 1½ miles south of the main opening. These shafts reach the coal at a much lower level and it is the intention of the operators to concentrate all the drainage of the mine at these points and then force it to the surface by pumps located at the foot of the shafts. Beyond Shaft No. 3 it is probable that the coal can be more profitably taken out by a shaft located near the Wabash Railway.

The most advantageous way of mining the body of coal lying south of the Pennsylvania Railroad and east of Cherry Valley is from shafts along this valley. The mines of the Pittsburg and Eastern Coal Company are admirably located as far as the dip of the coal is concerned. By shafts 120 feet or less in depth the coal is mined in three places at an elevation of about 960 feet. By extending these works to the east along a true bearing of S. 70° E. and in an opposite direction along a course N. 65° W., the main gangway may be kept on a level or with a slight up grade from the bottom of the shafts, affording gravity drainage and a down-grade haul for all of the coal between the main gangway and the Pennsylvania Railroad.

Another good position for a shaft mine is farther up Cherry Valley, near the old Rankin Mill. At this place the coal lies about 200 feet below the surface and at an altitude of about 860 feet above sea level. From this point the coal has an up slope in all directions except to the west, and consequently mining could be done at the least possible expense. This location can be reached easily from both the Wabash and the Pennsylvania lines, as mentioned in the remarks on transportation.

The deepest part of the Cross Creek basin lies in the valley of Burgetts Fork of Raccoon Creek, about 3 miles south of Burgettstown. At this point the valley is broad, giving ample room for mining operations. A shaft 225 feet deep would reach the coal at the lowest point in the basin, and thus a large area of coal on all sides of the shaft would become available for economical mining.

At Westland the coal has already been opened by a drift and is extensively worked. The mine mouth is at almost the highest point of an anticlinal dome, which, however, is so broad that a large quantity of coal may be removed before any serious inconvenience is experienced through the backward dip of the coal. In the future this area will require shafts for the economical drainage of the mines and also probably for the delivery of the coal. A shaft mine in this territory could be advantageously established at some point along the Wabash Railway east of and within 3 miles of Hickory. From the bottom of this shaft entries could be driven south up the slope of the coal and connected with the workings of the Westland mines. To this shaft all of the drainage of the mines would be brought by gravity, and to it the coal between these openings and for a considerable distance both east and west could be carried at slight expense. At the same time it would permit the whole output of the mines to be shifted from one railroad system to the other as occasion demanded.

The drift mines operating southwest from Westland can best be drained by a shaft sunk on a branch of Chartiers Creek west of Millers Schoolhouse. At this place the coal will be found at a depth of less than 150 feet from the surface. From this shaft all of the coal to the west and east is accessible, and the coal can be carried to the foot of the shaft and the mine drained by gravity.

The coal in the synclinal basin at the south edge of the quadrangle could be easily worked from a shaft at Wilsons Mill. A shaft 260 feet deep would reach the coal in the bottom of the synclinal trough, and workings could be extended to advantage in any direction. Farther up the South Fork of Cross Creek other shafts may be located. These would reach the coal at shorter distances below the surface, but at higher elevations above the sea, and would have the advantage of surface transportation against the disadvantage of a long underground haul.

At the first outcrop of the Pittsburg coal in Cross Creek Valley above West Middletown station, the coal is now being opened on the north side of the railroad. This mine is well located for drainage and economical working, and by extending the main drift on a true bearing of N. 45° E. the coal to the northwest of the drift would all become available and would be easily drained.

Pattersons Mill Creek and its south fork, together with their tributaries, constitute one of the best fields for the economical development of a large body of coal to be found in the quadrangle. Middle Fork has a general course almost parallel with the strike of the coal in this vicinity, and the rise in the valley of North Fork from

Pattersons Mill northward is only a little greater than the upward slope of the coal in that direction. The coal shows in natural outcrop at Pattersons Mill, and 3 miles up the valley of North Fork toward Eldersville it is only 70 feet below the surface. From the point of outcrop near Pattersons Mill an entry driven about N. 30° E. would have sufficient grade to drain itself, and the coal could be delivered to the mouth of the mine by gravity. With a branch railroad up the main Pattersons Mill Creek shafts could be sunk along this line at intervals of a mile or so, and the whole system could be connected by underground workings, thereby permitting natural drainage of the entire area through the first opening, near Pattersons Mill. This system of development would permit the mining of a large body of coal to the north and northeast and its delivery to the various shafts in question by short down-grade hauls.

COAL IN WASHINGTON NEAR PORTLAND, OREG.

By J. S. Diller.

The discovery of additional coal deposits on the Pacific coast is always a matter of economic interest, especially when located near convenient lines of transportation.

Last August, while attending the Miners' Congress at Portland, my attention was called to a bed of coal recently opened in the State of Washington about 55 miles northwest of Portland. The coal occurs on Coal Creek, 12 miles west of Kelso, a station on the Northern Pacific Railroad, and only a few miles from a slough at tide level leading to the Columbia River.

Mr. Ralph Moody, of Portland, kindly guided me to the locality where we found a small mine in operation. An incline follows the coal downward at an angle of from 5° to 18° for 400 feet. Drifts run a short distance both ways, and two men were working at each breast. The cars are drawn to the surface by a small stationary engine, and about 25 tons of coal were already in the bunkers.

The coal bed is 6 to 7 feet in thickness, with two small partings of sand. The top bench has 12 to 18 inches of bony coal, the middle bench 2½ feet of better quality, and the lower bench 18 inches of coal in part good. The coal bed is overlain by soft sandstone.

In the mine the coal looks bright, but on exposure it loses its luster, cracks somewhat, and partially slacks. Some part of it is well banded and contains small pieces of fossil resin.

Two specimens were taken for analysis, one from the middle (6760) and the other (6761) from the lower bench. The work was done by W. T. Schaller in the Geological Survey laboratory, with the following results:

Analyses of coal from Coal Creek, Washington.

	No. 6760.		No. 6761, finely ground.
	Finely ground.	Coarsely ground.	
Moisture	15.24	22.22	16.26
Volatile combustible matter	36.28	33.30	36.33
Fixed carbon	29.54	27.11	30.05
Ash	18.94	17.37	17.36
	100.00	100.00	100.00
Sulphur	4.39	4.03	4.61
Color of ash	Light red-brown; noncoking.		

Mr. Schaller reports that—

The bottle containing No. 6761 was broken when received at the laboratory. A moisture determination of the coarsely ground sample gave 17.79 per cent, showing that the coal had lost moisture in transit, due to the bottle being broken. For this reason no data are given for the coarsely ground No. 6761 sample.

An aluminium sulphate occurs on the joint planes of 6761. The values for volatile combustible matter, fixed carbon, and ash in the coarsely ground No. 6760 are calculated from the corresponding figures of the finely ground sample.

The high percentage of water, ash, and sulphur present are all against its utility. The coal was used in running the engine of the mine and appeared to burn well, but as to later developments in the mine no information is at hand.

The bed of coal is interstratified with a lot of shales and shaly sandstones well exposed along Coal Creek near the mine. The strike of these beds near the mine is northwest-southeast, with a dip of about 15° SW., and it seems probable that if the coal on trial proves of sufficient value to work it could be traced to higher ground where gravity would be of greater service in operating the mine. There are igneous rocks cutting the coal-bearing beds in that region and the strata are faulted locally, but neither igneous rocks nor faults were seen near the mine.

Marine shells occur in the strata 3 feet above the coal. Among them is the ribbed *Venericardia planicosta*, which is characteristic of the Eocene. The coal is of essentially the same age as that farther north in Washington.

COAL IN CLALLAM COUNTY, WASH.[a]

By Ralph Arnold.

INTRODUCTION.

Location.—Clallam is the northwestern county of Washington, and occupies a long, narrow strip in the northern portion of the Olympic Peninsula. Two coal fields in the county are now being prospected. The first is located immediately south of Freshwater Bay, 7 miles west of Port Angeles, the county seat, while the second is between the Pysht River and Clallam Bay, about 35 miles west of the same town. The Freshwater Bay field is accessible by road or boat from Port Angeles, while that at Clallam Bay is reached only by water.

Description.[b]—The natural and commercial development of northwestern Washington is dominated by the Olympic Mountains, a portion of which occupies the greater part of Clallam County. These mountains, which are a labyrinth of sharp, serrated ridges and jagged peaks, occupy an area of about 3,000 square miles in the central portion of the Olympic Peninsula and culminate in Mount Olympus at an altitude of 8,150 feet. Between the mountains and the Strait of Juan de Fuca is a narrow, rather rolling terrace, averaging about 200 feet in elevation, while to the west of the Olympics is broad strip of hilly country extending from the vicinity of Ozette Lake to Grays Harbor.

Owing to the heavy precipitation on the peninsula (Neah Bay, in the northwest corner, having the maximum mean annual rainfall for the United States), many rivers rise in the central portion of the Olympics and descend through deep, precipitous canyons to the more level border lands. These rivers are navigable only for canoes, and for these only in the lower channels, but they offer an unlimited field for the development of cheap power.

[a] These notes on the coal resources of Clallam County were made in June, 1904, during a reconnaissance of the Tertiary formations of the Olympic Peninsula coast line, under the direction of Dr. William H. Dall. The writer was assisted in the field work by Mr. Chester Washburne, of Eugene, Oreg., and by Mr. Russell G. Wayland, of Seattle, Wash.

[b] The only description of the little-known Olympic Mountain region heretofore published is found in "The Olympic country," by the late S. C. Gilman: Nat. Geog. Mag., vol. 7, 1896, pp. 133–140, with map.

The whole country below timber line, which in this region is at an elevation of approximately 5,500 feet, is heavily timbered with hemlock, cedar, spruce, fir, etc. Between the larger trees is a dense undergrowth of devils club, salal, brakes, ferns, and vines, which offers an almost impenetrable barrier to ordinary progress.

Clallam County is sparsely settled, and the few settlements in it are located in the lowlands flanking the mountains, and all, with two or three exceptions, are situated on the coast. Except for several short logging roads no steam transportation is carried on in the county, all of the freighting being done either by pack animals and wagons or by the steamers which ply between Seattle and the ports along the strait.

GENERAL GEOLOGY.

Owing to the inaccessibility of the inner country little is known of the geology of Clallam County except of that portion bordering the coast. Mr. Gilman,[a] in referring to the Olympic country in general, says: "The country rocks of the mountains are syenite, gneiss, quartzite, protogene, crystalline and chlorite schists, slate (hard black flinty to soft green talc), shale, sandstone, trap, and basalt." From evidence obtained by the writer along the western end of the peninsula and by Mr. Chester Washburne, the writer's assistant, in the Soleduck River Canyon, south of Lake Crescent, it appears probable that at least the greater part of the Olympic Mountains lying in Clallam County is composed of a hard gray sandstone of pre-Oligocene age.

Eocene.—The oldest rocks of definitely known age in the area are a series of black basic basalts and greenish basalt tuffs found in the vicinity of Port Crescent. The tuffs of this series contain *Venericardia planicosta* Lamarck and several other characteristic Eocene fossils. The formation occupies the Point Crescent promontory, west of Crescent Bay, and a ridge 300 to 400 feet in height lying next to the coast and extending from Crescent Bay eastward for 3½ miles, to Freshwater Bay. The Point Crescent area and a small outcrop 1 mile west of the latter are isolated from the adjacent formations by faults.

Pre-Oligocene.—In addition to the hard gray sandstones of the northern slopes of the Olympics there is a complex series of gray sandstone, quartzite, greenstones, and serpentine outcropping in the western end of the county, about the age of which little is known except that it is pre-Oligocene and probably either Eocene or Mesozoic or both. The pre-Oligocene rocks, as a rule, are considerably contorted, and contain quartz and calcite veins in many places, some of the former carrying small amounts of gold and silver. Indica-

[a] Nat. Geog. Mag., vol. 7, 1896, p. 138.

tions of oil were found in the pre-Oligocene series at three localities—in serpentine 1½ miles south of Point of the Arches, in a soft gray sandstone (possibly Oligocene or younger) 3 miles north of the mouth of the Ozette River, and 3 miles south of the mouth of the Quillayute River, where a 1,500-foot abandoned well is located. Fragments of carbonaceous matter and small stringers of lignite are found in the sandstones between Point of the Arches and the mouth of the Ozette River and in the vicinity of Cape Johnson.

Oligocene-Miocene.—All of the pre-Pleistocene deposits along Juan de Fuca Strait from Freshwater Bay to Cape Flattery, with the exception of the Crescent Bay basalts and tuffs and the sandstone and conglomerate of the Clallam Bay–Hoko River region, belong to the Oligocene-Miocene group.[a] At least the greater part, and possibly the whole, of the thick section of conglomerates, sandstones, and shales exposed in the Cape Flattery promontory also belongs in the same division. The sandstones and shales exposed in the hills south of the Bogachiel River for several miles east of its junction with the Soleduck belong either in the top of this series or in the base of the Pliocene. A generalized section of the Oligocene-Miocene group for the Freshwater Bay–Clallam Bay region gives:

Generalized section of Oligocene-Miocene rocks of the Freshwater Bay–Clallam Bay region.

	Feet.
Coal-bearing coarse sandstones and conglomerates	500+
Massive gray shales and fine gray sandstones	1,300
Fine gray shale, massive at top, thin bedded below	975
Coarse conglomerate, with occasional sandstone layers and lenses	875
Total	3,650+

Both of the coal fields described later are found in the Oligocene-Miocene group, the Freshwater Bay beds occurring probably near the base, while the Clallam Bay coal-bearing strata are found nearer the top.

Pliocene.—The Pliocene epoch is represented by a series of alternating conglomerates and coarse sandstones, which form the steep cliffs along the strait from Clallam Bay to the mouth of the Hoko River. No fossils contemporaneous with the formation were found in it, but many of the waterworn sandstone bowlders of the conglomerate contained numerous Miocene fossils in a good state of preservation. As the formation is certainly pre-Pleistocene, the above evidence locates it with certainty in the Pliocene.

[a] It is deemed best to use the term "Oligocene-Miocene," as the separation of the two members of this group will necessarily have to be made on paleontological grounds, and will require a more careful study of the material collected than it is possible to make at the present time.

Pleistocene.—Pleistocene deposits of till and bedded clays, sands, and gravels compose the bluffs which skirt the Strait of Juan de Fuca from the eastern end of Clallam County westward to Freshwater Bay. Evidences of the same formation were also found at Gettysburg and as far west as the mouth of the Pysht River. The Pleistocene deposits are thickest in the eastern part of the county, gradually thinning out, until in the region west of Gettysburg they form but a comparatively thin layer over the Oligocene-Miocene shales. Pleistocene sands and gravels of varying thickness are also found capping the bluffs which skirt the ocean along the western end of the county. These Pleistocene sands and gravels carry small quantities of gold,[a] platinum, and iridosmine at several places along the coast from Point of the Arches south as far as the mouth of the Quillayute River.

GEOLOGIC STRUCTURE.

As indicated by the exposures along the coast, the structural lines in the region from Port Angeles to Gettysburg average approximately parallel to the trend of the Olympics, N. 70° W.–S. 70° E.; those in the Gettysburg-Clallam Bay territory almost perpendicular to this, or a little east of north, and those in the Clallam Bay–Cape Flattery stretch N. 30° W.–S. 30° E., or again parallel with the ridges which extend along the coast in this region. A syncline, with its southern limb resting against the sandstones south of Lake Crescent and its northern one truncated by the waters of the Strait of Juan de Fuca, is the major structural feature of the Port Crescent-Gettysburg region. The Freshwater Bay coal field is located in the northern portion of the trough of this syncline. A rather broad syncline, with its axis extending in a northeasterly-southwesterly direction, occupies most of the territory between the Pysht River and Clallam Bay. The Clallam Bay coal field occupies this synclinal trough. The region between Clallam Bay and Cape Flattery is formed by a great northeast-dipping monocline, the beds of which appear to have a total thickness of over 15,000 feet.

South of the Clallam Bay–Cape Flattery monocline is the western extension of the axis of the Olympic Mountains. The structure in the region about this line of disturbance is complex, but toward the south it becomes simpler.

A great uplift followed by a considerable period of erosion appears to have taken place in the Olympic Peninsula region at or near the close of the Miocene epoch, and still another lesser one during the late Pliocene. That these orogenic movements are still taking place or have occurred since the deposition of the Pleistocene is evidenced by

[a] See "Gold placers of the coast of Washington," this bulletin, pp. 154–157.

the very gently folded and tilted clays, sands, and gravels of that age found in the vicinity of Port Angeles.

COAL.

Historical.—The existence of coal in Clallam County has been known at least since 1864 or 1865,[a] when a prospect was opened in the sea cliff about 2½ miles east of Slip Point, Clallam Bay. Mr. S. C. Gilman, in his article on the Olympic country, has this to say regarding the old mine:[b]

> Between Pillar Point and Clallam Bay, on the Straits of Fuca, is the abandoned Thorndike coal mine. There are said to have been "six leads of coal, ranging in thickness from 1 to 3 feet, dip, 10°; distance between coal leads, 12 to 100 feet; formation, sandstone." This is said to have been one of the best coals found in Washington. It was mined for some time, until it pinched out or was cut off by a fault, and the vein was lost and the work abandoned.

The remains of the old pier from which the coal at the mine was loaded onto schooners, were still visible in 1892, when Mr. J. S. Diller visited the locality. The location of the mine is given on the Coast and Geodetic Survey chart (No. 6300) as 2½ miles east of Slip Point, Clallam Bay. Mr. Bailey Willis also mentions the occurrence of coal measures on the Clallam and Psyche (Pysht) rivers in his report on the coal fields of Washington Territory.[c]

Coal, said to have been[d] "taken from a vein at the headwaters of the Quillayute River," gave the following analysis:[e]

Analysis of coal from headwaters of Quillayute River, Washington.

	Per cent.
Moisture	5.10
Volatile combustible matter	39.15
Fixed carbon	47.01
Ash	7.77
Sulphur	.97
Total	100.00

Freshwater Bay field.—The easternmost locality in the county at which prospecting operations for coal have been carried on is in the region about Freshwater Bay, 7 miles west of Port Angeles. As before mentioned, this field lies just to the south of the bay, on the northeastern portion of a rather broad synclinal trough. The only

[a] Landes, Henry, The coal deposits of Washington: Ann. Rept. Washington Geol. Survey, vol. 1, 1901, p. 258.

[b] Nat. Geog. Mag., vol. 7, 1896, p. 139.

[c] Tenth Census, vol. 15, 1886, p. 760.

[d] Bethune, Geo. A., Mines and minerals of Washington: Ann. Rept. First State Geol. Survey, pp. 15, 16. Olympia, 1891.

[e] Op. et loc. cit.

evidence of coal found by the writer along the beach of Freshwater Bay was on the eastern side, about 1½ miles east of Observatory Point. Here a 25-foot series of hard, alternating gray and brown, thin-bedded sandstone strata outcrops between the fine, gray, sandy shale which is exposed for some distance along this part of the beach. The sandstone dips S. 50° W. at an angle of 20°, and is full of more or less altered fragments of wood, some of which are 6 inches in length, and most of them full of teredo borings.

Mr. D. J. O'Brien, superintendent of the Port Angeles Coal and Coke Company, which is prospecting in this field with the diamond drill, has kindly furnished the writer with the following record:

Locality of hole, deep gulch about one-half mile south of the eastern end of Freshwater Bay; top of hole approximately at sea level.

Record of boring near eastern end of Freshwater Bay, Washington.

	Ft.	in.
Dark sandstone	39	8
Coal	0	4
Gray sandstone	24	0
Soft white sandstone	17	0
Sandstone containing oyster shells	10	0
Sandstone containing green bowlders	10	0
Sandstone	40	0
Fire clay	20	0
Gray sandstone	40	0
Hard blue shale	30	0
Gray sandstone	50	0
Coal	2	2
Gray sandstone	240	0
Coal	4	8
Total	527	10

No samples of the coal from any of these beds were seen by the writer, but Mr. O'Brien is authority for the statement that it is similar to that found in the Clallam Bay field, described below. The glacial drift and gravel around Freshwater Bay makes all forms of prospecting, except with the diamond drill, almost impossible, so that further information concerning this field will have to be obtained by boring.

Clallam Bay field.—Coal-bearing sandstones and conglomerates form the Pillar Point promontory and the bluffs along the Strait of Juan de Fuca from 2½ miles west of Pillar Point to within 2⅓ miles of Slip Point, on Clallam Bay. This latter exposure, which is about 3½ miles in length, occupies the basin of a syncline whose axis extends in a northeasterly–southwesterly direction and which is truncated on the north by the waters of the strait. The southwesterly extension of the syncline is rather problematical, although from statements made by Mr. O'Brien, who says he has found coal veins at 4 miles and again at 7 miles from the beach, it seems likely that the trough extends inland at least for several miles.

The coal-bearing formation proper consists of at least 500 feet of coarse, thick-bedded to massive sandstone, with some interstratified, medium-grained conglomerate lenses and layers. The sandstone and sand matrix of the conglomerate are rather coarse and vary in composition from arkose to very siliceous. The pebbles in the conglomerate are in diameter from 6 inches down and consist of angular shale fragments and cobbles and pebbles of quartz, hard black quartzite, basalt, diabase, jasper, granite, and schist. Many of the pebbles in the thicker beds of conglomerate in the Pillar Point area are faulted. Small lenses and stringers of hard black lignite and occasional pieces of less altered wood occur throughout the formafossils and leaf impressions, occur in the sandstone and indicate its Miocene age.

Local folding and some faulting occur in the formation, and may make the exploitation of the coal seams difficult. The faulting is more prevalent, however, in the eastern portion of the syncline and in the Pillar Point exposure, where no coal of economic importance has been discovered.

The principal prospect in this field is that at a point on the coast 3½ miles east of Slip Point, Clallam Bay, or about three-fourths of a mile east of the old Thorndike property. The coal outcrops about 30 feet above the base of the high bluff which skirts the strait from Pillar Point to Clallam Bay, but is visible for only a short distance, owing to the undergrowth and broken surface of the slope. At the time of the writer's visit (June 23, 1904) the pit exposing the coal had been sunk only 2 or 3 feet, so that the sample taken from it, of which an analysis is given later, might almost be considered a surface specimen.

The seam [a] is 36 inches thick [b] and dips S. 70° W. at an angle of about 45°. The hanging wall is 12 inches of hard dark-colored shale, above which is coarse sandstone; sandstone also forms the foot wall. The coal is remarkably uniform throughout the layer, and makes a clear-cut contact both above and below. On this account it will be easy to keep it free from impurities during the process of mining.

In hand specimens the coal is seen to be a clean, hard, glossy, black lignite. It breaks with a conchoidal fracture, the fragments having extremely sharp edges. Small patches and veinlets of pyrite

[a] A 12-inch seam 75 feet stratigraphically below the main bed and a 22-inch seam 100 feet above it had been exposed by landslides previous to the writer's visit, but were not visible at that time.

[b] Later exploitation has shown it to be 40 inches thick, according to the superintendent of the property.

are scattered throughout the mass, and along joint cracks the weathering of the pyrite has coated the coal with a thin film of rusty oxide.

Mr. M. R. Campbell, of the United States Geological Survey, who is a member of the committee in charge of the Government coal-testing plant at St. Louis, has this to say regarding the Clallam Bay coal:

I know of no use for which it may successfully compete with other coals that reach the Pacific coast; but, judging from the results which have been obtained at the Government coal-testing laboratory at St. Louis during the past summer, I feel sure that the black lignite represented by this sample, although only 3 feet in thickness, may have considerable value. Tests made on similar lignite from the Rocky Mountain States show that it will produce a gas of higher power than that obtained from any of the bituminous coals of the Mississippi Valley, and if gas producers and gas engines replace the ordinary type of steam engines, which seems altogether probable, it will give to this lignite a value almost, if not quite, equal to the best bituminous coal.

A sample, slightly better than the average, from the 36-inch seam at the Clallam Bay prospect was sent to Prof. N. W. Lord, of the department of metallurgy and mineralogy, Ohio State University, Columbus, Ohio, who has kindly furnished the following results of his analysis:

Analysis of coal from Clallam Bay field, Washington.

	Per cent.
Moisture	6.55
Volatile combustible matter	34.25
Fixed carbon	47.80
Ash	11.40
Total	100.00
Sulphur	6.37

Other localities.—At least two other localities within Clallam County have yielded indications of coal. One of these is an indefinite locality "at the headwaters of the Quillayute River," previously mentioned, and the other is on the ocean beach below Portage Head, in the western part of the county. At this latter place small seams, stringers, and fragments of a hard, black lignite were seen in the gray sandstone, and the writer was told by Mr. W. W. Loveless, who lives in that vicinity, that during certain times of the year, when the rocks are bare of sand, a seam of coal several inches wide is exposed at low tide. This coal was used by Mr. Loveless in his stove and found to burn very well and give very little ash.

RÉSUMÉ.

Clallam County, located on the Olympic peninsula, in the northwest corner of Washington, contains two fields where coal occurs in apparently workable quantities. A small quantity of coal was shipped from one of the fields a few years ago. However, not much development work has been done since, and it remains for future exploitation to determine whether or not the deposits are of economic importance.

One field lies in a synclinal trough immediately south of Freshwater Bay. Its detailed structure, however, is imperfectly known, owing to the glacial drift which covers most of the country rock of the region. The presence of coal in this field was disclosed by a drill hole, which cut through three seams, as follows: A 4-inch bed at 40 feet, a 26-inch bed at about 250 feet, and a 56-inch bed at 525 feet. The quality of this coal is said to be similar to that found in the Clallam Bay field.

The second field lies between Pillar Point and Clallam Bay, and it also occupies a syncline. The structure of the basin is more or less complicated by sharp local folds and faults which may interfere with the working of the deposits. Three seams have been found in this field, the main one being 36 inches thick, while above this is a 22-inch bed and below it a 12-inch one. The coal is a clean, hard, glossy, black lignite, which breaks with a conchoidal fracture, and contains some pyrites. According to Mr. M. R. Campbell, this lignite is particularly well adapted for use in gas producers.

The local demand for coal in the county is small. It therefore will have to be shipped if mined in very large quantities. A factor in favor of both fields is their nearness to the navigable waters of the Strait of Juan de Fuca. The coal, after mining, can be loaded immediately on seagoing vessels, thus doing away with much of the expense of handling and hauling to tide water, which is added to the cost of mining in the case of the other Washington coals with which the product of the Clallam County fields will necessarily come into competition.

COAL IN THE NICHOLAS QUADRANGLE, WEST VIRGINIA.

By George H. Ashley.

Location and present development.—The Nicholas quadrangle lies near the center of the State of West Virginia, from 60 to 100 miles east of Charleston, the capital. It lies just east of the northern part of the New River coal field as developed on New River, and of the Kanawha coal field as developed along Kanawha and Elk rivers. The developed portion of the New River field just overlaps the southwest corner of this quadrangle. Geologically the whole area is practically a continuation eastward of the two coal fields just mentioned. With the exception of the southwest corner, this quadrangle represents a coal field containing a large quantity of commercial coal of the highest grade lying in such a position that it has been entirely untouched. At the present time the Chesapeake and Ohio Railroad passes down New River within a few miles of the southwest corner, and two branches of that road just project into the quadrangle. The Coal and Coke Railroad up Elk River runs only a few miles away from the northwest corner. A branch of the Baltimore and Ohio projects into this area from near the northeast corner well down the eastern side to the town of Richwood, but this branch has as yet been constructed only for the transportation of lumber, and not for coal. A private road is at present building up Strouds Creek, through Beaver Creek Valley to Muddlety Creek, for the purpose of reaching the adjacent lumber. This road will connect with the Baltimore and Ohio near Camden. Another road is in part under contract to be built up Buffalo Creek with the object of ultimately connecting the Coal and Coke Railroad at Clay with the Baltimore and Ohio near Camden. A series of surveys is also being run up Gauley River and Meadow River from the Chesapeake and Ohio and the Hocking Valley railroads at Gauley Bridge; also from the Chesapeake and Ohio at Alderson northward into this region; and there seems fair prospect that within the near future a railroad will be built into the southern part of this quadrangle for the removal of the coal and timber. In view of this prospective development in the near future the coal resources of this area become a matter of considerable interest. In the last few years a number of companies having large holdings within this quadrangle have been doing active prospecting work which was of the greatest assistance in determining the resources of the quadrangle.

Topography.—The surface of this quadrangle consists mainly of very narrow V-shaped valleys, 500 to 1,000 feet deep, separated by rather broad, rounded, fairly even divides. The farms are mainly on the divides or on a broad shelf lying on the north side of Gauley River. The streams are rapid and are actively cutting downward. Along these streams and all around the edges of the broad hilltops the harder sandstones make frequent cliffs. The coals outcrop along the slopes of the hills, and in the majority of cases will be reached by drifts from which inclines will carry the coal to the valley bottoms; thence it will be sent out by switches built up the streams. Most of the quadrangle drains to Gauley River, and on account of the dip the coal of the area south of the Gauley should be attacked from the northwest, preferably up Hominy Creek or some of its branches. The drainage of Elk River in the north edge of the quadrangle has cut to a much lower level than the drainage of the Gauley, and most of the coal north of the Gauley should be attacked from the Elk River side.

Stratigraphy.—The rocks of this quadrangle are confined almost entirely to rocks of Pottsville and Allegheny ages, the Pottsville here being considered to extend upward to and including the black flint. From the economic standpoint the rocks can be divided into those found in the New River coal field and those of the Kanawha coal field. Those of the New River coal field, beginning at the bottom, consist of: First, a series of sandstones and shales, which have a thickness of several hundred feet in the southwest part of the quadrangle. This group of rocks contains the coal known as the "Quinnimont" or "Firecreek" coal of the New River field, and also the Beckley coal, which is an important coal in Raleigh County. Above these appears the well-known Raleigh sandstone, a massive sandstone, often conglomeratic, having a thickness of from 50 to 100 feet or more. This has been traced clear across the southern part of the quadrangle. Then comes the group of sandstones and shales, in which occurs the Sewell or Nuttall coal. At the top of this group is the well-known Nuttall sandstone that makes the great cliffs at Nuttallburg, on New River, and along much of Gauley River. Above the Nuttall sandstone occurs the Kanawha formation, composed of sandstones and shales, some of the sandstones being prominent. It has a thickness of 700 to 1,000 feet and contains all but the uppermost of the coals mined along Kanawha River. The black flint forms the top of the Kanawha formation. Still above that are the sandstones that have been known as the "Charleston" sandstone, which in this region contains one of the most valuable coals. The red shales of the Conemaugh cap the hills in the northwest corner, and the Mauch Chunk red shales occur in the valleys in the southeast corner.

Structure.—In common with other parts of the Allegheny plateaus, all the rocks of this quadrangle have a general dip to the northwest. This is not entirely uniform, as in places it is as high as 300 or 400 feet to the mile and in some areas nearly dies out altogether or is reversed in the case of a few irregular anticlines that have been found in the quadrangle. These anticlines are, however, of only minor importance, unless they should prove to be areas of oil and gas production. One result of this dip is to divide the quadrangle into two coal fields, Gauley River practically forming the dividing line. South of Gauley River the rocks belong to the Sewell and lower formations, and in this respect correspond with the rocks of the New River coal field. North of Gauley River these rocks are carried by the dip below drainage, and the outcropping rocks are those associated with the Kanawha River coals. The northern part of the quadrangle is therefore an eastward continuation of the Kanawha coal field.

New River coals.—Practically all the present mining in the New River coal field is confined to one or the other of two coal beds, of which the lower is known as the "Quinnimont" bed, and the upper as the Sewell or Nuttall coal bed. The Quinnimont coal bed is not recognized with certainty within the Nicholas quadrangle, its horizon being below drainage over nearly all of the quadrangle. Drillings just south of the southwestern edge report a good 5-foot coal, which has been assumed to be the Quinnimont coal. In the southeastern part of the quadrangle there are two or three coals found below the Raleigh sandstone, all of which in places reach thicknesses of 4 to 6 feet. One of these may be assumed to be the Quinnimont coal. The presence of the Sewell coal within easy reach above drainage has prevented careful exploration of the lower seam. The Beckley coal, lying immediately below the Raleigh sandstone, may prove to be workable over a considerable extent of this quadrangle. It probably corresponds with one of the coals which is locally workable in the southeastern part of the quadrangle, and which while not seen in the southwestern part of the quadrangle was reported to be of workable thickness in several places. The Quinnimont coal should lie about 180 feet below the Beckley coal in the southwestern part of the quadrangle.

The Sewell coal in the Sewell formation is being extensively mined on Keeney Creek, in the southwest corner of the quadrangle, and has been mined at Clifftop, on Glade Creek, a few miles distant, both of these operations being part of the New River mining field. On Keeney Creek the coal shows an average thickness of about 3½ feet. At Clifftop it will average only about 2 feet 8 inches. The quality of the coal is the same as in the New River field in general. A typical analysis from Keeney Creek shows as follows:

Analysis of Sewell coal on Keeney Creek.

	Per cent.
Moisture	0.74
Volatile matter	27.09
Fixed carbon	70.58
Ash	1.59
Sulphur	.53
Phosphorus	.005

This is somewhat higher in volatile matter and lower in the other constituents, except moisture, than the average of the Sewell coal in the New River field. Toward Meadow River the coal appears to lose somewhat in thickness, and in some sections to be more split up with parting. Beyond Meadow River toward the east much the same conditions of nonworkability are at first found, but eastward toward the headwaters of Hominy Creek this coal or another at nearly the same horizon gains rapidly in thickness and quality until over a large area south and southeast from Hominy Falls it shows a thickness of from 3 to 7 feet of workable coal, the average probably being only 4 feet. East of Meadow River the workable coal is only 30 feet above the Raleigh sandstone, while west of the river the workable coal is about 70 feet above the Raleigh sandstone. This fact, coupled with the observed thinning of the two beds toward Meadow River, has led to the suspicion that the two beds are not the same, but overlap, each being thin in the principal region of the other. The area of workable coal covers all the headwaters of Hominy Creek, Meadow Creek, Mill Creek, Clear Creek, and Laurel Creek. Starting near drainage level at Hominy Falls, the coal gradually rises until it outcrops on the hills around Clear Creek at an elevation of about 4,000 feet above tide. In its best sections it shows from 6 to 7 feet, including one or two bone partings from 1 to 2 inches thick. Northwestward from Hominy Falls it decreases in thickness and at most openings in that direction appears to be less than 3 feet thick, and often badly broken up by partings. It is above drainage over most of the area south of Gauley River. East of north from Hominy Falls it is below drainage over a large area, but where it reappears on Gauley River near the mouth of Panther Creek it presents some excellent sections, showing up to 6 feet of coal. Around Richwood and to the north little prospecting has been done and little can yet be told of what may be expected of this bed in that region, but it is believed that the area in which this coal is workable will extend northeast from Hominy Falls toward Addison, and probably beyond the confines of the quadrangle. Analyses of this coal in this region show it to stand up well with the Sewell coal, as that is now being worked along New River. The average of a large number of analyses shows as follows:

Analysis of Gauley coal seam.

	Per cent.
Water	1.601
Volatile matter	27.614
Fixed carbon	66.351
Sulphur	.718
Ash	3.720
Phosphorus	.010

The New River coals pass below drainage on the north side of Gauley River. As yet exploration has not been sufficiently extensive to demonstrate whether they are workable or not in that area. Such data as are at hand, taken in connection with the observed thinning toward Gauley River, both in this quadrangle and along New River, suggest very strongly that the New River coals can not be depended upon to yield commercial coal north of Gauley River.

Kanawha coals.—In the region of Kanawha River at least seven workable coals have been found below the black flint. Much question still exists as to the correlation of these coals from point to point along the river, and it has been thought that probably coals of apparently the same horizons when carefully traced will prove to be at slightly different horizons and that probably workable coal will be found in this eastward extension of the Kanawha River field at as many horizons as on Kanawha River. At the present time exploration and development have been confined almost entirely to three coals in the lower part of the formation. These three coals may correspond with the No. 1 Gas, or Eagle, coal, the No. 2 Gas, or Ansted, coal, and the Cedar Grove coal, though such correspondence can not be asserted. The upper part of the Kanawha formation outcrops in portions of the hills but little inhabited, and exploration in that part of the field has been deterred in part by the presence of a thick coal a short distance above in the Charleston sandstone. Of the three coals mentioned, the lowest one is being mined for neighborhood use between Keslers Cross Lanes and Summersville and near the head of Birch River. It appears to be a rich, bright coal, but of very variable thickness. When it shows partings these are usually of clay. It will probably yield more or less workable coal in the quadrangle. The next coal above, thought to correlate with the Ansted coal at Ansted, averages about 4 feet in thickness. While in some sections it gives a greater thickness or is quite free from any partings, as a rule it shows a thin parting of bone coal that will greatly interfere with its commercial value. It occurs about 300 feet above the top of the Nuttall sandstone. It has been opened upon at a large number of points a short distance north of Gauley River. From 100 to 130 feet above this is another coal which may represent the Cedar Grove coal of the Kanawha River area. This coal is more commonly a solid coal of excellent quality, but on account of its variable thickness can not be counted upon to yield workable coal over more than a small percentage of the area. Immediately under the black flint on the western edge of the quadrangle is the coal correlated with the Stockton coal, which in one or two places shows a large thickness, but is badly split up with partings. It seems possible that further exploration may reveal considerable areas of workable coal at this horizon or at the horizon of the two or three coals immediately below.

Charleston sandstone.—The most important coal north of Gauley River in this quadrangle is correlated with the coal that occurs in the Charleston sandstone above the black flint. It is the coal which has been correlated by Mr. I. C. White as the Upper Freeport coal, but on paleo-botanic grounds appears to come at the horizon of the Kittanning coals. It is possible that it will be found to correlate with the No. 5 Block or Cannelton coal of Kanawha River, which is often very thick in that region. From its position in the Charleston sandstone it is limited to the northern part of the quadrangle and unfortunately over a large part of that area lies too near the tops of the hills to yield as large areas as might be wished. This bed shows almost everywhere at least 4 feet of workable coal, and in some sections as high as 12 feet of coal can be mined. As a rule the bed is split with partings, so that in most places part of it will not be mined. It shows total thicknesses of up to nearly 19 feet. The best single section shows a thickness of 13 feet, including two 6-inch partings. This coal as a rule lies within 200 or 300 feet of the tops of the mountains across almost the entire northern edge of the field, presenting its largest bodies in the divide between Elk and Gauley rivers and in the ridges which project northward and northwestward from this divide. This coal is often of a dull gray color and dry and splinty, and in some cases is extremely hard, for which reason it has been thought it would make an excellent coal for exportation. Associated with this coal, both above and below, are coals which give promise of being locally workable, though at present but little exploration has been made upon them, and it is probable that mining operations for some time will be concentrated upon the bed just described. Of these coals, one about 40 feet below the principal bed is most promising. In places it shows 3½ to 4 feet of coal in a single bench, though in many places it has a total thickness of up to 9 feet, but is so split up as not to be commercially valuable.

As a whole the coals of Kanawha River differ markedly from those of the New River field, and may be classed with the gas coals of Pennsylvania. A typical analysis would show as follows:

Analysis of Kanawha River coal.

	Per cent
Moisture	1. 744
Volatile matter	34. 686
Fixed carbon	56. 150
Ash	6. 240
Sulphur	. 560

THE COAL OF THE BLACK HILLS, WYOMING.

By N. H. Darton.

Location of beds.—In sandstones of lower Cretaceous age, on the west side of the Black Hills uplift, in Wyoming, there are local deposits of soft, bituminous coal which, at some localities, attain sufficient thickness to be of some commercial importance. In the extensive series of sedimentary rocks uplifted in the Black Hills region only the Lakota formation (lower Cretaceous) contains workable coal deposits and, in the thick mass of rocks of Carboniferous age, including the representatives of the Coal Measures of the East, only a few thin coaly layers appear. The areas of valuable coal are not large and they are separated by districts in which the strata appear to be entirely barren.

The coal is mined in four areas, the principal one being at Cambria, near Newcastle, Wyo. There are smaller workings near Aladdin, at the north end of the uplift. The coal has also been mined for local use at several points in the vicinity of Sundance and Edgemont.

Cambria.—In the vicinity of Cambria, north of Newcastle, there is a coal basin of considerable extent, the principal coal bed in which is 7 feet or more in thickness and of excellent quality. Coal has been mined at Cambria for the last fifteen years, and during this time somewhat more than 6,000,000 tons have been produced, having an average shipping value of about $1.50 per ton. For several years the product was over half a million tons, valued at $800,000, but a somewhat less amount is now mined. A portion of the product is converted into coke, which is shipped to smelting works in the northern Black Hills.

The mines are at Cambria, 6½ miles north of Newcastle, where a settlement of about 500 inhabitants owes its existence and sustenance to the mining and coking operations. It is connected with Newcastle by a branch line from the Burlington and Missouri River Railroad. The coal underlies all of the plateau on the west side of Salt Creek, but the coal measures have been cut through by Little Oil Creek, Oil Creek, Plum Creek, and their branches. To the south and west they dip below the surface, and pass beneath a thick mass of overlying sandstone and shale. The coal in this district varies greatly in thickness and purity, but there is a large area in which it is 5 feet thick or more, and in places it reaches a thickness of over 7 feet. In adjoining areas its thickness rapidly diminishes and the coal becomes extremely impure, in greater part giving place to dark carbonaceous shale. The principal basin of purer, thicker coal forms an oval area trending northeast and southwest, its axis passing through Cambria. To the northeast the coal has been entirely eroded away by Salt Creek, and, although some Lakota sandstone remains on the high ridges east of the valley of that stream, it appears not to be underlain by coal. To the southwest the coal, lying from 250 to 325 feet below the surface of the table, dips gently downward until, at the Mount Zion ranch, an abrupt increase in dip carries it farther below the surface. In the canyon a few rods southwest of Mount Zion ranch the following section was measured:

Section near Mount Zion ranch, Wyoming.

	Feet.
Bony coal	½
Hard sandstone	3
Good coal	4
Sandstone with coaly streaks	½ to 1½
Coal	2

This section is 150 feet below the top of the plateau. The overlying formations are sandstone and conglomerate. Underneath there are 40 feet of very light-colored massive sandstone, in part cross-bedded, lying on Morrison shale. A mile northeast of this locality two shafts were sunk in which the coal was found at depths of 312 and 324 feet, exhibiting a thickness of from 5½ to 6½ feet. In the mines the thickness of the coal averages from 6 to 7 feet over a wide area.

There are three mines—the Jumbo, lying east of Cambria; Antelope No. 1, between Cambria and Camp Canyon; and Antelope No. 2, between Camp Canyon and Grant Canyon. The two Antelope mines are connected by a continuous main gallery leading out to a breaker on the west side of the valley at Cambria, while the Jumbo mine is worked from the main drift opening on the east side of that valley. The dip is gentle to the southwest, so that the drainage of the mines is easily effected, the workings being 50 to 60 feet above the valleys.

Section in Camp Canyon, Wyoming.

	Feet.
Coal	6
Shale and bone	1½
Coal	6

A coal bed averaging 6 feet in thickness contains about 3,000,000 tons of coal per square mile, but there is considerable loss in working. There are now in the Cambria coal field about 10 square miles underlain by coal that would average 5 feet or more in thickness, so situated that it is available for working. It is estimated that this area would yield a total of 30,000,000 tons.

Aladdin.—The deposits of coal in the lower portion of the Lakota formation are developed to a considerable extent at Aladdin, on the north slope of the Black Hills uplift. A branch railroad extends from the mines down Hay Creek to connect with the Northwestern system near Belle Fourche. The shipments in 1902 amounted to about 10,000 long tons, and the product is a good soft bituminous coal, suitable for locomotives and domestic use. The principal basin lies to the north of Hay Creek. It contains coal beds of considerable thickness, but these become thinner and merge into more impure beds laterally. Two principal beds are worked, an upper one 3 to 5 feet thick and a lower one 2 feet thick, separated by about 10 to 12 feet of sandy shale. The deposits are broken by a number of small faults, which add greatly to the difficulties of mining.

The mines comprise four openings in the lower slope of the ridge on the north side of the Hay Creek Valley at Aladdin. They begin at the coal outcrop under a steep cliff of Lakota sandstone, and two of them extend nearly a quarter of a mile north along the coal beds, which dip very gently to the northeast. One small opening is on the lower coal bed, which is about 2½ feet thick, and the others are on the upper bed, which averages about 4½ feet thick in the mines. The coal basin appears to extend over an area of considerable size about Hay Creek, and numerous prospect holes show beds of pure coal, which in most portions of the area are a foot or less in thickness. It is possible that other basins may be found in the region, for the coal horizon, which is at the base of the Lakota sandstone, is above ground all along both sides of the Bearlodge Mountains north of the head of Redwater Creek, in the basin of Pine, Oak, Deep, Hay, and North Redwater creeks, and the slopes on the south side of Medicine Creek; little prospecting, however, has been done outside the valley of Hay Creek. The coal horizon is usually hidden by talus from the sandstone cliffs above, and when coal is present in the lower Lakota beds it often crumbles or burns away at the outcrop, and the overlying sandstone sinks down into its place for some distance. At a number of localities in the outcrop area of basal Lakota beds, as above mentioned, there are exposures of an apparently complete succession of the beds down to the underlying Morrison shale, showing little or no trace of coal, probably indicating that if coal beds are present west and north of the Hay Creek basin they are of limited extent.

Sundance region.—At several localities south and west of Sundance there are found local deposits of coal in a northward extension of the Cambria coal field. The deposits are not continuous, and they thicken and thin irregularly. Owing to the talus of sandstone blocks, which accumulates on the slopes of the coal measures, there is great difficulty in exploring the coal horizon, and only at a very few points was it found bare of talus, while even at these localities the coal may have weathered or burned out and the sandstone roof closed down.

Coal has been mined to some extent for local use 2 miles southeast of Holwell ranch and at several localities west of Sundance. Recently some openings have been made 3 miles west of Inyankara Mountain, exposing a thick deposit. The main opening southeast of Holwell's is on the southeast quarter of sec. 31, T. 48, R. 62. An adit about 115 feet in depth has been run, exposing a face of coal 8½ feet thick, comprising 5 feet of hard, pure coal, 1½ feet of bone merging into cannel coal, and at the base about 2 feet of pure, very hard coal, which is particularly valuable for blacksmiths' use. The upper coal contains considerable sulphur, which is of infrequent occurrence in the lower bed. Over the coal are about 2 feet of sandy shale overlain by hard sandstone, which makes an admirable roof. The floor is sandstone of the basal bed of the Lakota formation. The bone burns well, but leaves a large amount of white ash, and it slacks readily. The dip is very gentle to the southwest. About 60 feet above the main bed is a smaller one, varying from 1½ feet to 3 feet in thickness. It consists of a mixture of clay, sand, and coal, too impure for fuel. The following analyses of the coals of the main bed have been furnished through the kindness of Mr. Bidwell, of the Chicago and Northwestern Railroad Company:

Analyses of coal from Sundance region.

	Sample No. 1, from large tunnel.	Sample No. 2, from small tunnel.	Sample No. 3, bituminous shale parting.
	Per cent.	*Per cent.*	*Per cent.*
Moisture	10.45	11.00	4.77
Volatile combustible matter	39.51	41.16	30.85
Fixed carbon	41.87	40.37	25.69
Ash	8.17	7.47	38.69
Total	100.00	100.00	100.00
Sulphur	3.63	4.03	2.40

In the same quarter section, about 500 feet farther west, is another adit, 100 feet long, on the main coal bed, which is here 6½ feet thick, and does not contain the bony deposit near its bottom. The coal is very firm and of excellent quality. It is overlain by 3 feet of light-colored, sandy clay, capped by a thick mass of smooth, uniform sandstone, which forms a good roof. The floor is a very hard sandstone, as in the other adit. Two miles southwest, on sec. 12, T. 47, R. 63, near the north line of the northwest quarter, is another adit, 100 feet long. The same bed is exposed here, where it is about 5 feet 4 inches thick, and nearly all pure coal of great hardness. The roof at this place is sandstone, without the intervening shale. West of Holwell Ranch, on the west side of Skull Creek, coal has been exposed at one or two points at the base of the sandstone cliffs, but its thickness and extent have not been ascertained, although apparently the deposit in this locality is of diminished thickness.

On the ridge west of Inyankara Mountain it is reported that the coal deposit near the base of the Lakota formation has a thickness of 9 feet, including a number of layers of shale and bone.

West of Sundance the principal coal exposed is a bed somewhat over 4 feet in thickness and of excellent quality. One tunnel 300 feet long is in the center of sec. 13, T. 51, R. 64 W. Another tunnel 650 feet long is in the SW $\frac{1}{4}$ sec. 11, T. 50, R. 64 W., while a third tunnel, not now in use, 100 feet long, is in sec. 10, on the opposite side of the canyon from the last. The coal from these has been mined to a moderate extent, for use in Sundance and vicinity.

Edgemont.—Along the southern slope of the Black Hills uplift the Lakota formation contains local coal basins, but no large amount of coal has been found in any of them. The principal openings have been made on the north bank of Cheyenne River, east of Edgemont, in NW. $\frac{1}{4}$ of NE. $\frac{1}{4}$ sec. 24, T. 9 S., R. 3 E., where there are two tunnels 75 feet or more in length about 30 feet above the river, from which a small supply of coal has been obtained. The bed is 5 feet thick for some distance, but it averages much less. It thins out to the east and gives place to sandstone, as may be plainly seen in the bluffs below the river, and it grades into coaly shale to the northwest. The mine product was, in part, light-weight bituminous coal of good quality, containing thin, bony layers, and only a moderate amount of pyrite. To the east only a trace of coal was found in the Lakota formation, but to the north occasional thin bodies of coal and considerable coaly shale are exposed in the river gorge. In Craven Canyon there was at one time a small mine, and there was also a small production from Coal Canyon.

GEOLOGICAL SURVEY PUBLICATIONS ON COAL, LIGNITE, AND PEAT.

A number of the more important United States Geological Survey publications on the subjects of coal, lignite, and peat are listed below:

ASHLEY, G. H. The Eastern Interior coal field [Illinois and Indiana]. In Twenty-second Ann. Rept., pt. 3, pp. 265–306. 1902.

——— The Cumberland Gap coal field. In Bulletin No. 225, pp. 259–275. 1904.

BAIN, H. F. The Western Interior coal field [Iowa, Missouri, Kansas]. In Twenty-second Ann. Rept., pt. 3, pp. 333–366. 1902.

BURCHARD, E. F. Lignites of the middle and upper Missouri Valley. In Bulletin No. 225, pp. 276–288. 1904.

BURROWS, J. S. The Barnesboro-Patton coal field of central Pennsylvania. In Bulletin No. 225, pp. 295–310. 1904.

BUTTS, C. Coal mining in Cambria Co., Pa. In Bulletin No. 225, pp. 325–329. 1904.

CAMPBELL, M. R. Geology of the Big Stone Gap coal field of Virginia and Kentucky. Bulletin No. 111. 106 pp. 1893.

——— Recent work in the bituminous coal field of Pennsylvania. In Bulletin No. 213, pp. 270–275. 1903.

——— The Meadow Branch coal field, W. Va. In Bulletin No. 225, pp. 330–344. 1904.

CAMPBELL, M. R., and MENDENHALL, W. C. Geologic section along the New and Kanawha rivers in West Virginia. In Seventeenth Ann. Rept., pt. 2, pp. 473–511. 1896.

CHANCE, H. M. Anthracite coal mining. In Mineral Resources U. S. for 1883–84, pp. 104–143. 1885.

DILLER, J. S. The Coos Bay coal field, Oregon. In Nineteenth Ann. Rept., pt. 3, pp. 309–376. 1898.

FISHER, A. C. Coals of the Bighorn basin, Wyoming. In Bulletin No. 225, pp. 345–362. 1904.

——— Coal fields of the White Mountain region, New Mexico. In Bulletin No. 225, pp. 293–294. 1904.

FULLER, M. L., and ASHLEY, G. H. Recent work in the coal fields of Indiana and Illinois. In Bulletin No. 213, pp. 284–293. 1903.

HASELTINE, R. M. The bituminous coal field of Ohio. In Twenty-second Ann. Rept., pt. 3, pp. 215–226. 1902.

HAYES, C. W. The coal fields of the United States. In Twenty-second Ann. Rept., pt. 3, pp. 7–24. 1902.

——— The southern Appalachian coal field [Alabama, Georgia, Tennessee, Kentucky, Virginia]. In Twenty-second Ann. Rept., pt. 3, pp. 227–264. 1902.

——— Coal fields of the United States. In Bulletin No. 213, pp. 257–269. 1903.

LANE, A. C. The Northern Interior coal field [Michigan]. In Twenty-second Ann. Rept., pt. 3, pp. 307–332. 1902.

SHALER, N. S. Origin, distribution, and commercial value of peat deposits. In Sixteenth Ann. Rept., pt. 4, pp. 305–314. 1895.

SMITH, G. O. The Pacific coast coal fields [Oregon, Washington, California]. In Twenty-second Ann. Rept., pt. 3, pp. 473–514. 1902.

SPURR, J. E. Coal deposits in Esmeralda County, Nev. In Bulletin No. 225, pp. 289–292. 1904.

STOEK, H. H. The Pennsylvania anthracite coal field. In Twenty-second Ann. Rept., pt. 3, pp. 55–118. 1902.

STONE, R. W. The Elders Ridge coal field [Pennsylvania]. In Bulletin No. 225, pp. 311–324. 1904.

STORRS, L. S. The Rocky Mountain coal fields [Montana, Wyoming, Colorado, Utah, New Mexico]. In Twenty-second Ann. Rept., pt. 3, pp. 415–472. 1902.

TAFF, J. A. Geology of the McAlester-Lehigh coal field, Indian Territory. In Nineteenth Ann. Rept., pt. 3, pp. 423–600. 1898.

——— Preliminary report on the Camden coal field of southwestern Arkansas. In Twenty-first Ann. Rept., pt. 2, pp. 313–329. 1900.

——— The Southwestern coal field [Indian Territory, Arkansas, Texas]. In Twenty-second Ann. Rept., pt. 3, pp. 367–414. 1902.

TAFF, J. A., and ADAMS, G. I. Geology of the eastern Choctaw coal field, Indian Territory. In Twenty-first Ann. Rept., pt. 2, pp. 257–311. 1900.

VAUGHAN, T. W. Reconnaissance in the Rio Grande coal field of Texas. Bulletin No. 164. 100 pp. 1900.

WEEKS, J. D. The manufacture of coke. In Mineral Resources U. S. for 1883–84, pp. 144–213. 1885.

WHITE, D. The bituminous coal field of Maryland. In Twenty-second Ann. Rept., pt. 3, pp. 201–214. 1902.

WHITE, D. and CAMPBELL, M. R. The bituminous coal field of Pennsylvania. In Twenty-second Ann. Rept., pt. 3, pp. 127–200. 1902.

WHITE, I. C. Stratigraphy of the bituminous coal field of Pennsylvania, Ohio, and West Virginia. Bulletin No. 65. 212 pp. 1891.

WILLIS, B. The lignites of the Great Sioux Reservation [Dakota]. Bulletin No. 21. 16 pp. 1885.

——— Some coal fields of Puget Sound [Washington]. In Eighteenth Ann. Rept., pt. 3, pp. 393–436. 1898.

WOODWORTH, J. B. The Atlantic coast Triassic coal field [Virginia, North Carolina]. In Twenty-second Ann. Rept., pt. 3, pp. 25–54. 1902.

PETROLEUM, NATURAL GAS, AND ASPHALT.

THE FLORENCE, COLO., OIL FIELD.

By N. M. Fenneman.

Previous work.—In 1891 Mr. George H. Eldridge made a brief but very satisfactory examination of this field and published a report on it.[a] Not much detailed knowledge of the field has been added since this study was made. There were at that time but 82 wells. At present there are about 500. In so far as later drilling has added to our knowledge, it seems generally to have confirmed the conclusions drawn by Mr. Eldridge. A careful study of the 500 wells now drilled might, however, add to our understanding of the detailed distribution of the oil.

A brief examination of the economic conditions of the field was made by the writer during the summer of 1904. At the same time some observations were made on smaller folds which may prove to be of importance in the determination of the laws of the distribution of the oil.

Location.—The field is located in and south of the city of Florence, Fremont County, Colo., the city itself being on the Arkansas River 30 miles northwest of Pueblo, on the lines of the Denver and Rio Grande and Santa Fe railroads. In area the field covers from 10 to 20 square miles.

General structure.—The location here defined is on the east side of a triangular structural basin about 15 miles in length from north to south and having a maximum width of perhaps 10 miles. This basin is limited on the southwest by the foothills of the Wet Mountains; on the north by the foothills of the southern end of the Front Range. Its eastward limit is determined by an uplift of the strata which underlie the plains. The basin is thus seen to be contained within the reen-

[a] Proc. Am. Inst. Min. Eng., vol. 20, 1892, pp. 442–462.

trant angle of the mountain border caused by the échelon relations of the Front and Wet ranges, the triangular boundary being completed by a fold in the Cretaceous and older strata on the east.

The probable depth of this basin as defined by the Dakota sandstone is fully 8,000 feet when measured from the tops of its steeply dipping crags in the foothills to the same stratum in the bottom of the basin. As a generalized statement of the depth of the basin below its eastern rim, it may be said that it is about equal to the thickness of all the formations represented in the Florence field above the Niobrara. These higher formations aggregate in thickness about 5,000 feet and are eroded from the eastern rim of the basin.

The bottom of the basin is not reached by a uniform slope. On the east side the greater part of the descent is accomplished by steep dips—frequently 20°. Approximately along the meridian of the eastern end of the city the dips fall to about 5°, and from this line westward for a few miles the average dip is less than that amount. It is in these strata of small westward dip that the oil is found. The deepest part of the basin is a few miles west of the developed oil field. The latter, therefore, lies upon a structural slope whose local dip is relatively small.

Subordinate folds in the oil field.—As might be expected from the position of the oil field within the basin, the dips in its northern half are south of west and those in its southern half north of west, leaving a transverse trough near its center, pitching gently to the west. A class of smaller and very gentle folds is revealed mainly by local variations of strike. It seems probable that detailed work might reduce these minor folds to systems. One such fold appears to be the cause of a complete arrest of the general westward dip, giving rise to a narrow belt of horizontal beds trending north by west and lying a little east of the villages of Coal Creek and Williamsburg. A detailed study of these smaller folds might show them to be intimately related to the distribution of the oils.

A class of still smaller and probably superficial folds also exists. These occur frequently in the freshly exposed shales of newly cut stream gorges. In breadth they rarely exceed 10 or 20 feet, though their folding is frequently sharp. Not uncommonly they have a trend somewhat north of east, but trends in all directions are likewise observed and it is not now possible to generalize on this point. Some small and eminently superficial anticlinal folds of this character appear along the axes of newly made stream gorges. Their appearance is so fresh as strongly to suggest that they are younger than the gorges themselves. It is impossible to resist the suggestion that the rocks have been under compressive strain and that local unloading has afforded opportunity for these small and superficial folds. Even in the highest cliffs no such folds were observed at greater depths than about 20 feet. It is highly important that these superficial folds be carefully distinguished from the profounder structural features.

Strata containing oil.—The oil is contained within the Pierre (Cretaceous) beds, which at this place have a thickness estimated by Eldridge to be about 4,450 feet. These beds furnish both the so-called " cap rock " and the reservoirs for the oil. The latter consist of certain more arenaceous beds, very limited in lateral extent. From the isolated positions of these arenaceous beds it will be seen that the part played by folding in determining the limits and distribution of the oil bodies is by no means the same in this case as in the case where the oil-bearing sand is continuous. There is good reason, however, for attaching much importance to the folds, and they demand close attention.

Oil has been found at almost all depths between 1,300 and 3,100 feet. The deepest well in the field is 3,650 feet, but no oil is known to have been found below 3,090 feet. There is no depth at which oil, or even a bed capable of containing oil, is certain to be found. While there is within the limits named no considerable thickness of rock which does not show indications of oil in some part of the field, yet oil is not equally abundant at all horizons. Several attempts have been made to range the several occurrences or showings of oil into certain limited thicknesses of beds separated by relatively barren bands. An oil-bearing horizon as thus defined is, of course, not horizontal, but parallel to the bedding. Some years have elapsed and many wells have been drilled since the last revision of such a classification of horizons. Any future revision should not only take into account the newer wells, but should be based on carefully revised data of dips and strikes, showing the position in which the deeper beds probably lie.

Communication between oil bodies.—The cases in which two wells appear to have tapped the same oil body, or in which the production of one well has affected that of another, are rare indeed. One occurrence has been interpreted, apparently with good reason, as evidence of an open fissure at the bottom of a deep well. The cavity was revealed by a sudden drop of the drilling tools. Upon attempting to fill this supposed crevice, at least two wagon loads of gravel were thrown in and apparently disappeared. If the interpretation of this phenomenon as an open crevice be correct, it suggests the probable existence of other similar openings. These should be of the first importance in the vertical distribution of the oils. The objection that such cracks, which, on account of the synclinal folding, might be expected to open from below upward, would communicate with the great reservoir of artesian water supposed to be contained in the Dakota sandstone is not conclusive. It may indeed prove to be the case that such cracks are limited in their downward extension by the superincumbent weight and that this limit is reached at a depth less than that of the Dakota sandstone. There are no data showing the strength of the soft Benton shales, but it is not impossible that a burial approximating 2 miles might suffice to bring them within the zone of flowage.

Behavior of wells.—Gas has been found at irregular depths in beds similar to those containing oil. It may occur either with the oil or in distinct layers. There is in this field no phenomenon of gushing, but when the oil is struck it commonly rises at least a few hundred feet in the hole and may approach the mouth of the well. The issuance of gas and oil has at times been violent, but such occurrences have been of brief duration. A moderate supply of gas may continue during the life of the well, or may cease after a few days.

In general, but little water is encountered below that which is classed as surface water. The absence of a water supply in an occasional isolated layer of friable sandstone emphasizes the fact that such bodies are of very limited lateral extent. Their character is sometimes such that if continuous under large areas they might well be expected to afford abundant flows. A few instances of salt water have been met at considerable depths. There is nothing here to correspond to the relations of water and oil in the Appalachian fields, where the water forces the oil upward and follows the oil in the well. The characteristic phenomenon in the failure of a producing well in this field is not the advent of water taking the place of the oil, but only a gradual disappearance of the latter. In those cases where water has apparently failed to enter the hole after the exhaustion of the oil there has apparently been a sealing or gumming of the pores by the heavier constituents of the oil.

Number of wells and production.—The total number of wells drilled in the field approximates 500. Of these, about 175 have been producers; 60 are at present pumping. The line between producers and (for practical purposes) dry wells may be placed at about 7 or 8 barrels a day. Despite the good quality and price of the oil, it has proved unprofitable to pump wells yielding smaller amounts than this on account of the expense of labor, and the further fact that the wells are so widely separated that several pumps can not conveniently be operated from a single source of power. Upon this classification, therefore, only about three wells in eight can be regarded as producers. However, despite these adverse facts, the field has proved commercially profitable, partly on account of the high grade of the oil, in part, also, on account of the long life of the wells, and in part because the field has escaped the various disadvantages attending a boomed field. The average life of a well is not far from five years. Many wells have yielded oil for from ten to twenty years. One well has been pumped for a still longer time and has yielded more than one million barrels of oil. The product is for the most part refined at Florence.

NOTES ON THE GEOLOGY OF THE MUSCOGEE OIL FIELDS, INDIAN TERRITORY.

By Joseph A. Taff and Millard K. Shaler.

The recent active well drilling in Muscogee, Ind T., brings to light a new source for oil at a lower geologic horizon than heretofore known in the Indian Territory-Kansas field. The oil is also of a higher grade than that found elsewhere in this region.

Location.—The Muscogee oil field is at present limited to the immediate vicinity of Muscogee, in the eastern Creek Nation, Ind. T. Those wells which produced oil in paying quantity at the time investigations were made in July, 1904, are in the southeastern part of the town, on a strip of land 1 mile by one-fourth mile in extent, the longer diameter of the field having a northeast-southwest course. Six wells drilled near the center of this oil-producing belt were barren. A few wells drilled near the border of the town site, on the north, east, south, and west sides, did not yield oil in paying quantity. Other wells have been drilled a few miles southwest of Muscogee; also at Fort Gibson, 7 miles northeast, and at Wagoner, 14 miles north, each to a depth reaching or passing beneath the oil-bearing sands, without profitable results.

Discovery.—Oil was discovered at Muscogee in 1894, when two wells were drilled. In one of these oil was encountered in sand at a depth of 665 feet. This sand, after being shattered by an explosive, yielded 12 barrels of oil a day. Another sand, encountered at 1,100 feet, produced 60 barrels a day when similarly treated.

Active drilling for oil began in February, 1904, and during the year more than 30 productive wells have been drilled. Their combined capacity is estimated at 1,000 barrels a day.

Character of oil.—This oil is dark green, turning to cherry-red when held toward the light. It is of a much higher grade than any other oil produced in the Indian Territory-Kansas fields, having a gravity of 42° Baumé. Other oils in Indian Territory and in Kansas range from 28° to 32° Baumé.

The oil at Muscogee resembles some of the Pennsylvania oils in appearance and gravity, and also in having a paraffin base. The oils produced in all of the other oil districts of Indian Territory and Kansas have an asphaltum base.

Market.—The oil is sold principally to the Standard Oil Company, which has constructed at Muscogee a 25,000-barrel storage tank. A small independent refinery of 250 barrels daily capacity

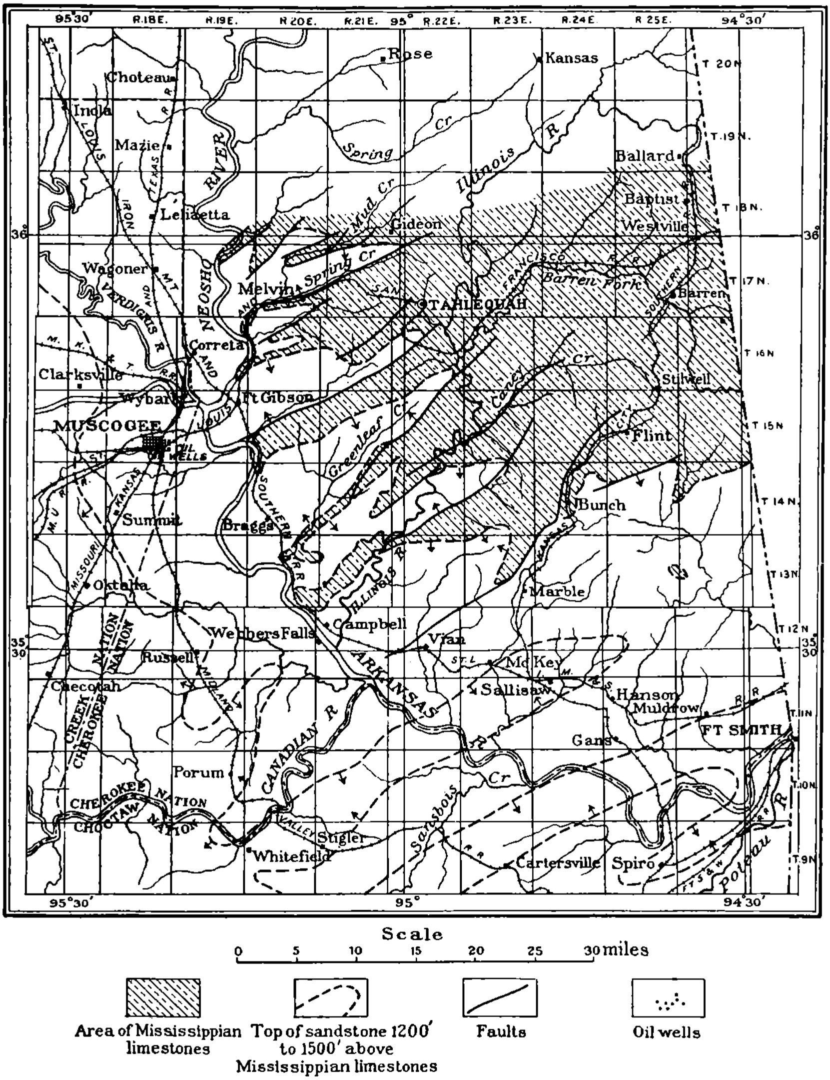


FIG. 21.—Map of the Muscogee oil field, Indian Territory.

recently erected in the city affords another market. At present (January, 1905) the price obtained by the Muscogee producers for their oil is $1.10 per barrel, the highest paid for oil in the Indian Territory-Kansas field.

Gas.—At a depth of 800 to 840 feet is a sand which yields, locally, salt water and gas. It is referred to by the driller as "salt sand." Several of the wells have yielded considerable quantities of gas from this horizon. As in most cases the yield was not large, drilling was continued down to the oil sand. In one well—the "Great Chief"—located near the center of the west side of the oil-producing area, a gas flow was encountered at a depth of 825 feet, the capacity of which was estimated to be 1,000,000 cubic feet per day. This gas was utilized for fuel in the ice and electric-light plants for some time, but later drilling was continued to the oil sand and a profitable flow of oil secured. Another well, "The United," at the north end of the area, yielded an estimated flow of more than 1,000,000 cubic feet of gas, but the well became flooded by a strong flow of salt water and had to be abandoned.

Rock section.—The wells at Muscogee were put down by several drilling companies. The oil-bearing sand was encountered at approximately the same depth, but there are considerable differences between the reported sections as to the succession of shale, sandstone, and limestone. The Survey has not been able to obtain drillings from the Muscogee wells. If these had been secured, it is believed a more satisfactory record could be constructed. A well recently drilled to a depth of 1,176 feet at Fort Gibson furnished 65 samples, from which a fairly accurate section of the rocks can be constructed. The material from this well has shown that the cherty Boone formation of the Mississippian series exposed at the surface in eastern Cherokee Nation is simply a dark-colored siliceous limestone where it reaches depths below the level of weathering. The cherty Boone limestone forms a large part of the Mississippian in eastern Cherokee Nation, and is the only part known to the well driller. The change in character of the Mississippian cherty limestone where it passes below depths of a few hundred feet has caused the well driller to fail to interpret this formation correctly. This cherty limestone was believed to be the datum below which oil does not occur in the Indian Territory-Kansas field.

The logs of the Muscogee wells, however, accord generally in showing that shales and sandstones with little lime make the rock section from the surface to a depth of about 700 feet. At this depth thick limestones are generally encountered and greater resistance to the drill is reported. Limestone, shale, and sandstone in alternating succession continue, according to report, to the oil-bearing sand, which is entered at depths of 1,020 to 1,060 feet. On comparing this general record with detailed sections made between Tahlequah and Neosho or Grand River and with the section of the Fort Gibson well, it is found that the top of the limestones is 100 to 200 feet above the top of the Mississippian. In this region the thickness of the Mississippian is found to vary between 200 and 300 feet. According to this interpretation of the well records, the Muscogee oil sand occurs interbedded with or near the Mississippian limestones.

The Mississippian limestones, as exposed in the hilly country of the western Ozark region east of Neosho River, in the Cherokee Nation, are locally folded and faulted, and are inclined at low angles toward the west. Above the Mississippian limestones comes the Pennsylvanian series, consisting of shales, thin sandstones, and limestones. All the rocks of northern Indian Territory above the Mississippian limestones west of Neosho River belong to this series. In these Pennsylvanian deposits are found the local oil pools or oil-bearing sands, which occur in the Chelsea, Bartlesville, and Redfork fields. Like the Mississippian rocks, they are tilted toward the west without appreciable local folding, at inclinations of 60 to 100 feet per mile. The edges of these rock beds outcrop west of the Neosho River Valley.

The geologic conditions governing the occurrence of oil in the Pennsylvanian rocks in northern Indian Territory and Kansas have become comparatively well known by means of geologic surveys and extensive well drilling. The oil is apparently retained in local deposits of porous rocks, inclosed by impervious deposits of shale.

Structure.—The structure of the Mississippian rocks and of the strata both above and below them in eastern Cherokee Nation is complicated. A survey of the region between Muscogee and the Arkansas-Indian Territory line supports the following statements, which may have bearing upon the occurrence of oil: 1. There is an unconformity between the Mississippian limestone and the overlying Pennsylvanian deposits. 2. There are indications that folds were developed in the Mississippian rocks before, and probably during, the earlier part of the deposition of the Pennsylvanian. 3. The Mississipian limestones lie across the folded and eroded surface of Silurian and Ordovician limestones, sandstones, and shales.

In no instance, however, have the older rocks been very steeply tilted. Fig. 21 shows approximately the outcrop of the Mississippian rocks and the strike of a sandstone bed which lies in the Pennsylvanian series, 1,200 to 1,500 feet above the Mississippian. It shows that, instead of having even westerly dips, the Mississippian and lower Pennsylvanian rocks east of Neosho and Arkansas rivers have been thrown into low folds, with which faults are usually associated. The folds and faults bear in a southwesterly direction. The faults do not extend far westward into the rocks above the Mississippian. The folds with which they are associated continue farther westward, but become rapidly flatter until they are lost. It is presumed that if oil occurs in the region south and southeast of Muscogee its collection into pools would be influenced by the location of the upward folds. If the oil should occur in the Silurian or Ordovician rocks, the interpretation of the structural conditions governing its occurrence would be more difficult, for but little is known of the folding produced in these rocks before the formation of the Mississippian limestone. These older rocks are exposed at several places in the valleys of Illinois River and Sallisaw Creek, and were penetrated in the well at Fort Gibson below a depth of 850 feet. The data obtained indicate that they are tilted westward and southward at a greater inclination than are the overlying rocks. Should this structure continue westward, successively higher beds of the Silurian would be found toward Muscogee. Should oil occur in the Silurian rocks, it would be led upward against the flat-lying Mississippian limestones. The fact, however, that the oil sand beneath Muscogee lies practically flat argues in favor of its being above the base of the Mississippian series.

OIL AND GAS OF THE INDEPENDENCE QUADRANGLE, KANSAS.

By Frank C. Schrader and Erasmus Haworth.

The aim of this paper is to present in advance of the full report a summary of what is known concerning the distribution, occurrence, development, production, character, and utilization of the oil and gas of the Independence quadrangle, Kansas.

SKETCH OF THE REGION.

Location.—The Independence quadrangle is in the southeastern part of Kansas, and includes an important part of the Kansas-Indian Territory oil and gas field. This field has an area of nearly 11,000 square miles and extends from Paola, in eastern Kansas, southwestward about 200 miles to Muscogee, Ind. T., and Cleveland, Okla. The Independence quadrangle lies near the middle of this great belt. It embraces all of Montgomery County, the southern third of Wilson County, and portions of adjoining counties. Its southern edge is the Kansas-Indian Territory boundary, while its eastern edge is approximately 47 miles west of the Kansas-Missouri line. The principal towns are Independence, Coffeyville, Cherryvale, Neodesha, Caney, and Elk City. Independence, situated near the center of the quadrangle, is about 140 miles from Kansas City.

GEOLOGY.

The rocks exposed in the quadrangle are characteristic of the Pennsylvanian series (Coal Measures) of the Carboniferous. They consist of heavy beds of shale and sandstone, alternating with thinner beds of fine-grained crystalline or semicrystalline limestone. There are in all 7 formations, which have an aggregate thickness of about 1,000 feet, of which considerably more than three-fourths is shale and sandstone and less than one-fourth limestone. The rocks exhibit but little evidence of disturbance and lie nearly flat or dip gently west-northwest at the rate of about 15 feet per mile.

These surface rocks are not the reservoir of the oil and gas, but serve rather as a blanket to confine the oil and gas in rocks of geologically lower horizons, the nearest outcrops of which, by reason of the northwesterly dip of the series, occur about 30 miles east of Independence.

The oil and gas of the quadrangle, as now known, is found chiefly in the lowest formation of the Pennsylvanian series, known as the "Cherokee shale." This shale rests upon the eroded surface of a chert and flint-bearing limestone "floor"—the Boone formation—which is commonly known by the drillers as the "Mississippi lime," and is noted for the zinc and lead ores that occur in it in southeastern Kansas and adjacent parts of Missouri and Arkansas. The Boone is not an oil and gas bearing formation, and oil and gas have not been found below it in the Independence quadrangle.

A sketch of the geology relating to the oil and gas of the quadrangle is, therefore, concerned mainly with certain formations of the Pennsylvanian series, of which the Cherokee shale is preeminently the most important. The following tabular statement gives the facts of principal importance concerning these formations:

Geologic formations of the Independence quadrangle.

Formation.	Thickness.	Lithologic character.	Location of outcrop.
	Feet.		
Sandstone, probably Elgin.	10+	Medium grained.	Lower portion only occurs in extreme northwest corner of quadrangle.
Painterhood limestone, probably Oread.	12	Fine grained, fossiliferous.	Crosses extreme northwest corner of quadrangle.
Buxton formation, probably Lawrence shale.	320	Shale with beds of sandstone and coal and lenses of limestone; contains workable coal, brick shale, building stone, and glass sand.	Occupies a belt along the northwest portion of the quadrangle, narrowing from 8 miles in width at the north edge to 2 miles at the south.
Wilson formation, 280 feet:			
Piqua limestone.	40–0	Medium to coarse grained, crystalline, pure; good for making Portland cement.	In a belt 1 to 8 miles wide, extending from north edge to south edge of the quadrangle, west of its median line.
Vilas shale	70	Compact, light or yellowish; good for making Portland cement.	In the scarps along west side of Fall and Verdigris River valleys south to Elk River and Table Mound.
Iola-Allen limestone.	30–0	Semicrystalline, compact; useful in making Portland cement.	Do.

Geologic formations of the Independence quadrangle—Continued.

Formation.	Thickness.	Lithologic character.	Location of outcrop.
	Feet.		
Wilson formation—Cont'd.			
Chanute shale, in part.	140	Heavy beds of shale and sandstone; contains workable coal seams, brick shale, building sandstone, and thin beds of limestone.	Extends across the quadrangle in a belt widening from about 10 miles in the northeast corner to 15 miles at the southern edge.
Drum formation.	10–90	Medium grained, semicrystalline, fossiliferous. Is useful for making Portland cement and for building purposes.	Outcrops are contained in a belt about 3 miles wide, extending diagonally across the southeastern part of the quadrangle. It caps the mounds north and southwest of Cherryvale.
Coffeyville formation, 250 feet:			
Cherryvale shale.	100	Compact, useful in making brick. It supplies the brick plants about Cherryvale.	Eastern part of the quadrangle, in a belt about 3 miles wide extending from Morehead along Drum Creek to near Liberty.
Dennis limestone.	10	Medium grained	Eastern part of the quadrangle, in a belt about 4 miles wide extending from Drum Creek southeastward between Cherryvale and Morehead.
Galesburg shale.	35–50	Arenaceous, red	Eastern part of the quadrangle, east of Cherryvale, in a belt 2 to 3 miles wide.
Mound Valley limestone.	10	Compact, semicrystalline.	Eastern part of the quadrangle, in Big Hill Creek region, northeast of Liberty. Here it outcrops in a belt 3 miles wide.
Ladore-Dudley shale.	90	Compact, useful in making brick.	Southeastern part of quadrangle, in a belt that has a width of 6 miles southeast of Liberty and narrows southwestward toward Indian Territory.
Parsons formation.	80	Crystalline, fossiliferous limestone and compact shale.	Crosses southeast corner of the quadrangle below Coffeeville in a belt 5 to 6 miles wide.
Bandera shale	140	Compact, contains considerable thin-bedded sandstone, some of which is quarried for flagging.	Just east of the southeast corner of the quadrangle, in a belt trending northeast-southwest.
Pawnee limestone.	20–50	Massive	East of the quadrangle, at Fort Scott, Darlington, and near Girard, in a belt about 3 miles wide trending northeast-southwest.

Geologic formations of the Independence quadrangle—Continued.

Formation.	Thickness.	Lithologic character.	Location of outcrop.
	Feet.		
Labette shale	110	Contains but little sandstone.	East of the quadrangle, at Girard, in an irregular belt 4 or more miles wide, having a northeast-southwest trend.
Fort Scott limestone.	40	Limestone, 10 feet; shale, 15 feet; limestone, 15 feet.	East of the quadrangle, east of Girard, in an irregular northeast-southwest belt 3 to 5 miles wide.
Cherokee shale	450	Compact shale, containing considerable sandstone in the form of lentils at various horizons, in which occur the oil and gas of the Kansas fields.	East of the quadrangle, in a belt about 38 miles wide extending from Missouri across the southeast corner of Kansas into Indian Territory.

HISTORY AND GEOGRAPHIC DISTRIBUTION OF OIL AND GAS.

History.—The presence of oil and gas in the Kansas fields was known from surface seepage as early as 1855. Some prospect drilling was done in 1860, but development did not begin until late in the eighties. The earliest operations were begun in Miami County about 100 miles northeast of Independence. Near Paola traces of oil and gas were found in numerous wells; and in 1865 a small quantity of oil was found in two wells about 10 miles east of Paola. By the drilling of other wells Paola became the first city supplied with natural gas west of the Mississippi.

In 1863 a well producing both gas and salt water was drilled at Iola, about 50 miles northeast of Independence. In the latter part of the eighties, along the State line east of Paola a number of wells were drilled that produced a few barrels of oil daily. In the meantime, and soon after, drilling was extended, with fair results, to Osawatomie, near Paola, to Thayer, and to Neodesha, Cherryvale, and Coffeyville, the three places last named being in the Independence quadrangle.

The first gas field within the quadrangle was soon recognized, trending north and south, with Coffeyville over its center. It reached south to the State line and north 5 or 6 miles beyond the town. At first the wells were shallow and the gas pressure was correspondingly light. Soon, however, wells were sunk to depths of 900 to 1,000 feet, and a much larger supply of gas was obtained; at the present time an enormous amount of gas is produced, mostly from wells recently sunk, about 4 miles west of Coffeyville.

In 1890 and 1891 the supply of gas obtained at Cherryvale became sufficient to permit its general use for domestic purposes in the town, and both Cherryvale and Coffeyville have had an abundance of gas since that time. It is practically the only fuel and illuminant used in both of these places. The recently established electric light plants depend on it for the generation of steam.

The development of gas at Independence has a history similar to that at Cherryvale and Coffeyville, excepting that it took place a few years later. Independence was not supplied with gas until 1893. In this same year the first good gas wells were obtained, near Neodesha, and the gas was piped into the town. Prospect drilling was soon extended over the whole of southeastern Kansas and into Indian Territory, but with varied success. A well drilled near Caney early in 1904 reached a depth of nearly 1,600 feet and yielded a flow of gas reported to be close to 20,000,000 cubic feet per day.

Though oil had long since been produced a few miles north of Neodesha, not much was produced in Montgomery County until 1903, when the development of the Bolton pool, a mile northeast of Bolton, began. Here, in the southeast quarter of sec. 17, were drilled a number of wells, each with an initial production exceeding 500 barrels per day, so that until the middle of 1904 the Bolton was the most prominent and popular pool in the State.

In 1903 a shallow oil sand was also encountered at a depth of 350 feet a short distance southeast of Coffeyville. This, within a limited area, was fairly productive.

During the winter of 1903–4 a number of oil wells were obtained in the vicinity of Tyro, and almost immediately south of Tyro, within 100 feet of the south line of the State, a flowing well filled a 250-barrel tank every day for the first week. It is still an excellent producer. In 1904 the Wayside pool also was opened.

Oil and gas are usually intimately associated. Though some small areas are very productive of gas but show no oil, while others produce large quantities of oil but show little gas, the association of the two products is such that their respective areas can scarcely be separated on a map or in a description of their geographic distribution. At present the most productive areas are the Bolton, Wayside, Caney, Tyro, Coffeyville, Independence-Dearing, Drum Creek, Cherryvale, Salt Creek, and Neodesha. A brief description of each follows.

Bolton pool.—The Bolton pool is about 5 miles southwest of Independence, between Walker Mound and Bolton, on the Santa Fe Railway. Almost this entire area, which has an extent of 3½ miles, produces oil and gas, particularly oil, and the largest oil wells in the State are located here. The gas wells are intimately associated with the oil wells to a remarkable degree, and numerous dry wells are associated with the productive ones.

Wayside pool.—From 5 to 6 miles southwest of Bolton, between Wayside and Havana, is another very productive oil area known as the Wayside pool. It is not nearly so productive, however, as the Bolton field, having produced fewer first-class wells. Here, also, gas is sometimes found, but it is not so closely associated with the oil as in the Bolton field.

Caney pool.—In the southwest part of the quadrangle, a few miles east of Caney, another field produces both oil and gas. The oil wells are situated principally along the Missouri Pacific Railway, about midway between Caney and Tyro, but there are some wells south of this area, near the State line.

In the Caney field, as elsewhere, the oil and gas occur in intimate association. For example, 2 miles east of Caney, around the southeast corner of sec. 8, is a group of wells, of which eight or ten yield a fair amount of oil and three are good producers of gas, the latter ranging in capacity from 15,000,000 to 20,000,000 cubic feet a day.

Tyro pool.—During the summer of 1904 considerable drilling was done around Tyro and to the south and southeast. It seems that this pool is, in a measure, distinct from the Caney area, but future developments may connect them. The Tyro field is similar to the others in that the oil wells, gas wells, and dry holes are interspersed in an irregular manner.

Coffeyville area.—As generally understood the Coffeyville field has a width of 8 or 10 miles. Originally gas only was produced. It was found in great abundance at and on all sides of the city. Recently, however, oil has been discovered in considerable quantities both southeast and northeast of the city and to some extent within the city limits. The strongest gas wells are 3 or 4 miles west of Coffeyville, on both sides of the Missouri Pacific Railway and along Onion Creek. In fact, this gas field reaches west beyond Dearing, south to the State line and north probably to the great Independence-Dearing field, next to be described. The Dearing portion of the field seems to be relatively free from oil, but it is generally believed that after the gas pressure shall have diminished oil will become available.

Independence-Dearing area.—This field lies between Dearing and Independence and about midway between the Bolton and Coffeyville areas. It is 5 or 6 miles across. Although developed within the last twelve months it contains more large gas wells than any other area in the Kansas field. Some are authentically reported to have a production over 30,000,000 cubic feet a day. Late in November, 1904, one was bought by a large gas company and paid for on a basis which assumed an output of 33,000,000 cubic feet a day.

Drum Creek pool.—About 3 miles southeast of Independence a small but promising area, commonly known as the Drum Creek oil pool, has also been developed within the last twelve months. It is situated principally on the east side of Verdigris River, and is unique in being almost solely an oil pool, having thus far yielded but little gas.

Cherryvale area.—Cherryvale has long been known as a gas area. There are many gas wells in the eastern part of the town and in the adjacent country for a few miles eastward. During the last four years another portion of the area very rich in gas has been opened up from 3 to 6 miles north of town. Oil also has been obtained in fair amount, mostly on the hill lands, from 1 to 2 miles northwest of town. During the summer of 1904 oil was found from 2 to 3 miles south and southeast of Cherryvale.

Salt Creek pool.—Another oil pool has been developed on Salt Creek, about 4 miles southeast of Neodesha.

Neodesha area.—Neodesha has long been looked upon as a center of production of both oil and gas in the Kansas fields. The Standard Oil Company's refinery and tank field are located here. The oil is found principally in the immediate vicinity of the town, but there are excellent gas wells also in the outlying areas to the northwest and east. The gas wells to the northwest, between Verdigris River and the St. Louis and San Francisco Railway, were the first ones developed in this vicinity. Later those farther east, in range 17, were brought in and found to be a superior group.

Northwest part of the quadrangle.—A few gas wells and oil wells of small capacity have been obtained near Elk City and also near Lafontaine, where considerable drilling has been done, but in general the results thus far obtained by prospecting in the northwest quarter of the quadrangle have not been very satisfactory. The entire quadrangle, however, is underlain by the oil- and gas-bearing formations, and any part of the area not yet thoroughly prospected may become productive.

OCCURRENCE OF OIL.

Though small bodies of oil and gas are frequently found at depths of a few hundred feet below the surface, the larger bodies occur at greater depths in and near the Cherokee formation. At Coffeyville, where the strata overlying the Cherokee are thinner than at any other point, three oil sands are encountered at the depths of 350, 600, and 900 feet. The best wells, yielding oil of 32° B. gravity, strike oil in the middle or 600-foot sand.

In the Independence region the productive zone ranges from 450 to 600 feet; at Cherryvale, from 700 to 800; at Neodesha, from 800 to 900; at Bolton and Caney, from 1,100 to 1,200. At Wayside, midway between Bolton and Caney, two oil sands occur at the depths of 700 to 800 and 1,350 to 1,450 feet. The sands that are struck between 1,350 and 1,450 feet probably correspond roughly to those of the Tyro pool, where most of the oil is struck at about 1,300 feet. This also is approximately the depth at which the oil is reached in the Bartlesville field in Indian Territory. For convenience in comparison these depths may be indicated in the following table:

Depths at which most of the oil is found.

	Feet.
Bartlesville, Ind. T	1,300–1,600
Bolton	1,100–1,200
Caney	1,100–1,200
Cherryvale	700– 800
Coffeeville	600
Drum Creek	450
Fredonia	1,100–1,150
Independence	450– 600
Neodesha	800– 900
Sycamore	700– 800 1,100–1,200
Tyro	1,300
Wayside	700– 800 1,350–1,450

Though the above variations in depth are in some instances due in part to surface relief, intimate association of dry holes with productive wells, as shown by a study of the well logs from any of the fields, indicates that the oil does not occur in a single continuous stratum of sand underlying the field, but in disconnected lentils at various horizons in the larger shale formations. The productive sands seem to be uniformly fine grained, as might be expected from close association with the shales.

Operation and development of the region.—Most of the wells are operated by companies which lease the land for a stated period from the owner, to whom they pay a stipulated royalty, which frequently includes gas delivered for domestic use on the premises. The area under one lease varies from a few acres in or near a highly productive area to many square miles in a new or unprospected part of the field. A quarter section is a fair average.

There is a small independent refinery at Humboldt, which, with the others that are being built at Paola, Erie, Cherryvale, Niotaze, and elsewhere, and that are expected to be in operation by September, 1905, will make six independent refineries in all. Since about 1896, however, operations in the Kansas field have been largely in the hands of the Prairie Oil and Gas Company, the Kansas branch of the Standard Oil Company, although during the latter half of 1893 and the first half of 1894 many new companies were formed and much development resulted.

In 1896 the Standard Oil Company erected an oil refinery at Neodesha. This, to keep pace with the development of the field, was twice enlarged so that in 1903 it was given a capacity of 3,000 barrels a day. Throughout 1903 the development became so great that the company could not build storage tanks rapidly enough to meet the supply of oil. Therefore it began the erection of a larger refinery at Sugar Creek, almost in the western suburbs of Kansas City, and built a pipe line from the Kansas oil fields to this new refinery.

The Sugar Creek refinery began operations in the latter part of 1904. But this and the Neodesha refinery combined can care for only about 2,000,000 barrels a year, whereas the production at the close of 1904 was at the rate of almost 9,000,000 barrels, and the Standard had more than 5,000,000 barrels stored in Kansas and Indian Territory. To handle this large amount of oil and the probable increase in the future a pipe line is now being laid to the Standard refinery at Whiting, Ind., where it will meet the Standard's eastern system of pipe lines. It is expected that the new line will be ready for service by July, 1905.

Owing to higher freight rates oil-well supplies are reported to cost about 5 per cent more here than in the Pennsylvania fields, but the nature and attitude of the formations render drilling easy. The cost of drilling is only about 90 cents a foot, and the rate, under average conditions, is about 100 feet per day. This fact, together with the favorable climate, topography, and railroad facilities has enabled development to proceed very rapidly.

The rate of development in different parts of the quadrangle may be roughly indicated by the monthly reports of operations issued by the pipe-line department of the Prairie Oil and Gas Company. That company's report for the month closing January 25, 1904, is as follows:

Wells drilled in Independence quadrangle in January, 1904.

District.	Producing, previous report.	Abandoned.	Completed.	Producing now.	Drilling.	Rigs up and building.
Neodesha	280	13	18	285	18	3
Cherryvale	49	1		50		
Independence	111	15	47	143	34	29
Total	440	29	65	478	52	32

This report shows 65 wells drilled, 29 abandoned, and an increase of 38 producing wells during the month which it covers, with 52 wells drilling and 32 rigs up and building. Activity was almost wholly confined to the country about Neodesha and in the Bolton field, which in the above table is contained in the Independence district. From corresponding reports for the months of April, July, and September, 1904, the following condensed totals are deduced:

Wells drilled in Independence quadrangle in April, July, and September, 1904.

Month.	Producing, previous report.	Abandoned.	Completed.	Total now producing.	Drilling.	Rigs up and building.
April	573	19	101	655	50	14
June				617		
July	569	30	142	883	54	5
September	948	11	79	1,016	47	14

The July report includes also the Elk City, Caney, and Coffeyville areas, and the September report includes, in addition to these, the Wayside pool. The figures, besides showing the ratio of completed, abandoned, and producing wells, are of interest in showing a gain of nearly 400 producing wells between the end of April and the end of September, with a total number of 1,016 in active operation on the latter date. The largest wells yet procured are in the Bolton field. One had an initial production of 700 barrels a day, while others flowed about 500 barrels a day for a number of weeks. A great many have been obtained, however, which produced from 100 to 200 barrels a day at first, and have maintained a good pumping production to the present time.

Character and value of the oil.—Like all Kansas oils, the oil of the Independence quadrangle has an asphaltum base. It is dark brown or black in color, and heavy, but varies greatly in specific gravity from place to place, sometimes within narrow geographic limits. When the Standard Oil Company began buying oil and established a general market in these fields, it divided the Kansas territory into two divisions, which it named North Neodesha and South Neodesha. As the division line between the two areas thus created is the township line, passing about 3 miles north of Fredonia and 9 miles north of Neodesha, the whole of the Independence quadrangle lies in the South Neodesha division. This is the division containing the heavier oils, for which until recently the company has constantly paid 20 cents per barrel more than for oil from the North Neodesha division.

Late in the year 1904 the Standard Oil Company revised this mode of classifying oils and begun buying by gravity tests. It sets its highest price on the oil with a gravity of 32° B. (0.8641), which it still calls South Neodesha oil. Oils heavier than this were discounted 10 cents a barrel for each degree, so that an oil testing 28° B.

(0.8860) was priced at 40 cents a barrel below that testing 32°. Strangely, the company has not increased the price for oils above 32°, although much of the oil tests considerably higher. Oil from the Bolton region varies slightly from well to well, but ranges about 34° B. (0.8536). Neodesha oil in general runs about 36° B. (0.8433), while oil from the eastern part of Montgomery County, around Cherryvale and Coffeyville, is variable, some of it being heavy enough to fall below 30° B. (0.8750). The readjustment of prices practically amounted to a very appreciable reduction in the total amount of money paid for Kansas oil.

It is found that by the evaporation of its lighter volatiles oil standing in an open tank decreases in gravity at an average of one degree a week for the first few weeks, thus causing a discount of about 10 cents per barrel a week. One test recently made with oil fresh from the pump showed a loss of more than 7.3° in three months. The evaporation is much greater in dry or warm than in wet or cold weather. This loss probably accounts for the fact that the oil in many instances tests below the expectations of the producer, who nearly everywhere uses open tanks, usually wooden ones, without a protecting cover. The Standard Oil Company avoids this great loss as far as possible by making its tanks practically air-tight and closing them immediately after they are filled.

Prices paid by the Standard Oil Company for Kansas oil, as compared with other American oils, are shown in the following table, which is the market quotation for Monday, December 5, 1904:

Prices of Kansas oil, December 5, 1904.

Pennsylvania	$1.60
Tiona	1.75
Corning	1.37
New Castle	1.47
North Lima	1.07
South Lima	1.02
Indiana	1.02
Kansas oil, 30 gravity	.67
Kansas oil, 29 gravity	.57
Kansas oil, 28½ gravity	.52
South Neodesha	.87
Corsicana, light	.85
Corsicana, heavy	.50
Kansas, heavy	.46
Bartlesville, Ind. T	.87
Somerset	1.01
Ragland	.60
Petrolea (Ont.)	1.53

When Pennsylvania oil is $1.60 the best grade of Kansas oil is 87 cents, a difference of 73 cents a barrel. This constant difference has been maintained with but slight exceptions all through the variations in prices of oil during the last two years. Early in the summer of 1903 South Neodesha oil sold as high as $1.38, the highest price ever reached by Kansas oil.

Since the marketing of the oil is a most vital question on which the prosperity of the region depends, it is unfortunate that the Standard Oil Company continues to be practically the sole purchaser for the entire Kansas-Indian Territory field. Notwithstanding the present low price of oil, due to overproduction and want of purchasing competition, the energies of the producer, who is largely responsible for the glutted market, show no abatement in prosecuting the work of development.

Though small companies may locally embark in the oil business, they can not hope in the long run to cope with the Standard. Among the projects that are being discussed to relieve the market the most plausible, perhaps, is the construction of an independent pipe line to Port Arthur, on the Gulf of Mexico, about 500 miles distant, or the transportation of the oil by water via the Neodesha, Arkansas, and Mississippi rivers to New Orleans, at either of which points it would be enabled to compete in the open markets of the world. The novel plan of installing a State refinery and causing all pipe lines to be made common carriers under State supervision is also being considered by the Kansas State legislature.

UTILIZATION OF GAS.

Thus far most of the gas has been put to local use. It constitutes the light, fuel, and power of practically all the cities and towns and most of the farm communities, and is extensively used for fuel in drilling and pumping. It also supplies the city of Parsons, east of the quadrangle, by a pipe leading from east of Neodesha. All this, however, forms but a small per cent of the amount consumed, and to be consumed, by the manufacturing industries to which this natural commodity has largely given rise. Of the products the most important are brick,[a] tile, pottery, glass, cement,[b] flour, oil, zinc, and lead.

The smelting industry has become very important by the importation of large quantities of ores from the Joplin district in order to make use of the gas in extracting their metals—zinc and lead. Large spelter plants are in operation at Caney, Cherryvale, and Neodesha. At Neodesha the American Portland Cement Company holds a contract from the city granting to the company natural gas from the city's mains at the rate of 3 cents per 1,000 cubic feet.

[a] For a statement of this and associated industries see pp. 546–549.

[b] For a statement of the cement industry see pp. 506–509.

Since early in the season of 1904 strenuous efforts have been made by the Kansas Natural Gas Company to pipe gas from the Independence quadrangle and other parts of the Kansas fields to Kansas City for manufacturing and other purposes. The measure meets with strong opposition on the part of the home citizens, who realize that the industrial life of their communities is largely dependent upon the home consumption of this natural commodity. The efforts of the company, however, are proving successful. Its pipe line has been completed to Joplin, Mo., and on the way from there northward to Kansas City will supply many cities, such as Garnett, Ottawa, Lawrence, Topeka, and numerous smaller places, while beyond Kansas City it will also supply Leavenworth and other towns in the northeastern part of the State, where the company has contracts and franchises.

OIL FIELDS OF THE TEXAS-LOUISIANA GULF COAST.

By N. M. Fenneman.

INTRODUCTION.

During the summer months of 1904 a study was made of all the oil fields, producing and prospective, on the Coastal Plain of Texas and Louisiana. Some of these had been studied before by representatives of the United States Geological Survey, and the results obtained are published in Bulletins 184 (Adams) and 212 (Hayes and Kennedy). A comprehensive résumé of the results obtained up to 1902 is given by Mr. C. W. Hayes in Bulletin 213, "Contributions to economic geology, 1902." The detailed results of last summer's study will shortly be published in a bulletin.

The fields which were producing oil at the time of the publication of Bulletin 212 were the following: Spindletop, 3 miles south of Beaumont, Tex.; Sour Lake, 20 miles northwest of Beaumont; Saratoga, 10 miles north of Sour Lake, and Jennings, La., 90 miles east of Beaumont. To these have since been added the following: Batson Prairie, 14 miles northwest of Sour Lake; Matagorda, on the shores of Matagorda Bay, about 85 miles southwest of Galveston, and Welsh, La., about 16 miles west of the Jennings field. Recent reports also indicate that one or more pumping wells have been brought in at Humble, 16 miles north of Houston. The Jennings field itself has in the meantime grown from a very small factor in the oil situation to the leading place in the Southwest. In addition to the work in these producing fields, visits were made to a large number of prospective fields, at most of which some drilling has been done.

RECORDS AND PRESENT CONDITION OF THE PRODUCING FIELDS.

The commercial importance of the several fields is fairly illustrated by the following brief summaries of their records. Taken in connection with their present rate of yield, these figures give a fairly good basis for estimating the outlook for the immediate future.

Spindletop.—There have been sold from the Spindletop field nearly 34,000,000 barrels of crude oil. If the amount wasted be added the total production would no doubt approximate 37,000,000 barrels.

As this field has an area of but 225 acres, the oil withdrawn would cover it to a depth approximating 22 feet. Inasmuch as less than 3,000,000 barrels were produced in 1904, and the production near the close of the year was less than 4,500 barrels a day, it may be expected that the history of the field is drawing to a close. Near the end of 1904 some wells were being pumped which yielded less than 10 barrels a day. This means approximately $4 worth of oil. No new territory is being added, though a little drilling continues to be carried on in the already proven field.

Sour Lake.—Sour Lake ranks second among the Texas fields, both in point of time and in the total amount of oil produced. It has yielded, to the close of 1904, more than 13,000,000 barrels of oil. The daily yield in November, 1904, was still 16,000 barrels, and some large wells have been brought in since that time. While no entirely new territory is being added to the field, considerable development is still in progress, and the immediate prospects therefore do not indicate an early or rapid decline.

Batson Prairie.—The sudden and enormous development of this field was a sensational feature of the oil business in 1904. In one year it produced more than 10,000,000 barrels, but at the close of the year its daily yield was only about one-third of the average daily yield for the entire year. The decline is occasionally interrupted by the bringing in of new wells, but on the whole it has been rapid. New territory is not being added, although drilling in the old territory has by no means stopped.

Saratoga.—The Saratoga field has been a small producer since the summer of 1903 and is at present producing between 2,000 and 3,000 barrels per day, an amount greater than at any former time and the production is apparently on the increase. Not only have recently drilled wells been its largest producers, but their location has extended the area of the field. Large areas in the vicinity remain untested.

Matagorda.—The one other field in the Coastal Plain of Texas is that on Big Hill, 3 miles from the town of Matagorda. The principal development in this field has taken place since the spring of 1904. It has a few good wells whose somewhat unsteady production has at times aggregated several thousand barrels daily. At the time of the field work the boundaries of this field were not yet determined. Salt water was present in abundance, but this has not prevented some wells from yielding considerable amounts of oil.

Jennings.—The Jennings, La., field began regularly to market the product of its wells in 1902, and continued for several years to be a small producer. Beginning, however, in August, 1904, there has been brought in a series of gushers which have rapidly brought its production to approximately 60,000 barrels a day. While the field is roughly, though not accurately, outlined on nearly all sides by dry wells, there remains room for further development in that part of the field which affords the strongest wells, and its remarkable production may continue for a time or, perhaps, even increase.

Welsh.—In Louisiana the Welsh field ranks second in production, although in size it is not to be compared with the Jennings. It produces oil at the rate of a very few hundred barrels a day. The character of this oil is such as to offer some difficulties in its disposal, either for refining purposes or as fuel oil. There seems to be no reason to fear that these difficulties will prevent its use, but treatment involving more or less time is necessary.

Anse la Butte.—At this point, about 6 miles north of Lafayette, La., some promising development work has been carried on and several wells have been pumping small quantities for the market. It is too early to forecast the future of this field.

PROSPECTING IN VARIOUS PLACES.

Heavy oil at small depths.—Of the more or less hypothetical or prospective fields visited, a considerable number agree in this point, namely, that they yield at small depths a heavy oil which is generally suitable for lubricating purposes. Of all the large fields, in none of which the oil has come from a depth of less than 700 or 800 feet, only 3 have yielded also this shallow and heavy oil. The first of these is Jennings, where the main oil comes from a depth of 1,700 to 2,000 feet. In the southern part of this field, however, a lubricating oil is pumped from a considerable number of wells approximating 100 feet in depth. The other fields referred to are Sour Lake and Saratoga, where the conditions are similar, though the shallow oil has been but little explioted.

The oldest and far the best-known area characterized by such heavy oils is the Nacogdoches field of eastern Texas. A large number of wells were drilled from ten to fifteen years ago about 16 miles southeast of the town of Nacogdoches. These wells were bailed and the best of them yielded perhaps 5 or 6 barrels of oil a day. The enterprise stopped, but probably not on account of the failure of the oil. During the latter part of 1904 deep drilling has been in progress near this field, but a producing oil well is not yet reported. At Kiser Hill, on Brazos River, near Columbia, Tex., a considerable supply of excellent lubricating oil was obtained. The pumping of this oil has been stopped for want of a market. At various points near San Antonio similar oil in small quantities is taken from shallow depths and finds a local market for lubricating purposes. At Vinton, La., a few wells, none of which exceed 30 feet in depth, are supplying lubricating oil to local manufacturing concerns. The pumping is done by hand and not more than one-half barrel a day is obtained from each well. Similar oil, though too heavy to be used as a lubricant, is found at shallow depths in one or two wells on the banks of the Atchafalaya River, near Bayou Bouillon, about 30 miles northeast of New Iberia. A half dozen or more wells have been sunk at this place. The derivation of small quantities of lubricating oil from small depths at Sulphur Mine, Louisiana, is also well known. Several of the fields here enumerated, notably Kiser Hill and Vinton, are on elevated ground similar to the Spindletop mound.

Prospecting on mounds.—A considerable number of the remaining spots where prospecting has been active agree in the fact of their location on mounds. Among these Damon Mound has attained some distinction on account of the drilling carried on there for several years. Certain surface phenomena, frequently associated with the Coastal Plain oils, are noted here, but no oil supply has been encountered. Bryan Heights, near Velasco, is a similar mound and has likewise failed to produce oil, though several wells have produced large quantities of gas. Hoskins Mound, near the coast, about 30 miles west of Galveston, has been pierced by several wells, one of which struck a considerable pocket of gas and blew out violently for a few hours, but no oil has been obtained except that which came out with this gas. Barbers Hill, 18 miles south of Dayton, has also been the scene of considerable drilling, but no oil has thus far been obtained. About 6 wells have been drilled on High Island, about 30 miles northeast of Galveston. There are at this place some springs emitting gases of the kinds frequently associated with the Coastal Plain oils, but the search for oil has been without success. Hackberry Island, Louisiana, is very similar to those described above. Test wells have been put down on most of the salt islands of Louisiana. Such a well on Belle Isle, after passing through five thin beds of salt, obtained a very small quantity of light-yellow oil, which may be burned in a lamp without refining. This field shares with Anse la Butte the distinction of having yielded oil from beneath the salt, although here, and probably also at Anse la Butte, the salt passed through was not the main body, but only minor lateral extensions. In general, experience has not been favorable to the finding of oil beneath the salt.

Prospective fields marked chiefly by gas.—Of the remaining prospective fields it may be said that an abundant emission of gas, with an occasional seepage of oil, constitute the chief surface indications. Of such fields the vicinity of Dayton, in Liberty County, offers good examples. Several wells have been drilled about 8 miles west of this place, and others to the east and north. The conditions in San Augustine and Jasper counties are similar to those near Dayton. Near Ottine, in Gonzales County, gas is very abundant. On the flood plains and terraces of San Marcos River are numerous mud volcanoes. Wells at this place found considerable gas, but have not as yet reached oil in commercial quantities. The conditions at Sutherland Springs are similar to those at Ottine, but no active mud volcanoes are found. At Humble, 16 miles north of Houston, the emission of gases has caused the presence of oil to be suspected for a long time. The first wells drilled in this field were ruined by violent eruptions of gas. Recently, however, it is understood that at least one well has been successful in reaching a body of oil and is now pumping.

SURFACE INDICATIONS.

Gas and oil seeps.—The surface indications which have led to the exploiting of the several fields are various. In a general way they may be subdivided into two classes, those which are common to this and other oil fields and those which depend for their significance upon the peculiar relations of the Coastal Plain oils. Of the indications common to this and to other fields a seepage of oil is the best. This evidence has been found in a considerable number of fields named above. It may, however, be confused, as it frequently has been, with another phenomenon which bears no relation to oil—the appearance of a scum of iron oxide on stagnant water in regions where the soil is strongly colored with limonite. This appearance is very common in the red-soil districts of eastern Texas. Closely related to a seepage of oil is the asphaltic substance sometimes found impregnating the soil at shallow depths. This evidence is not so widespread as are oil seepages in the Coastal Plain. It is well illustrated at Anse la Butte, and there are so-called "tar springs" in the northwestern part of Jasper County, Tex. Far the most common of all evidences is the escape of gases. Indeed, this phenomenon is so widespread that it is entirely unsatisfactory as an indication of the place where drilling should begin. In this, again, the phenomena of importance are frequently confused with those which have no significance whatever. To the latter class belongs the escape of marsh gas from recently buried sediments. A very simple distinction having some significance is that based upon the leaving of an oily film on the water after the breaking of a bubble.

Indications based on local conditions.—Of the class of surface indications depending upon the peculiar relations of the Coastal Plain oil deposits, probably the escape of hydrogen sulphide gas is the one deserving the most consideration. At places the bubbling up of the gas itself through stagnant water is all that is to be seen. At other places the waters have become more or less strongly sulphureted. In some districts, around the mouths of shallow wells, an incrustation of pure sulphur is continuously forming. Closely related to the escape of this compound of sulphur are the so-called "sour waters." These are best known at Sour Lake, but are by no means uncommon. Their salts are largely sulphates and their significance may be similar to that of sulphureted hydrogen, all being members of a group of substances which are related in origin. It is by no means to be inferred that the escape of a large amount of gas is a better indication than that of a small amount. Indeed, the best oil fields of the Coastal Plain have been marked by very modest surface indications.

A phenomenon which has carried far more weight than justly belongs to it is found in the so-called "gas mounds." These are low, rounded mounds, averaging perhaps 2 feet in height and several rods in diameter. Considering their vast numbers on the flat Coastal Plain, they show remarkable uniformity in size and shape. They are popularly supposed to be connected with the escape of gases from the soil. Whatever be their origin, there is as yet no evidence that they are in any way related to oil bodies. Even were such a relation assumed, these mounds are so widely distributed over the flat Coastal Plain that as guides to drilling they are of no value whatever.

Approximately one-half of the developed and prospective fields belong to that part of the Coastal Plain whose topography is as yet unaffected by erosion. On this part of the Coastal Plain there is one class of topographic features which rises prominent over all others. This class comprises the so-called "mounds" (not the "gas mounds" spoken of above), which in size range from several hundred to several thousand acres and in altitude to a maximum of 75 or 100 feet above the surrounding plain. This class of mounds, of which the Spindletop oil field and the Salt Islands of Louisiana are the best known examples, has doubtless been represented on the older and now eroded parts of the Coastal Plain, but their former presence there is now difficult to determine. Corresponding to the topographic mound there is, beneath each of these limited areas, an assemblage of rocks and a geologic structure which do not exist outside the area covered by the elevation. It is in mounds of this class that drilling for oil has been persistent, on account of the phenomenal success of the search at Spindletop. Of those oil fields, both developed and prospective, which lie upon the eroded part of the Coastal Plain, some show the peculiar internal structure of the mounds. The same structure might perhaps be found in all of the productive fields by sufficiently deep and thorough exploration. Where the surficial mound is absent or obscure, it may be on account of subsequent erosion, but it must also be noted that the elevation is not a necessary accompaniment of the peculiar geologic structure. In the most typical case of all (Spindletop) the elevation above the surrounding flat is but 7 feet. It is therefore to be expected that there are other similar occurrences of the peculiarly associated materials, including oil, whose positions have never been marked by any topographic features. On the perfectly uneroded parts of the Coastal Plain far the largest significance has very justly been attached to these mounds as suggestions of the possible presence of oil. The failure to distinguish these from hills of erosion is a very common error.

Structure of the mounds.—For the first 700 to 1,000 feet below the surface at Spindletop the material consists of unconsolidated Coastal Plain deposits, most largely clay, but to a less extent sand and gravel. There are occasional thin beds of hard limestone. At the higher mounds these beds are thinner. On the Salt Islands they are at places all but absent. At Damon Mound the next lower formation appears locally at the surface. Beneath these characteristic deposits of the Coastal Plain there is, at Spindletop, a highly porous and crystalline limestone. The pores may be small, giving to the rock a sugary appearance, or they may be large caverns. Those seen in hand specimens are sometimes as large as walnuts, but there seems no reason to doubt that the caverns of this kind reach a very much larger size. A corresponding porous limestone occurs at some of the other mounds and in some other oil fields (e. g., Sour Lake and Batson), where a surficial mound has either never existed or been obscured by erosion.

The porous limestone here referred to is in some fields the principal reservoir of the oil. Even at Spindletop, however, some of the oil seems to have worked its way upward from this reservoir and was found to be contained in sandy beds inclosed between dense clays. While at Spindletop far the largest part of the oil was found in the limestone, the proportion of that contained in limestone to that contained in the overlying sands varies greatly in the different fields. At Sour Lake perhaps one-half of the wells derived their oil from the limestone; at Batson, much less than one-half; at Saratoga and at Jennings all the oil thus far obtained has come from the sandy beds.

A considerable amount of sulphur has been found at various depths and in various relations. The reports of "solid sulphur," however, must be received with caution. In so far as pure sulphur has been brought to the surface it has been found to be contained within the same caverns described above as containing the oil. There are also sulphurous clays and sands. Whether the sulphur-filled caverns exist for the most part above the horizon of the oil or below remains to be determined. Naturally the larger part of the deposits discovered was above the oil, but there is some reason for supposing that if the 200 feet below the oil horizon were as well explored as are the beds above that horizon the sulphur would be found in larger quantities at the greater depths. Thus far it can only be said that the sulphur found has always been in positions in which a body of oil might have been for a time retained. It is not an infrequent occurrence to find the cavities of the oil-filled rock lined with sulphur crystals. It is not improbable that the occurrence of these sulphur deposits, the large amount of sulphur dissolved in the crude oil, and the escape of sulphurous gases at the surface are genetically related.

Gypsum has been found in considerable quantities beneath the oil rock, both at Spindletop and elsewhere. It is frequently separated from the oil rock by many feet of clay, marl, or even sand. In some of the mounds this gypsum has a thickness of hundreds of feet. Beneath the gypsum horizon rock salt has been encountered in so large a number of the mounds that it is impossible to draw a line distinguishing the Salt Islands on the one hand from the oil fields on the other. The same materials arranged in the same order characterize both types. These materials, named in descending order, are (1) the unconsolidated clays, etc., (2) porous limestone, with oil and sulphur, (3) gypsum, (4) salt. Not all the members of this series are present in each case, but the number of repetitions of this series, in whole or in part, is strikingly large. There are no significant departures from the order here given for the solid materials. The oil, as pointed out above, is frequently found in the overlying sandy beds, and in the two cases named small amounts of oil were found after passing through streaks of salt branching out from the main body.

ORIGIN OF THE MOUNDS.

The origin of these several materials characteristically associated with the oil-producing mounds is not fully determined. That the porous limestone is a deposit from solution in water is evident on account of its thoroughly crystalline texture. The sulphur may perhaps have been deposited from solution in the oil. That it has been known to precipitate in tanks lends plausibility to this supposition, and the fact that its position wherever found has been essentially the same as that in which oil bodies are found further strengthens the assumption. Of the origin of the gypsum and salt nothing definite has been ascertained.

The mounds at the surface plainly owe their existence to some force exerted from beneath upward. It is inconceivable that any lateral pressure in these uncompacted Coastal Plain deposits should have resulted in approximately circular hills rising above the dead flat. It is too early to frame an exact hypothesis as to the nature of that force exerted from beneath, but the indications in the field strongly suggest some association with an expansive force accompanying the crystallization of the minerals characteristic of such mounds.

It would be difficult to make valuable suggestions for the further prospecting of the oils on the uneroded part of the Coastal Plain. Nothing definite can be added to the suggestions of topography and surface indications already being followed by the exploiting companies. But a word of caution is necessary with regard to drilling in supposed mounds on that part of the Coastal Plain more remote from the Gulf and already somewhat subjected to erosion. The true mounds of the Spindletop type may indeed be partially preserved on the slightly eroded plain (as, for example, at Jennings), but where erosion has advanced somewhat further, surface topography offers no suggestions whatever, and the first question to be answered with regard to a hill in which it is proposed to drill is whether this hill is of the mound type or is of purely erosional origin. It is highly probable that many such mounds have been destroyed by erosion, and that could their sites be found, drilling would reveal the characteristic internal structure and materials, perhaps including oil.

In view of the character of the Texas and Louisiana Coastal Plain oils, it was formerly supposed that they would be in small demand for refining. Their gravity varies from 16° B. to 27° B. (generally nearer the former than the latter), and they have an asphalt base. While still used largely for fuel, improved methods of refining have succeeded in obtaining from Beaumont crude oil 17 per cent kerosene of a good quality and 15 per cent solar oil. Similar proportions are derived from the crude oils of the neighboring fields.

OIL AND ASPHALT PROSPECTS IN SALT LAKE BASIN, UTAH.

By J. M. Boutwell.

INTRODUCTION.

The exposure of asphalt by the recent recession of Great Salt Lake has stimulated exploration for oil and bituminous products in Salt Lake basin. Gas occurs at several points along the east shore of Great Salt Lake in the vicinity of Farmington; oil is reported from Skull Valley, southwest of the Oquirrh Range, and asphalt is being prospected on the north shore of Great Salt Lake south of Rozel Hills. Ground has been extensively located in each of these localities, and several companies have been organized to explore for oil and asphalt. One company, controlled and operated by the Guffey & Galey Company, of Pittsburg, has been actively engaged in boring for about a year, one is now boring, another has sunk several test borings in asphalt, another has contracted with professional drillers to sink three wells to 4,000 feet if necessary, and others have been chiefly engaged in securing properties awaiting developments.

In the early spring of 1904, in the course of work in the neighboring Park City mining district, the writer visited the only property where exploration was then actually in progress, and in the fall of that year visited the oil and asphalt prospects at Rozel Hills. This work was of a reconnaissance character, and it was not possible during these brief visits to make a complete study of the geologic problems involved. As certain general facts which were obtained may be of immediate service in future exploration in this region, it seems advisable to publish them at once. These are presented in the following sketch, after a general statement on the geography and geology of the region, under descriptions of the oil prospect near Farmington—so far as known the next deepest boring in Utah—and of the oil and high-grade asphalt prospects at Rozel Hills.

GENERAL GEOGRAPHY AND GEOLOGY.

The region which is being prospected for oil and asphalt lies in the northwestern part of Utah, along the eastern and northern shores of Great Salt Lake, from 10 to 60 miles northwest of Salt Lake City. The areas are situated in the extreme eastern part of the Great Basin and comprise a portion of the bed of Lake Bonneville. Solution of the practical geologic problems which are met in the exploration of these areas thus involves an understanding of the geologic history recorded by these two great features.

The Great Basin is, broadly viewed, a vast plain walled in by the massive Sierra Nevada on the west and by the lofty Wasatch Range on the east, and is interrupted by numerous linear north-south mountain ranges. The portions of these Basin ranges now visible are in many cases only the crests of once lofty ranges

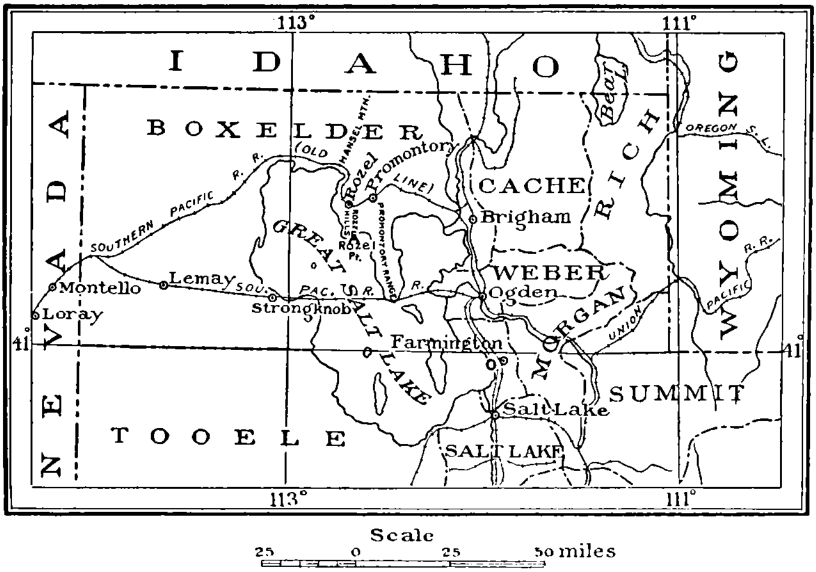


FIG. 22.—Map of northern Utah, showing location of oil and asphalt prospects.

which are now buried to unproved depths under waste deposits. At a comparatively recent date a depression on the extreme eastern side of the basin was occupied by an inland sea which washed the slopes of the Wasatch wall and extended westward into the present State of Nevada, southward to cover the present Escalante Desert in Iron County, northward into Idaho, encompassed several of the present Basin ranges, making them islands, and overflowed through Red Rock Pass into the Snake River system. Its extent and history are recorded by the prominent shore lines which characterize the slopes of elevations throughout this area. Waste from the surmounting land masses passed into this lake, covered the submerged mountain slopes and intermontane rock bottoms, and accumulated thereon to a depth of many hundred feet. After draining to the lowest point of its outlet, the lake continued to shrink under the influence of evaporation, recording its fall during halting stages by well-marked shore lines, until it reached its present state—a comparatively small body in the lowest portion of the old basin. Thus a topography has been developed which is characterized by excessively flat stretches of desert interrupted by narrow, steep-sided, deeply dissected, north-south ranges, with their lower slopes contoured by shore lines.

The rocks composing the great Wasatch wall and the Basin ranges include sandstones, limestones, and schists, which were considered by the geologist of the Fortieth Parallel Survey to range from Archean to later Tertiary in age. In the region bordering the area under discussion the Wasatch section embraces rocks ranging from pre-Cambrian to Pliocene Tertiary, and the youngest sedimentary rocks mapped in the neighboring Basin ranges are Carboniferous.[a]

The lake sediments forming the intervening stretches are clays, sands, and unconsolidated conglomerates, composed of material shed from adjoining slopes, and also carry interbedded plant and animal remains. The geological problem presented is, then, to ascertain whether an oil- and asphalt-bearing series occurs in these unconsolidated sedimentary fillings or in the underlying bed rock.

OIL.

Prospecting for oil has been carried on at several points, and many hundred claims have been taken up along the eastern and northern shores of Great Salt Lake. No oil has yet been encountered in this vicinity, though boring is still in progress at the Rozel Hills. About 150 miles farther south, at Fillmore, Utah, a small amount of boring is being continued with a view to tapping commercial quantities. It is understood that the lower portion of this boring, at the depth where oil was struck, was in bed rock.

The next deepest boring in the State has been put down by the Guffey & Galey Company about a mile southwest of Farmington. A depth of about 2,000 feet has been attained, and the results of that work have been placed at the service of this Survey.

Ground was selected by this company adjoining that from which gas was obtained for a limited time about twelve years ago for domestic use in Salt Lake City.[b] It lies in a belt bordering Great Salt Lake, which has been exposed by the recent recession, and is

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[a] U. S. Geol. Explor. 40th Par., Geologic Atlas (Map III, west half) and vol. 2, p. 422.

[b] The data regarding this former gas industry, collected by G. B. Richardson of this Survey, are presented on pages 480–483 of this volume.

characterized by low elliptical mounds of recent lake deposits of clay and sand, which are sometimes considered by oil experts to indicate the presence of oil. On a number of these mounds, usually at their apices, are circular pits about 25 feet in diameter, occupied by actively bubbling springs of cold water. An odorless gas escapes from the bursting bubbles, which ignites with a slight report and for a brief period gives a pale light. No oil was observed in association with either this gas or the rising water. These springs were the guides to the gas which was formerly exploited, and together with the apparently significant topography led to the choice of location for the present exploration.

This well penetrates waterworn siliceous and calcareous sands and gravels, bearing occasional shells, fragments of wood, considerable hot water, and gas. It has reached a depth of about 2,000 feet, where a more solid formation, believed to be coarse bowlders, was encountered. This interfered with further sinking by making the bore crooked, and thus led, in December, 1904, to the abandonment of the well. The detailed evidence afforded by samples of the material penetrated in drilling, which were supplied by the operators and studied by the writer, is shown in the following tabular statement:

Log of the Guffey & Galey well, 1 mile southwest of Farmington, Davis County, Utah.

Character of strata.	Thickness.	Depth.
	Feet.	*Feet.*
1. Clay and sand, occasional wood	170	1- 170
2. Sand and gravel	30	170- 200
3. Greenish micaceous sand and gravel	100	300- 400
4. Fine gray clay with fresh-water shells	70	420- 490
5. Fresh-water shells	....	500
6. Fine sand	60	510- 570
7. Coarse gravel, ½ to 1 inch diameter, from igneous rocks	30	630- 660
8. Coarse sand, partly from schists	30	700- 730
9. Coarse gravel and fine sand	40	730- 770
10. Angular fine gravel	25	770- 795
11. Greenish cemented gravel and micaceous sand	90	810- 900
12. Green sand, coarse waterworn gravel, with blackened wood	300	900-1,200
13. Green sand and rounded gravel	50	1,200-1,250
14. Sand and gravel	50	1,250-1,300
15. Rounded gravel, quartz sand, occasionally cemented by pyrite, wood fragments	100	1,300-1,400

Log of the Guffey & Galey well, 1 mile southwest of Farmington, Davis County, Utah—Continued.

Character of strata.	Thickness.	Depth.
	Feet.	*Feet.*
16. Angular gravel, quartz sand, with pyrite and many bits of wood	110	1,400-1,510
17. Brown, earthy, micaceous sand, possibly some gypsum	15	1,510-1,525
18. Angular quartz sand	35	1,525-1,560
19. Fine, sandy, olive-colored clay	10	1,560-1,570
20. Greenish gravel and sand	20	1,570-1,590
21. Gravel, quartz, and micaceous sand	13	1,597-1,610
22. Brown earthy clay and sand	10	1,610-1,620
23. Olive clay, sand, and gravel	20	1,740-1,760
24. Green clay, fine waterworn gravel	40	1,790-1,830
25. Greenish clay	10	1,830-1,840
26. Fine quartz sand, with pyrite and mica	5	1,840-1,845
27. Brown, earthy, micaceous sand	10	1,845-1,855
28. Pinkish clay and sand	10	1,865-1,875
29. Fine sand	20	1,875-1,895
30. "Bowlders"		2,000±

At the early period when gas was exploited in the adjoining area it is reported to have diminished in amount after a time, and eventually to such an extent that the enterprise was abandoned. The reason assigned for the short life of the wells was their shallowness (500 to 700 feet), and it was held that great depths would afford not only permanent gas, but, in all likelihood, oil also. The present deep well partially disproves this assertion. "Blowouts" of gas and water were encountered at several points, notably at 20, 58, 158, 198, 325, and 390 feet, and several at greater depths. In some instances these were so forceful as to eject the casing. But, so far as known, no oil was found. The unconsolidated material cut by the boring is composed mainly of quartz, with some feldspar and mica, and the gravel shows that the chief source of this material was crystalline and metamorphic rock. The olive and greenish tints which characterize several of the beds penetrated is largely due to a mica of that color which probably occurred in a metamorphic schist. Both the mica-schist and the crystalline rock were doubtless derived from formations which occur abundantly to-day along the western slope of the Wasatch, overlooking this basin area. Throughout the section fragments of wood, blackened and somewhat altered, were plentiful. The shells found at a depth of 500 feet beneath the present surface have been determined (April 15, 1904) by Dr. W. H. Dall, paleontologist of the United States Geological Survey, to be *Valvata utahensis* and *Sphærium striatinum*, and reported by him to be characteristic "fresh-water shells living in still water and muddy bottom." This would seem to indicate that at the time these beds were deposited the waters of Lake Bonneville were fresh and possibly had not become an inclosed inland sea. The chief scientific value of this deep boring is to show that the unconsolidated deposits are here at least 2,000 feet thick, and thus that the base of the great western fault scarp or front of the Wasatch Range and the bed-rock floor underlying the recent deposits in this basin are more than 2,000 feet below the present land surface. This boring proves that oil does not occur in the vicinity in the beds cut.

ASPHALT.

The only occurrence of asphalt known in this region is in the northwest part of Great Salt Lake, at the Rozel Hills. The nearest railway station is Rozel, 10 miles north, but the most convenient starting point is Promontory, on the Southern Pacific Railway. From that point in the Promontory Range a drive of 15 miles southwestward across the intermontane desert known as Rozel Flats, brings one to the southern end of the Rozel Hills, at their descent to Salt Lake. The region is topographically a portion of this desert, which extends westward athwart the course of the Rozel Basin Range.

The geology of the region is little known. The Promontory and Rozel ranges are made up mainly of well-bedded calcareous sediments, which have been deformed, folded, and broken. At the south end of the Promontory Range, along the route of the new Lucin cut-off, are steeply tilted schists and gneisses, which doubtless form the foundation for the sediments, while extensive masses of a basic extrusive cap the Rozel Hills and indicate a late eruption. The sedimentary beds, according to the geologists of the Fortieth Parallel Survey, are of Carboniferous age, a conclusion reached by general correlation of the strata here with those of the Promontory Range.

At the south end of the Rozel Hills the buff and gray limestones are much silicified and metamorphosed. They have been crumpled into a series of broad folds and much broken and brecciated. An extensive body of a basic extrusive with amygdaloidal structure forms the crest of the hills. This was believed by the observers of the Fortieth Parallel Survey to be "the same flow, now separated by the Quaternary deposits of the valleys," that outcrops to the north, on the Hanzel Mountains, and also to the west of the lake, on the hills next north of the Terrace Range. It is quite possible that this extensive flow was effective in metamorphosing the nearby limestones, and its ejection may be causatively related to the folding and brecciation of these beds. Whatever the cause, the significant fact remains that at the south end of the Rozel Range, in the immediate vicinity of occurrences of asphaltic matter, the limestone country rock is folded and brecciated and cut and capped by a basic extrusive.

The occurrence of this asphaltic substance appears, so far as now known, to be restricted to the shallow littoral portion of Great Salt Lake, one-fourth to 1 mile out from the present shore line, immediately southeast of the Rozel Hills. It there exudes through the unconsolidated material on the bottom of the lake and bubbles up into the water in the form of hollow spherical or tubular masses 1 to 2 inches in length, and of threads and hairs 6 to 18 inches in length. These small masses spot the bottom in great numbers throughout this area. At certain points the emissions are concentrated into considerable seepages or "pitch springs," 1 to 2 feet in diameter. The source of these seepages appears to those who have prospected this ground to be a bed of ashpalt 2 or 3 feet thick, which was encountered 80 feet below the present lake bed, and an underlying series of asphaltic beds 3 to 5 feet thick, which alternate with beds of clay to a depth of 140 feet, at least. In the vicinity of these seepages the asphaltic matter cements the calcareous oolitic deposits of the lake bottom into a bituminous limestone. This forms numerous low islets, 1 to 50 feet in diameter, which are distributed in rough alignment. This alignment and the presence of intensely brecciated zones in the limestone on the mainland suggest the possibility that the seepages may be along zones of fracture. These may have served merely to open exits for the fluid asphalt in unconsolidated lake beds, or may have also delivered it from deeper reservoirs in underlying bed rock into its present position. In brief, the asphalt occurs either in bituminous oolitic limestone, as the cement, or in springs, as liquid asphalt from beds 3 to 5 feet thick, intercalated with clay beds at a depth of 80 to 140 feet.

In character this substance is opaque, brownish-black, oily, viscous, and strongly asphaltic in odor. Its consistency varies readily with the temperature, from a thin, semiliquid state at body temperatures to a rigid, brittle state in outdoor winter temperatures, which permits it to be chipped with a pick. The composition has been studied and numerous analyses have been published in current mining magazines, which show high percentages of asphalt and oil.

The results of two chemical examinations of the asphaltic product have been placed at the disposal of the writer, one by Mr. A. W. Dow, inspector of asphalts for the District of Columbia, who analyzed a sample collected in 1903 by Hon. Thomas Kearns, Hon. Joseph Lippman, and J. R. Morris, and made special tests to ascertain its suitability for paving purposes; the other by Mr. Ruschhaupt, who investigated its suitability for other commercial uses.

Analysis of asphalt from Rozel, Utah.

	Per cent.
Bitumen soluble in carbon disulphide	95.00
Foreign organic matter	1.84
Mineral matter (quartz sand and limestone)	3.16
Total	100.00

Analysis of the bitumen soluble in carbon disulphide.

	Per cent.
Bitumen soluble in naphtha, 60–80 b. p. (petrolene)	81.25
Bitumen insoluble in naphtha, 60–80 b. p. (asphaltene)	18.75

Heat test.

	Per cent.
Loss on heating at 300° F. for twenty-four hours	2.33
Further loss on heating at 400° F. for twenty-four hours longer	3.81
Character of residue left after heating (penetration)	85.00

Test for susceptibility to change in temperature.

Penetration at 32° F. (by No. 2 needle under 200 grams for one minute)	12
Penetration at 77° F. (by No. 2 needle under 100 grams for five seconds)	50
Penetration at 100° F. (by No. 2 needle under 50 grams for five seconds)	170

Ductility test.

Length in inches to which cement will pull before breaking at temperature of 75° F	70

From these results Mr. Dow concludes that the cement yielded by refining off 11 per cent water and volatile oils is of "good quality and will, without doubt, make an excellent pavement." In a report to the owners of this property, Mr. Ruschhaupt gives practically the same components. He further states that the crude substance contains no petroleum nor paraffin, and that gum asphalt is its only fixed base. In view of the composition and properties determined, he concludes that after proper treatment this substance is suitable for use as a lubricant, paint, varnish, preservative, pavement, and for other purposes.

The amount of this substance obtainable has not been determined. Comparatively little development work has been done. The earliest work known, according to the Hon. Joseph Lippman, was done about eight years ago by Mr. Jeremiah Schenck, who is reported to have sunk a boring at a point in the lake about a quarter of a mile from the shore to a depth of 130 feet through a mixture of asphaltum and detrital lake deposits. The writer is further informed by Mr. J. J. Driver, president of the Utah Oil and Liquid Asphalt Company, which controls this property, that "five wells have been sunk" on one of the islets, "two of which are about 140 feet deep, the others from 80 to 100 feet." He also states that an experiment in facilitating the flow of the viscous asphalt was made by running a steam coil down one of the wells for about 100 feet and forcing the steam thence into the asphalt bed. As a result it is reported that the viscous asphalt was partially liquefied and flowed up more readily for a few hours, when it was cut off by apparent caving of the walls about the bottom orifice of the casing. At the rate of flow which was maintained during those few hours, the operators estimated that about 12 to 15 barrels (of 52 gallons capacity) could be obtained in a day. The aggregate thickness of beds of asphalt cut in the course of this development is estimated by Mr. Driver to be about 30 to 35 feet. The areal extent of these beds has not been even roughly determined. One writer states that the deposits occur throughout a tract of several acres. Another has estimated that they extend for 10 miles along the shore and for 3 or 4 miles in a direction transverse to the shore. The actual dimensions, however, would probably be found, on proving the ground, to fall considerably below this estimate. As yet development work is insufficient to prove either the extent of the asphalt deposits in depth or areally, or their form.

Commercially the property is to be regarded as in the prospect stage, practically the entire output being 20 barrels, shipped to Ogden for use as paving. In the event that sufficient quantity is found to render its regular operation commercially desirable, its economical extraction would prove a serious problem. In brief, the future of this property as an asphalt producer will depend upon the result of future development and the solution of the problem of extraction.

As a possible indication of oil, this occurrence of asphalt possesses an additional interest, for an intimate relationship has been recognized by students of the subject,[a] and some hold that "the origin of the hydrocarbons as such and in the bituminous compounds * * * may be traced * * * to petroleum,"[b] Thus Eldridge has found that "in the geological investigation of the

[a] Eldridge, G. H., Asphalt and bituminous rock deposits of the United States: Twenty-second Ann. Rept. U. S. Geol. Survey, pt. 1, pp. 231–232. Hayes, C. W., and Kennedy, William, Oil fields of Texas-Louisiana Gulf coastal plain: Bull. U. S. Geol. Survey No. 212, p. 139.

[b] Eldridge, G. H., idem, p. 231.

asphaltites, bituminous sandstones, and related materials the view of their origin" from petroleum "suggested by chemistry has in many ways been reenforced. The asphaltic earths and solid bitumens in part are frequently associated with active petroleum springs, or are found in regions renowned as oil producing."[a]

About one-half a mile north of the asphalt seepages at Rozel Point a well is being sunk, with churn drill, under the direction of an experienced driller. Its site, evidently selected after due study of the folds in the limestone forming the neighboring ridge, is at the base of the eastern slope of the Rozel Hills.

MISCELLANEOUS PROSPECTS.

Other prospecting has been reported in Salt Lake basin, or the northern portion of the area occupied by Lake Bonneville. This has not, so far as known, developed significant results. The prospect at Farmington for oil and those at Rozel Point for asphalt embrace the most extensive and important work undertaken in this area in search of bituminous products. But the importance of obtaining water in the great desert west of Salt Lake renders the evidence gained by deep prospecting valuable.

Along the Southern Pacific Railway,[b] within the Bonneville basin, several wells have been sunk through lake deposits, and in one place a strong flow of excellent water was encountered. At Strongknob, on the west side of the lake and 52 miles west of Ogden, a well was sunk in clay to a depth of 800 feet. Some gas was struck, but neither oil nor asphalt. At Lemay, 28 miles farther west and well within the present Great Salt Lake Desert, a well has been sunk to a depth of 2,480 feet. No good water or oil has been found, though salt water, sulphurous gases, and water showing a temperature of 120° have been encountered. The boring is reported to have penetrated, in the upper 850 feet, clay carrying some gypsum; then to have passed through a considerable thickness of blue limestone carrying fossils—shells and coral—and then to have passed into brown sandstone. Boring is still in progress here. Another deep well sunk on this railway line, with practically the same result, though outside the Bonneville basin, is at a point about 50 miles east of Reno, in the Truckee Valley, in western Nevada. This is stated to be in clay for its entire depth of 2,700 feet and to have tapped saline and heated waters.

[a] Eldridge, G. H., Asphalt and bituminous rock deposits of the United States: Twenty-second Ann. Rept. U. S. Geol. Survey, pt. 1, p. 231.

[b] The studies along this line have been facilitated and valuable information has been given by Messrs. C. S. Fee, general passenger agent of the road; G. F. McGonagle, assistant engineer, and F. Easton, road master of the Ogden division.

At Loray, Nev., 131 miles west of Ogden, an abundant supply of good water was found. The point selected for boring is near the eastern outlet of an extensive reentrant or bay on the western border of the Bonneville basin. This embayment is a topographic basin in the Gosiute Range, draining eastward, and is partially filled with recent waterlaid waste material. The general dip of the sediments constituting the bed-rock bottom of the basin is toward the northeast, but on approaching the outlet followed by the railway the beds change in dip and strike, the dip becoming vertical. Good water is stated to have risen in the well 110 feet above its bottom (538 feet) and to have maintained that level constantly despite a drain (by pumping) of 10,000 gallons an hour for twenty-four hours. The supply appears from general observations to be artesian, but the geologic structure noted about the outlet may tend to make the actual extent of the artesian basin much less than the apparent extent.

CONCLUSIONS.

As to the probability of finding bituminous products in Salt Lake basin in sufficient quantity to be of commercial value, ultimate conclusions must await detailed geologic study. Little is yet known about the structure of the Bonneville beds, and less about the rocks that underlie them. The recent exploration described in the preceding pages affords valuable evidence, which is conclusive so far as it goes.

The Farmington well, sunk 2,000 feet in unconsolidated material, in a region characterized by abundant escape of gas and hot and cold water from crests of elliptical mounds, has failed to strike oil. Many deep borings in unconsolidated material have also been made in search of water in the vicinity of Salt Lake City and farther south without disclosing oil. This evidence shows that oil does not occur in the unconsolidated material in the immediate areas explored, and on general grounds it is unfavorable to the discovery of oil in these sediments elsewhere in Salt Lake basin.

The extent of the occurrences of liquid asphalt at Rozel Point has not been determined. Although the seepages thus far uncovered by the receding lake waters are comparatively small, the high grade of the product, its proved suitability for commercial use, and the readily accessible location of the ground, both by land and by water, render systematic development desirable in order to prove the form and size of the deposits. In view of the possibility that this asphalt may have been derived from petroleum deposits, the outcome of the boring for oil in the immediate vicinity is important.

The evidence thus far gained by development, however, does not reveal the character and contents of the bed rock underlying the unconsolidated deposits. The location of the occurrences of asphalt leads to suggestive broad geologic considerations, which upon detailed field study might prove to be of economic value.

The Promontory asphalt deposit lies in the general line of orogenic deformation, marked by a well-defined Basin mountain range. Tertiary sediments (Green River and Bridger) in eastern Utah are known to be bituminous; sediments in neighboring regions (believed from the description of their localities to be Cretaceous) are reported to afford seepages of oil, while in the Cretaceous and older formations elsewhere very important oil fields have been developed. Tertiary beds (Vermilion Creek) are reported by geologists of the Fortieth Parallel Survey to extend westward beyond the Wasatch Mountains, down their western slopes into the Great Basin just north of Salt Lake City. If this be true it is not improbable that they may underlie the recent deposits in that vicinity. The possibility thus arises that oil-bearing Tertiary, Cretaceous, or Carboniferous beds may occur along the line of orogenic deformation, and may therefore have been fissured and opened so as to permit the escape of such fluid or semifluid contents as oil or asphaltic substances. In view of this possibility it is desirable that exploration should be made in regions where surface indications are most favorable, and that it should be continued deep enough to prove or disprove the presence of oil or asphalt in the consolidated rock bottom of the basin.

NATURAL GAS NEAR SALT LAKE CITY, UTAH.

By G. B. Richardson.

During a study of underground water in the valley of Jordan River, Utah, in the summer of 1904, natural gas was found escaping from a number of water wells, and examination revealed its common occurrence in the vicinity of Salt Lake City. About eight years ago this field was extensively prospected, and for over a year the city was supplied with natural gas. Though the quantity obtained proved insufficient, gas is still found in greater or less abundance, which leads to sporadic attempts to further develop the field. It seems desirable, therefore, to record[a] the little that is known of the occurrence of natural gas in this vicinity. An outline of the topographic and geologic relations of this region, and all available information concerning the presence of other hydrocarbons, oil and asphalt, are given in a paper by J. M. Boutwell, on pages 468–479.

Natural gas occurs at a number of localities along the eastern shore of Great Salt Lake, notably in the vicinity of Brigham and Corinne, near the mouth of Bear River, and in the vicinity of Salt Lake City, adjacent to the mouth of Jordan River. Only the last-mentioned field was visited by the writer. Near Salt Lake City gas has been found in an ill-defined area, extending at least 10 miles west of the city and 15 miles north, as far as Farmington. This area was formerly occupied by Lake Bonneville,[b] the Pleistocene predecessor of Great Salt Lake.

The surface is almost flat, though the country rises gently eastward to the base of terraces that mark the shores of the ancient lake. Within the last fifteen years the level of Great Salt Lake has been gradually lowered about 10 feet, and the shore line varies considerably in horizontal position annually, consequent upon the changing

[a] The statistics here recorded were obtained through the courtesy of R. J. Haywood and H. L. Driver, of Salt Lake City.

[b] Gilbert, G. K., Lake Bonneville: Mon. U. S. Geol. Survey, vol. 1, 1890.

relations of evaporation, precipitation, and inflow. The border of the lake, therefore, is marshy and is covered more or less with evaporated salts. The underlying deposits are chiefly sand and clay derived from the disintegration of the adjacent mountains and deposited in Lake Bonneville.

Though gas has been found in numerous wells within the area outlined above, the greatest development has occurred about 12 miles north of Salt Lake City, in the marshy tract near the shore of Great Salt Lake. Gas is reported to have been discovered in this region in 1892, and in the winter of 1894–95 a 6-inch pipe line was laid to Salt Lake City. The producing field was confined to an area of only about 1 square mile in sec. 36, T. 3 N., R. 1 W. Here about 20 wells, ranging from 2 to 4 inches in diameter and averaging about 500 feet deep, were sunk. Two wells were also driven in the lake deposits to depths of 1,200 and 1,400 feet. Records were not kept of these wells, but the drillers state that in general a variable succession of fine-textured, unconsolidated sand and clay was encountered, and that bed rock was not reached. Detailed conditions vary in adjacent wells, indicating lenticular arrangement of the deposits.

Gas occurs at different depths in the area developed, but mostly between 400 and 700 feet. In one well three gas horizons were struck at 502, 542, and 602 feet. In another well, 800 feet deep, nine "good strong flows" of gas are reported. The gas is said to occur in sand which is underlain and overlain by clay, the beds ranging from 3 to 20 feet in thickness. The productive sands are reported generally free from water, though small artesian flows were found in overlying beds.

The pressure of the gas in the wells is said to have averaged about 200 pounds, and a maximum pressure of 250 pounds has been recorded.

Prof. J. T. Kingsbury, assisted by students of the University of Utah, in the fall of 1894 made the following analysis of gas collected at the wells:

Analysis of Salt Lake gas.

[Per cent, by volume.]

CH_4	22.3
C_2H_6	37.8
C_2H_4	.7
CO	1.2
CO_2	.8
H	16.6
N	19.7
O	.9
Total	100.0

This is the only analysis available, and it is remarkable for showing considerable variation from typical natural gas. The methane is low and the ethane and nitrogen are correspondingly high.

For nineteen months Salt Lake City was supplied from this source, but the amount produced is not definitely known. Measurements at the wells show that an average monthly supply of 8,500,000 cubic feet was maintained, while measurements in the city recorded a little less than 7,000,000 cubic feet. Part of this discrepancy undoubtedly is due to leakage from the delivery pipe, and differences in accuracy of measurement may account for the rest. From September, 1895, to March, 1897, approximately 150,000,000 cubic feet were supplied. The maximum amount was delivered in August, 1896, when over 17,000,000 cubic feet were recorded at the wells.

From the beginning trouble was caused by the gas coming spasmodically. Each well, after being opened, diminished in pressure until the flow almost ceased, but when cleaned out the original pressures are reported to have been attained again, the wells having become clogged with sand and clay. Finally, however, in spite of the fact that new wells were sunk, the supply decreased until it became insufficient for the city's needs and the field was abandoned.

At present the sites of a number of the wells are marked by low mounds a foot or two in diameter, caused probably by mud brought from the wells by artesian water. Gas which can be readily lighted commonly escapes from these mounds, and has been thus escaping since the wells were abandoned.

Whatever its origin, the gas appears to have become imprisoned in lenses of sand which are overlain by impervious caps of clay. The source may possibly be in Tertiary beds that are thought to underlie the Bonneville deposits. The existence of such beds is inferred from the geologic history of the region, though their character, extent, and depth below the surface are unknown. It is well known that the hydrocarbons which are found east of the Wasatch Mountains occur in rocks of Tertiary age. But a more likely source is suggested by the fact that in a number of wells considerable amounts of organic matter, largely of vegetable origin, have been encountered. This organic matter was entombed in the old lake deposits, and its decomposition may account for the origin of the gas.

Though the field described has been the most productive of several known areas in the Bonneville region, it is quite possible that similar accumulations will be found in the future. There is little reason, however, for expecting much better results than already obtained. Doubtless considerable quantities of hydrocarbons have been formed from the decomposition of disseminated organic matter contained in the lake beds, but much may have escaped. The preservation of gas in quantity is dependent not only on a sufficient supply of organic matter, but also on the presence of porous reservoirs effectively capped by impervious material to collect and retain the hydrocarbons. Unfortunately, in the Bonneville area the presence of such conditions can not be predicted. It may be stated, though, that prospecting for gas should not be undertaken in the vicinity of the base of the mountains where recent faulting has taken place. Actual occurrences of gas in this region can be discovered only by the drill.

PUBLICATIONS ON PETROLEUM, NATURAL GAS, AND ASPHALTS.

The following list contains the more important papers relative to oil, gas, and asphalt published by the United States Geological Survey or by members of its staff:

ADAMS, G. I. Oil and gas fields of the western interior and northern Texas coal measures, and of the Upper Cretaceous and Tertiary of the western Gulf coast. Bulletin U. S. Geol. Survey No. 184, 64 pp. 1901.

ELDRIDGE, G. H. The Florence oil field, Colorado. In Trans. Am. Inst. Min. Eng., vol. 20, pp. 442–462. 1892.

——— The uintaite (gilsonite) deposits of Utah. In Seventeenth Ann. Rept. U. S. Geol. Survey, pt. 1, pp. 909–949. 1896.

——— The asphalt and bituminous rock deposits of the United States. In Twenty-second Ann. Rept. U. S. Geol. Survey, pt. 1, pp. 209–452. 1901.

——— Origin and distribution of asphalt and bituminous rock deposits in the United States. In Bulletin U. S. Geol. Survey No. 213, pp. 296–305. 1903.

——— The petroleum fields of California. In Bulletin U. S. Geol. Survey No. 213, pp. 306–321. 1903.

FENNEMAN, N. M. The Boulder, Colo., oil field. In Bulletin U. S. Geol. Survey No. 213, pp. 322–332. 1903.

——— Structure of the Boulder oil field, with records for 1903. In Bulletin U. S. Geol. Survey No. 225, pp. 383–391. 1904.

FULLER, M. L. The Gaines oil field of northern Pennsylvania. In Twenty-second Ann. Rept. U. S. Geol. Survey, pt. 3, pp. 573–628. 1902.

——— Asphalt, oil, and gas in southwestern Indiana. In Bulletin U. S. Geol. Survey No. 213, pp. 333–335. 1903.

——— The Hyner gas pool, Clinton County, Pa. In Bulletin U. S. Geol. Survey No. 225, pp. 392–395. 1904.

GRISWOLD, W. T. The Berea grit oil sand in the Cadiz quadrangle, Ohio. Bulletin U. S. Geol. Survey No. 198, 43 pp. 1902.

——— Structural work during 1901 and 1902 in the eastern Ohio oil fields. In Bulletin U. S. Geol. Survey No. 213, pp. 336–344. 1903.

HAYES, C. W. Oil fields of the Texas-Louisiana Gulf Coastal Plain. In Bulletin U. S. Geol. Survey No. 213, pp. 345–352. 1903.

——— Asphalt deposits of Pike County, Ark. In Bulletin U. S. Geol. Survey No. 213, pp. 353–355. 1903.

HAYES, C. W., and KENNEDY, W. Oil fields of the Texas-Louisiana Gulf Coastal Plain. Bulletin U. S. Geol. Survey No. 212. 1903.

HILGARD, E. W. The asphaltum deposits of California. In Mineral Resources U. S. for 1883–1884, pp. 938–948. 1885.

McGEE, W J Origin, constitution, and distribution of rock gas and related bitumens. In Eleventh Ann. Rept. U. S. Geol. Survey, pt. 1, pp. 589–616. 1891.

PHINNEY, A. J. The natural gas field of Indiana. In Eleventh Ann. Rept. U. S. Geol. Survey, pt. 1, pp. 617–742. 1891.

RICHARDSON, C. Asphaltum. In Mineral Resources U. S. for 1893, pp. 626–669. 1894.

STONE, R. W. Oil and gas fields of eastern Greene County, Pa. In Bulletin U. S. Geol. Survey No. 225, pp. 396–412. 1904.

VAUGHAN, T. W. The asphalt deposits of western Texas. In Eighteenth Ann. Rept. U. S. Geol. Survey, pt. 5, pp. 930–935. 1897.

WILLIS, B. Oil of the northern Rocky Mountains. In Eng. Min. Jour., vol. 72, pp. 782–784. 1901.

BUILDING STONE.

SLATE INVESTIGATIONS DURING 1904.

By T. Nelson Dale.

In the spring and fall of 1904 visits were made by the writer to all the principal slate-producing districts of the eastern States, except those of Slatington, Pa., and of eastern New York and western Vermont, which had already been visited during recent years.[a] The object was to collect material for a bulletin on the slate deposits of the United States, for which other geologists are also preparing papers, and which is expected to appear in 1905. In these visits special attention was given to the structural features of the principal quarries and to the collection of typical specimens for microscopic analysis.

In Maine all the working quarries near Monson, Brownville, and Blanchard were visited. The striking feature at all these places is the well-known frequent interbedding of the slate with quartzite, accounting for the high cost of quarrying and the high price of the product, which, however, is justified by its superior quality. The falling in of the side walls at some of these quarries, owing to undermining along steeply inclined bedding planes, involves considerable losses of capital, which could probably be avoided by occasionally employing a competent mining engineer and following his directions as to where to leave supporting walls.

The Peach Bottom slate belt in Harford County, Md., and York County, Pa., and the recently reopened quarries near Thurston, in Frederick County, Md., were also visited. Some of the larger quarries in both the "hard vein" and the "soft vein" belts of Northampton County, Pa., were examined.

The northern Vermont slate belts lie on the east side of the Green Mountain axis. Black slate was formerly quarried both at Northfield and at Montpelier, in Washington County, but at present only one quarry is in operation—that of the Vermont Black Slate Com-

[a] See page 493.

pany, at Northfield. The slate is closely related in quality to the Brownville slate of Maine, but is without the considerable percentage of magnetite which makes the Brownville slate objectionable for electrical purposes. It contains more pyrite and a very small amount of carbonate. Owing to the absence of flat joints and ribbons, it has to be channeled across the cleavage, and works up more economically as mill stock than as roofing slate, although it is very sonorous and has a fine cleavage. This new company is conducting its operations with more deliberation than is usual in slate quarrying.

A trip was made into Virginia. Certain slate prospects 5 and 6 miles southwest of Warrenton, in Fauquier County, which had been opened long before the civil war were examined and were found to be probably of little more than local value owing to the uncertain thickness of the formation at that point and the abundance of pyrite. The proximity of a sulphur spring also points to a considerable amount of pyrite in the slate.

The Arvonia slate district in Buckingham County, in the same State, was next visited. Arvonia slate has long been known, for it early furnished roofing both for the capitol at Richmond and for the University of Virginia. Although this slate contains a small amount of carbonate it is yet so crystalline as to rank among the better class of slates. In common with the Maine slate it contains considerable biotite. An important result obtained here was the determination of the recurrence of the commercial slate beds of Arvonia on the north side of the James River, 3½ miles north-northeast of Arvonia, in Fluvanna County, possibly owing to a slight deflection of the strike. The slate crops out on the estate of the late Dr. Casey Charles Cocke, 2 miles west-northwest of Bremo Bluff. Surface prospects show a crystalline slate of finer texture and lighter color and less carbonate than that of Arvonia and fully warrant expenditure for core drilling to penetrate the weathered zone and test the fresh slate itself.

Snowden, in the Blue Ridge, in Amherst County, was next visited. Although the deposit is extensive, but one quarry is operated. The attempt to use this slate for mill stock has been abandoned and it is now used exclusively for roofing. It appears to have less carbonate than the Arvonia slate, but to be less crystalline.

The new clay-slate district about Martinsburg, W. Va., which was briefly described in Bulletin 213 (1902), p. 363, was revisited and some new outcrops were located. At the only quarry opened—that of the Shenandoah Slate Company—the manufacture of roofing slate had been wisely given up and machinery was being installed for mill stock, for which the material is better adapted.

Full particulars as to all these slate deposits, as well as to those of Slatington, Pa., Hampton and Granville, N. Y., and Pawlet-Poultney-Fair Haven, Vt., will be found in the forthcoming bulletin on slate. Each slate district will there be treated according to the following method: After a brief geologic account of the deposit the slate will be described physically and microscopically and the results of such chemical analyses and physical tests as are available will be added. These descriptions will thus afford a scientific basis for comparative estimates of the various slates. There will also be chapters on the classification and origin of slate, the present state of science on roofing slates, the structure, geology, chemistry, and economic geology of slate, together with a bibliography. About two-thirds of the writer's paper on the slate belt of eastern New York and western Vermont, published in Part III of the Nineteenth Annual Report (1899), is to be carefully revised and republished in this bulletin, together with the material collected during a study of the Slatington quarries in 1902 and the trips referred to above. As stated, this bulletin will also contain papers by other geologists on the slates of California, Utah, and other States, and will thus serve as a reference work on the subject.

THE GRANITE INDUSTRY OF THE PENOBSCOT BAY QUADRANGLE, MAINE.

By George Otis Smith.

Introduction.—Maine stands first in the list of granite-producing States. By the statistics for 1903, compiled by the division of mineral resources, Massachusetts appears to lead Maine slightly, but the figures for the granite output of Massachusetts include the value of trap rock quarried in large amounts for road metal and railroad ballast, whereas Maine's production is almost wholly true granite. Thus in value of granite production, Maine leads by about $225,000. Of the total output of the State, valued at $2,586,765 in 1903, approximately one-half is the product of the quarries included within the Penobscot Bay quadrangle. This production of nearly $1,250,000 annually makes the granite industry of this area of considerable importance, and the geologic and economic survey of the quadrangle has furnished interesting data upon this subject.

Areal distribution.—The granite is distributed over the larger part of the land area included within the Penobscot Bay quadrangle and occurs in three principal areas aggregating over 100 square miles. One of these extends northward from Bluehill Harbor, another northward from the shore of Eggemoggin Reach through the towns of Sedgwick, Brooksville, and Penobscot, while the third belt extends from the southern part of Brooklin southwesterly across Deer Isle to Vinalhaven. This belt is the most important, including as it does the Stonington, Crotch Island, Vinalhaven, and Hurricane Island quarries. The situation of these quarries and others located on Bluehill Harbor and Eggemoggin Reach constitutes the most important natural advantages of the Penobscot Bay granite district. Deep-water channels suitable for the largest coasting vessels extend to the very edge of the quarries, so that the largest blocks of granite can be loaded directly upon the vessels which are to take them to the large cities of the Atlantic coast. Thus the cost of transportation is reduced to a minimum.

Description of the rock.—The granite of this region varies somewhat both in texture and in color. In general it is of a light-gray color, although locally, as in the northern part of Deer Isle and in the vicinity of Stonington, it has a light-pink tint. The granite contains both hornblende and biotite, but usually the darker minerals are not abundant, although evenly distributed throughout the rock. The grain of the granite ranges from fine to coarse, although most of the rock quarried might be termed medium grained. It is worthy of mention, as showing the uniformity of the granite both in color and in grain, that often work on the same contract is done at quarries several miles apart.

At a few localities dark knots are found in the granite, and in some quarries bands of aplitic material cut the coarser granite. Neither the basic segregations nor aplitic dikes are common enough, however, to materially affect the amount of clear stone available in the quarries. The granite of this area is also remarkably free from mineral constituents of a nature to cause staining of the rock. This is shown in the slight amount of discoloration on the weathered surface of the ledge. In most of the quarries only a few inches of the surface rock is slightly weathered, so that a very small amount of work is necessary to develop a quarry, and, indeed, often even the surface blocks are used.

A most important feature affecting the granite industry is the distribution of joints in the rock mass. The rift, or plane along which the granite splits most readily, varies in direction in the different quarries. In the vicinity of Stonington the rift ranges from north-south to N. 40° W., while the joints in the same localities range from N. 50° W. to N. 85° W. The "bottom," or approximately horizontal, joints, are perhaps the most conspicuous features in the granite, as it is exposed in the quarry face. The presence and spacing of these well-defined planes are often what determine the location of a new quarry. The spacing of these parting planes in the rock determines the kind of work for which each quarry is especially adapted, and while in a few quarries in the Penobscot Bay area the joints are so close together that only material for curbing and paving blocks can be quarried, in many other quarries exceptionally large blocks suitable for monoliths can be easily taken out. Examples of these will be given in a later paragraph.

Equipment of quarries.—The largest of the granite quarries of the Penobscot Bay area are those in the vicinity of Stonington and Vinalhaven, including the Crotch Island and Hurricane Island quarries. Several of these quarries doubtless rank as the largest in the United States, and are well equipped for a large output of both rough blocks and dressed granite. The works of the Bodwell Granite Company at Sand Cove on Vinalhaven has an equipment comprising traveling cranes, lathes, pneumatic hand tools, and plug drills, in addition to the usual number of derricks, hoisting engines, steam drillers, and surfacers necessary for a large quarry. At this company's Palmer quarry, at the mouth of Long Cove on the same island, there is a giant lathe, designed by Cheney & Spiller, of Boston, and built by the Philadelphia Rolling Machine Company, which will turn a monolithic column 70 feet in length and 7 feet in diameter.

On Hurricane Island the Booth Brothers and the Hurricane Island Granite Company are operating two quarry openings. Their equipment, which well illustrates the capacity of these larger quarries, consists of 2 locomotive cranes, 5 derricks with steam hoists, 4 steam drills, 19 pneumatic plug drills, 8 pneumatic dressers, 34 pneumatic hammers, 2 compressors, 1 lathe, which will turn a column 20 feet in length and 3 feet in diameter, 4 polishing lathes, 6 Nelson polishers, 4 pendulum polishers, and one Cavicchi pneumatic polishing machine.

The Rodgers quarry, on the west shore of Webb Cove, in Stonington, is also equipped with both steam and pneumatic drills, and pneumatic surfacers, 9 hoisting engines, 10 derricks, a 10-ton crane, and a railway and locomotive. On Crotch Island the Ryan-Parker Construction Company operates a large quarry with extensive dressing sheds, with full steam and pneumatic equipment, as well as a railway, running to the two docks and the entire length of the quarry. John S. Goss has a well-equipped quarry adjoining the last-mentioned quarry, and also one on Moose Island, on the opposite side of Deer Island Thorofare.

The topographic features of the granite coast of this region are such as to facilitate the quarrying operations. In most cases the quarries are opened on the slopes of hills rising directly from the shore, so that although the older quarries have been operated from twenty-five to fifty years the present conditions favor continued production without increase in expense. The larger part of the equipment of these quarries, therefore, is connected with the finishing of the product rather than with the quarrying of the granite blocks.

Production.—The greater part of the output of the Penobscot Bay quarries in 1903 was in the form of dressed granite for building purposes and paving blocks. The value of granite quarried and dressed within this quadrangle that year was over one-half the output of the State and nearly one-sixth the total production of that class of stone in the United States. The paving-block production is only one-half that of the dressed granite, but amounts to nearly one-fourth the product of the United States and exceeds the output of Massachusetts.

Other stone quarried here is in the form of dimension material, "random," and curbing, and some, notably from the quarry of the S. Clinton Sherwood Company, on Thurlow Knob, is shipped in the rough to be dressed elsewhere in monumental works.

An interesting fact concerning these quarries is their capability to furnish large blocks of stone. Several of the quarries ship blocks weighing from 15 to 30 tons. The Bodwell Granite Company furnished the General Wool monument in Troy, N. Y., which is 60 feet in height and 5½ feet square at the base. The discarded duplicate block remains at the Sands quarry and measures 65 feet in length and 5½ feet square at the base, tapering gradually to about 3½ feet at the top. The columns for the Cathedral of St. John the Divine, in New York City, were quarried at the Palmer quarry of the same company. The rough blocks for these measured 60 feet by 6 by 6, and weighed about 185 tons. One of these huge blocks was successfully turned in the giant lathe, but split after being finished and removed from the lathe. On this account the columns were turned in two sections. In this quarry the spacing of the joints is such that thick blocks are available even at the surface.

The principal markets for the Penobscot Bay granite are Boston, New York, Philadelphia, and Washington. Each of the larger quarries has furnished the dressed granite for many large and well-known buildings in these cities, while a few buildings have been erected of this granite in Chicago, Milwaukee, St. Louis, and other Western cities. Contracts that are being worked on at present include the New York bridges, the custom-house in New York, and the Naval Academy at Annapolis.

In conclusion, attention may be called to another phase of this industry. Its value to the community is not fully expressed by the mere statement of annual production. It is necessary to add that labor receives over 80 per cent of the value of the product of these quarries.

GEOLOGICAL SURVEY PUBLICATIONS ON BUILDING STONE AND ROAD METAL.

ALDEN, W. C. The stone industry in the vicinity of Chicago, Ill. In Bulletin No. 213, pp. 357–360. 1903.

BAIN, H. F. Notes on Iowa building stones. In Sixteenth Ann. Rept., pt. 4, pp. 500–503. 1895.

DALE, T. NELSON. The slate belt of eastern New York and western Vermont. In Nineteenth Ann. Rept., pt. 3, pp. 153–200. 1899.

——— The slate industry at Slatington, Pa., and Martinsburg, W. Va. In Bulletin No. 213, pp. 361–364. 1903.

——— Notes on Arkansas roofing slates. In Bulletin No. 225, pp. 414–416. 1904.

DILLER, J. S. Limestone of the Redding district, California. In Bulletin No. 213, p. 365. 1903.

ECKEL, E. C. Slate deposits of California and Utah. In Bulletin No. 225, pp. 417–422. 1904.

HILLEBRAND, W. F. Chemical notes on the composition of the roofing slates of eastern New York and western Vermont. In Nineteenth Ann. Rept., pt. 3, pp. 301–305. 1899.

HOPKINS, T. C. The sandstones of western Indiana. In Seventeenth Ann. Rept., pt. 3, pp. 780–787. 1896.

——— Brownstones of Pennsylvania. In Eighteenth Ann. Rept., pt. 5, pp. 1025–1043. 1897.

HOPKINS, T. C., and SIEBENTHAL, C. E. The Bedford oolitic limestone of Indiana. In Eighteenth Ann. Rept., pt. 5, pp. 1050–1057. 1897.

KEITH, A. Tennessee marbles. In Bulletin No. 213, pp. 366–370. 1903.

RIES, H. The limestone quarries of eastern New York, western Vermont, Massachusetts, and Connecticut. In Seventeenth Ann. Rept., pt. 3, pp. 795–811. 1896.

SHALER, N. S. Preliminary report on the geology of the common roads of the United States. In Fifteenth Ann. Rept., pp. 259–306. 1895.

——— The geology of the road-building stones of Massachusetts, with some consideration of similar materials from other parts of the United States. In Sixteenth Ann. Rept., pt. 2, pp. 277–341. 1895.

SIEBENTHAL, C. E. The Bedford oolitic limestone [Indiana]. In Nineteenth Ann. Rept., pt. 6, pp. 292–296. 1898.

PORTLAND, NATURAL, AND PUZZOLAN CEMENTS.

As noted below, the production in the United States of these three groups of cements was in 1903 valued at $31,931,341. In 1900 the value amounted to only $13,283,581. In both its total value and its rate of growth, therefore, the cement products of the country form a mineral resource which demands careful attention from this Survey. A brief sketch of the work already accomplished in this line, and of investigations planned for future field seasons, is, therefore, given below.

During 1903 and the early part of 1904 most of the cement-producing districts of the United States were visited, and their raw materials and processes examined. A report on the "Cement resources and cement industry of the United States" is now in press, and will soon be issued as Bulletin No. 243.

The bulletin referred to has been prepared chiefly in order to give information on cement materials, which is desired by two classes of persons. First, owners of lands on which marl, limestone, or clay deposits are found often inquire whether a given material is suitable for Portland-cement manufacture. In response to such questions the author of the report has attempted, in the preliminary chapters, to describe the chemical and physical properties, which a Portland-cement material must have, and also to show that the value of cement material depends almost entirely upon location with respect to fuel supply, transportation routes, and markets. Second, cement manufacturers and those wishing to engage in the cement industry often inquire concerning the localities in some given State or group of States where cement materials will probably be found, and desire information, in advance of actual testing, concerning the physical and chemical character of the materials. The latter portion of the report, dealing with the cement resources of the separate States, is designed to furnish information of this character.

The scope of the report is fairly well defined by the preceding statements. It is intended to be primarily a discussion of cement materials, not a manual of cement manufacture nor a guide to cement testing or utilization. A brief sketch of the processes of Portland cement manufacture is, however, presented, in order to make the subject clear to the great number of people who are interested, in one way or another, in the condition and growth of this important industry. The latter portion of the report contains comparatively brief discussions of the raw materials and the methods of manufacture of two classes of cements allied to Portland cement, i. e., natural cements and puzzolan (slag) cements.

While the report above described will, it is hoped, prove a satisfactory summary of present information regarding the cement resources and cement industry in the United States, its publication will by no means end Survey investigations of those subjects. As fast as possible the principal districts will be examined and mapped in greater detail than has been heretofore possible, and the results will be published in the form of separate papers or bulletins, supplementary to the report above noted. The present bulletin contains several such supplementary reports, dealing, respectively, with the cement resources of western Virginia, of Mississippi, of New York, and of Kansas.

THE AMERICAN CEMENT INDUSTRY.

By Edwin C. Eckel.

In the present paper the figures relative to cement production of the United States published annually by the Survey have been used as a basis for discussion. These figures, when rearranged and properly interpreted, bring out certain facts of interest in regard to the conditions and development of the cement industry.

CLASSIFICATION OF CEMENTS.

Commercial and engineering considerations have led to the separation of the hydraulic cements into three groups, which differ both in their methods of manufacture and in their properties. The facts on which this classification is based may be briefly stated as in the following paragraphs:

Natural cements.—Natural cements are produced by burning a naturally impure limestone, containing from 15 to 40 per cent of silica, alumina, and iron oxide, at a comparatively low temperature, usually about that of ordinary lime burning. The operation can therefore be carried on in a kiln closely resembling an ordinary limekiln. During the burning the carbon dioxide of the limestone is almost entirely driven off, and the lime combines with the silica, alumina, and iron oxide, forming a mass containing silicates, aluminates, and ferrites of lime. If the original limestone contained much magnesium carbonate the burned rock will also contain a corresponding amount of magnesia.

The burned mass will not slack if water be added after burning. It is necessary, therefore, to grind it finely. After grinding, if the resulting powder (natural cement) be mixed with water it will harden rapidly. This hardening, or setting, will also take place under water. Natural cements differ from ordinary limes in two noticeable ways:

(1) The burned mass does not slack on the addition of water.

(2) The powder has hydraulic properties—i. e., if properly prepared, it will set under water.

Natural cements differ from Portland cements in the following important particulars:

(1) Natural cements are not made from carefully prepared and finely ground artificial mixtures, but from a natural rock.

(2) Natural cements are burned at a lower temperature than Portland, the mass in the kiln never being heated high enough to even approach the fusing or clinkering point.

(3) Natural cements, after burning and grinding, are usually yellow to brown in color and light in weight, having a specific gravity of 2.7 to 3.1, while Portland cement is commonly blue to gray in color and heavier, its specific gravity ranging from 3 to 3.2.

(4) Natural cements set more rapidly than Portland cement, but do not attain so high a tensile strength.

(5) Portland cement is a definite product, its percentages of lime, silica, alumina, and iron oxide varying only between narrow limits, while brands of natural cements vary greatly in composition.

Portland cement.—Portland cement is produced by burning a finely ground artificial mixture containing essentially lime, silica, alumina, and iron oxide in certain definite proportions. Usually this combination is made by mixing limestone or marl with clay or shale, in which case the mixture should contain about three parts of lime carbonate to one part of the clayey materials. The burning takes place at a high temperature, approaching 3,000° F., and must therefore be carried on in kilns of special design and lining. During the burning, combination of the lime with silica, alumina, and iron oxide takes place. The product of the burning is a semifused mass called "clinker," which consists of silicates, aluminates, and ferrites of lime in certain fairly definite proportions. This clinker must be finely ground. After such grinding, the powder (Portland cement) will set under water.

Puzzolan cements.—The cementing materials included under this name are made by mixing powdered slaked lime with either a volcanic ash or a blast-furnace slag. The product is, therefore, simply a mechanical mixture of two ingredients, as the mixture is not burned at any stage of the process. The mixture is finely ground after mixing. The resulting powder (Puzzolan cement) will set under water.

Puzzolan cements are usually light bluish, and of lower specific gravity and less tensile strength than Portland cement. They are better adapted to use under water than in air.

Cement production, by classes.—The cement production of the United States for the years 1900–1903, inclusive, is given in the table following, the figures being those in the annual volume on Mineral Resources, published by the United States Geological Survey:

Value of cement production in the United States, 1900–1903.

	1900.	1901.	1902.	1903.
Portland cement	$9,280,525	$12,532,360	$20,864,078	$27,713,319
Natural cement	3,728,848	3,056,278	4,076,630	3,765,520
Puzzolan (slag) cement	274,208	198,151	425,672	542,502
Total	13,283,581	15,786,789	25,366,380	31,931,341

PORTLAND CEMENT.

Total production of Portland cement.—The figures tabulated below, taken from the volume Mineral Resources of the United States, annually issued by the United States Geological Survey, give the production of Portland cement, by States, for the years 1901, 1902, and 1903:

Production of Portland cement in the United States in 1901, 1902, and 1903, by States.

State.	1901.			1902.[a]			1903.[b]		
	Number of works.	Quantity.	Value.	Number of works.	Quantity.	Value.	Number of works.	Quantity.	Value.
		Barrels.			*Barrels.*			*Barrels.*	
Alabama				1			1		
Arkansas	1			1			1		
California	[c] 1	146,848	$513,968	2	294,156	$431,910	3	631,151	$1,019,352
Colorado	[d] 1	585,000	643,500	2	82,044	105,016	1	258,773	436,535
Georgia				1			1		
Illinois	4	528,925	581,818	4	767,781	977,541	4	1,257,500	1,914,500
Indiana	2	218,402	240,242	3	536,706	628,244	3	1,077,137	1,347,797
Kansas	1			1	830,050	1,017,824	1	1,019,682	1,285,310
Michigan	10	1,025,718	1,128,290	10	1,577,006	2,134,396	13	1,955,183	2,674,780
Missouri				1			2	825,257	1,164,834
New Jersey	3	1,612,000	1,450,800	2	2,152,158	2,563,355	3	2,693,381	2,944,604
New York	7	617,228	617,228	10	1,156,807	1,521,553	10	1,602,946	2,031,310
Ohio	[e] 7	689,852	758,837	7	563,113	685,571	8	729,519	998,300
Pennsylvania	13	7,091,500	6,382,350	15	8,770,454	10,130,432	16	9,754,313	11,205,892
South Dakota	1			1			1		
Texas	[f] 2	135,752	215,327	2	165,500	234,950	1		
Utah	1			1			1		
Virginia	1			1	334,869	433,286	1	538,131	690,105
West Virginia							1		
Total	56	12,711.225	12,532,360	65	17,230,644	20,864,078	71	22,342,973	27,713,319

[a] The States combined for 1902 are mentioned in the text of the report for 1902.
[b] The States combined for 1903 are given in the text below.
[c] Includes product of the single plant in Utah.
[d] Includes product of the only Portland-cement plant in Kansas.
[e] Includes product of the only Portland-cement plant in Virginia.
[f] Includes product of the single plant in South Dakota.

In such States as have but a single plant their production is combined with that of another State, in order that the separate figures of any plant shall not be revealed. In the table above the Portland-cement product of the only plant in Alabama which produces that variety of cement is combined with the product of the plants in Georgia, Virginia, and West Virginia. The plants in Missouri and Arkansas have their products combined; those in Kansas and Texas, and those in Utah, South Dakota, and Colorado also show combined products, and in each case the result is given in connection with the State which was the largest contributor to the total product.

Production of the Lehigh district.—The Portland-cement production of the important Lehigh district of Pennsylvania–New Jersey is given in the table below:

Portland-cement production of the Lehigh district, 1890–1903.

Year.	Lehigh district.		Entire United States.			Percentage of total product manufactured in Lehigh district.
	Number of plants.	Number of barrels.	Number of plants.	Number of barrels.	Value.	
1890	5	201,000	16	335,500	$439,050	60.0
1891	5	248,500	17	454,813	1,067,429	54.7
1892	5	280,840	16	547,440	1,152,600	51.3
1893	5	265,317	19	590,652	1,158,138	44.9
1894	7	485,329	24	798,757	1,383,473	60.8
1895	8	634,276	22	990,324	1,586,830	64.0
1896	8	1,048,154	26	1,543,023	2,424,011	68.1
1897	8	2,002,059	29	2,677,775	4,315,891	74.8
1898	9	2,674,304	31	3,692,284	5,970,773	72.4
1899	11	4,110,132	36	5,652,266	8,074,371	72.7
1900	15	6,153,629	50	8,482,020	9,280,525	72.6
1901	16	8,595,340	56	12,711,225	12,532,360	67.7
1902	17	10,829,922	65	17,230,644	20,864,078	62.8
1903	17	12,324,922	71	22,342,973	27,713,319	55.1

Production from various raw materials.—For the purposes of the present section it will be sufficiently accurate to consider that a Portland-cement mixture, when ready for burning, will consist of about 75 per cent of lime carbonate ($CaCO_3$) and 20 per cent of silica (SiO_2), alumina (Al_2O_3), and iron oxide (Fe_2O_3) together, the remaining 5 per cent including any magnesium carbonate, sulphur, and alkalis that may be present.

The essential elements which enter into this mixture—lime, silica, alumina, and iron—are all abundantly and widely distributed in nature, occurring in different forms in many kinds of work. It can therefore readily be seen that, theoretically, a satisfactory Portland-cement mixture could be prepared by combining, in an almost infinite number of ways and proportions, many possible raw materials. Obviously, too, we might expect to find gradations in the artificialness of the mixture, varying from the one extreme where a natural rock of absolutely correct composition was used, to the other extreme where two or more materials, in nearly equal amounts, are required.

The almost infinite number of raw materials which are theoretically available are, however, reduced to a very few under existing commercial conditions. The necessity for making the mixture as cheaply as possible rules out of consideration a large number of materials which would be considered available if chemical composition was the only thing to be taken into account. Some materials, otherwise suitable, are too scarce and some are too difficult to pulverize. In consequence, a comparatively few combinations of raw materials are actually used in practice.

The various combinations of raw materials which are at present used in the United States in the manufacture of Portland cement may be grouped under six heads: (1) Argillaceous limestone (cement rock) and pure limestone; (2) pure hard limestone and clay or shale; (3) soft chalky limestone and clay; (4) marl and clay; (5) alkali waste and clay; (6) slag and limestone.

Production of Portland cement from various materials.

Year.	"Cement rock" and pure limestone.		Hard limestone and clay.[a]		Marl and clay.[b]		Chalk and clay.	
	Barrels.	Per cent.	Barrels.	Per cent.	Barrels.	Per cent.	Barrels.	Per cent.
1898	2,682,304	74.9	315,608	8.8	545,372	15.2	39,000	1.1
1899	4,010,132	70.9	458,000	8.1	1,095,934	19.4	88,200	1.6
1900	5,919,629	70.3	874,715	10.4	1,444,797	17.1	184,400	2.2
1901	8,503,500	66.8	1,710,773	13.5	2,001,200	15.8	495,752	3.9
1902	10,923,922	63.6	3,673,790	21.3	2,214,519	12.9	372,412	2.2
1903	12,483,694	55.7	6,338,520	28.3	3,052,946	13.6	457,813	2.4

[a] Including also the product from two plants using slag and limestone.
[b] Including also the product from one plant using alkali waste and clay.

Geologic age of cement materials.—Though Portland-cement materials vary greatly in geologic age, the rocks of certain periods seem to have contained an especially large amount of limestone low in magnesia, while in those of other periods limestones are either very scarce or are commonly high in magnesia.

Geologic grouping of Portland-cement materials.

System.	States and number of plants using.	Total plants using.
Pre-Cambrian	None	0
Cambrian	None	0
Ordovician	New York (1), New Jersey (3), Pennsylvania (14), Georgia (1).	19
Silurian	New York (4), Virginia (1)	5
Devonian	New York (1), Michigan (2)	3
Carboniferous:		
Mississippian	West Virginia (1), Indiana (1), Missouri (3)	5
Pennsylvanian	Pennsylvania (1), Ohio (4), Illinois (3), Kansas (2).	10
Triassic	None	0
Cretaceous	Alabama (1), Arkansas (1), Texas (1), South Dakota (1), Colorado (1).	5
Tertiary	None	0
Quaternary	New York (4), Ohio (4), Indiana (2), Michigan (10).	20
Horizon doubtful	California (3)	3
Slag, alkali-waste	Pennsylvania (1), Michigan (1), Illinois (1)	3
Total		73

NATURAL CEMENTS.

The material used in the manufacture of natural cement is invariably a clayey limestone, carrying from 13 to 40 per cent of clayey material, of which 10 to 22 per cent or so is silica, while alumina and iron oxide together may vary from 4 to 16 per cent. These clayey materials give the resulting cement its hydraulic properties. Stress is often carelessly or ignorantly laid on the fact that many of the best-known natural cements carry large percentages of magnesia, but magnesia (in natural cements at least) may be regarded as being almost exactly interchangeable with lime, so far as the hydraulic properties of the product are concerned. The presence of magnesium carbonate in a natural-cement rock is, then, merely incidental, while that of silica, alumina, and iron oxide is essential. The 30 per cent or so of magnesium carbonate which occurs in the cement rock of the Rosendale district, New York, could be replaced by an equal amount of lime carbonate and the burnt stone would still give a hydraulic product. If, however, the clayey portion (silica, alumnia, and iron oxide) of the Rosendale rock could be removed, leaving only the magnesium and lime carbonates, the burnt rock would lose all of its hydraulic properties and would yield simply a magnesian lime.

This point has been emphasized because many writers on the subject have either explicitly stated or implied that it is the magnesian carbonate of the Rosendale, Akron, Louisville, Utica, and Milwaukee rocks that causes them to yield a natural cement on burning.

The manufacturing methods at a natural-cement plant are of the simplest kind, including merely the burning of the cement rock and the pulverizing of the product.

The burning is carried on in vertical kilns, closely resembling lime kilns in shape, size, etc. The limestone and fuel are usually fed into the kiln in alternate layers, though at a few plants more advanced types of kilns are in use. The burned product is crushed and then reduced to powder, commonly in buhrstone mills. Recently advances have been made in crushing practice, and several plants now reduce their product in tube mills.

Since, within very wide limits of composition, any clayey limestone will give a natural cement on burning, it can readily be seen that satisfactory natural-cement materials must be widely distributed and of common occurrence. Hardly a State is entirely without limestones sufficiently clayey to be available for natural-cement manufacture. The sudden rise of the American Portland cement industry, however, has acted to prevent any great expansion of the natural-cement industry. It would be difficult to place a new natural cement on the market in the face of competition from both Portland cement and from the older and well-established brands of natural cement. Such new natural-cement plants as have been started within recent years have mostly been located in old natural-cement districts, where the accumulated reputation of the district would help to introduce the new brand. The only exceptions to this rule, indeed, were the Pembina plant in North Dakota, the Rossville plant in Georgia, and a plant in the State of Washington. Of these the Pembina plant was established with the intention of making Portland cement, but the raw materials soon proved to be unsuitable, and the plant was converted. The plant in Washington is located in an area where any kind of cement is readily salable. The Rossville plant was built by an Akron, N. Y., cement manufacturer to utilize a peculiarly satisfactory natural-cement rock.

Production of natural-rock cement in 1901, 1902, and 1903, by States.

State.	1901.			1902.			1903.		
	Number of works.	Quantity.	Value.	Number of works.	Quantity.	Value.	Number of works.	Quantity.	Value.
		Barrels.			*Barrels.*			*Barrels.*	
Georgia	2	50,577	$40,967	2	55,535	$31,444	2	80,620	$44,402
Illinois	2	469,842	187,936	3	607,820	156,855	3	543,132	178,900
Indiana and Kentucky	15	2,150,000	752,500	15	1,727,146	869,163	15	1,533,573	766,786
Kansas	[a] 2	175,560	97,002	2	160,000	80,000	2	226,293	169,155
Maryland	4	351,329	175,665	4	409,200	150,680	4	269,957	138,619
Minnesota	[b] 2	126,000	63,000	2	150,000	67,500	2	175,000	78,750
Nebraska	1	....	....	....	....	....	....	....	....
New York	[c] 18	2,234,131	1,117,066	19	3,577,340	2,135,036	20	2,417,137	1,510,529
North Dakota	1	....	....	1	....	....	1	....	....
Ohio	[d] 1	104,000	62,400	2	....	....	2	67,025	46,776
Pennsylvania	7	942,364	376,954	6	796,876	340,669	7	1,339,090	576,269
Texas	1	....	....	1	....	....	2	....	....
Virginia	1	....	....	2	34,000	20,000	2	47,922	25,961
West Virginia	1	....	....	1	88,475	62,655	1	....	....
Wisconsin	2	481,020	182,788	2	437,913	162,628	2	390,522	139,373
Total	[e] 60	7,084,823	3,056,278	[f] 62	8,044,305	4,076,630	[g] 65	7,030,271	3,675,520

[a] Includes product of Nebraska and Texas.
[b] Includes product of North Dakota.
[c] The number of companies producing natural cement only is given, and the number given for 1899 and 1900 has been changed accordingly, as in those years the *total* number of companies in the State was given.
[d] Includes product of Virginia and West Virginia.
[e] This total includes one plant in North Dakota, which for this year is reported as having a natural-cement product.
[f] The States combined for 1902 are noted in the text of the report for 1902.
[g] The States wherein the product of cement was combined with that of some other State for 1903 are given in the text below.

The single cement plant in North Dakota has a production which for 1903 has been combined with that of the only plants producing natural-rock cement in Kansas and Texas. The other States stand in the table exactly as the reported productions are given.

PUZZOLAN CEMENTS.

The term "puzzolan cements" is applied to finely ground mixtures of slaked lime with certain argillo-calcareous materials. These added materials may be either natural volcanic products, like the pozzuolana, trass, and santorin of the European cement trade, or basic slags from the blast furnace. In America natural puzzolanic materials have never been used, though they are known to exist at various points in the West. Slag, however, has been extensively used in the manufacture of slag cement.

Slag cement, properly so called, is the product obtained by pulverizing, without calcination, a mixture of granulated blast-furnace slag and slaked lime. This product, though in reality a member of the class of puzzolan cements, is often marketed as Portland cement, in spite of the fact that it differs from Portland cements in method of manufacture, ultimate and rational composition, and properties. Seven plants are at present engaged in the manufacture of slag cement in the United States, the total product for some years past being given in the table on page 498.

The writer has discussed the manufacture of slag cement in detail in a recent publication.[a] A brief résumé of the technology of the material in question is here given.

As to composition, the material used in the manufacture of slag cement must be basic blast-furnace slag. Tetmajer stated that the ratio $\frac{CaO}{SiO_2}$ should never be less than unity, and that the best results were obtained when the ratio $\frac{Al_2O_3}{SiO_2}$ gave a value of 0.45 to 0.50. Prost and Mahon later obtained good results from slags in which the alumina was much higher than indicated by Tetmajer's ratio, and analyses of slags used in practice are shown in the following table, with the ratios $\frac{CaO}{SiO_2}$ and $\frac{Al_2O_3}{SiO_2}$ calculated for each slag:

Analyses of slags in actual use.

Constituent.	Middlesboro, England.	Bilboa, Spain.	Choindez, Switzerland.	Saulnes, France.	Chicago, Ill.
SiO_2	31.50	32.90	26.24	31.50	32.20
Al_2O_3	18.56	13.25	24.74	16.62	15.50
FeO	----------	.46	.49	.62	----------
CaO	42.22	47.30	46.83	46.10	48.14
MgO	3.18	1.37	.88	----------	2.27
CaS	----------	3.42	.59	----------	----------
$CaSO_4$	----------	----------	.32	----------	----------
S	2.21	----------	----------	----------	----------
SO_3	.45	----------	----------	----------	----------
$\frac{CaO}{SiO_2}$	1.34	1.44	1.78	1.46	1.49
$\frac{Al_2O_3}{SiO_2}$	.59	.41	.93	.52	.48

Slags allowed to cool slowly are only feebly hydraulic, even if of proper chemical composition. When used in the manufacture of slag cement, therefore, the slag must be cooled as suddenly as possible. This is effected by bringing the slag, as it issues from the furnace, in contact with a jet or stream of cold water. This sudden cooling "granulates" the slag, i. e., breaks it up into porous par-

[a] Mineral Industry, Vol. X. See also Mineral Resources U. S. 1900, p. 747, where a description of two Alabama slag-cement plants is given.

ticles, and has also two important chemical effects. One is that the slag, if of suitable chemical composition, is rendered strongly hydraulic; the other, that most of the sulphur is removed in the form of hydrogen disulphide. After granulation the slag is dried, usually in rotary driers, the Ruggles-Coles being a favorite American type.

The lime used for mixture with the slag should be low in magnesia, well burned, and carefully slaked. After slaking and drying, the lime is ready for mixture with the granulated and dried slag, which usually has received a preliminary reduction in a crusher, ball mill, Kent mill, or other comparatively coarse reducer. The proportions used will vary from 20 to 40 parts of lime for 100 parts of slag. The mixture and final reduction is usually accomplished in the American plants in tube mills. The composition of a number of American and European slag cements is shown in the following table of analyses collected from various sources:

Analyses showing composition of slag cements.

Constituent.	Choindez, Switzerland.	Donjeux, France.	Saulnes, France.	Chicago, Ill.	Ensley, Ala.
SiO_2	19.5	24.85	22.45	28.95	27.78
Al_2O_3	17.5	12.10	13.95	11.40	11.70 (with FeO)
FeO	----------	3.85	3.30	.54	
CaO	54.0	49.20	51.10	50.29	51.71
MgO	----------	1.75	1.35	2.96	1.39
S	----------	1.30	----------	1.37	1.31
SO_3	----------	1.35	.35	----------	----------
Loss on ignition	----------	5.65	7.50	3.39	----------

The composition of good slag cements may vary within the following limits: Silica, 22 to 30 per cent; alumina and iron, 11 to 16 per cent; lime, 49 to 52 per cent; magnesia, less than 4 per cent; sulphur, less than 1½ per cent. It will be noted that the lime content is lower and the alumina-iron content higher than in a cement of the Portland type. Slag cements also differ from Portland cement in being lower in specific gravity and lighter in color. Normally they set slower than Portland cement, though this defect can be overcome by treatment during manufacture. They are deficient in resistance to mechanical wear and do not set satisfactorily in dry situations. For use under water or in permanently damp ground, however, they would seem to be of service.

PORTLAND-CEMENT RESOURCES OF THE INDEPENDENCE QUADRANGLE, KANSAS.

By Erasmus Haworth and F. C. Schrader.

Sketch of the region.—The Independence quadrangle lies in the southeastern part of Kansas, adjacent to Indian Territory and within the Kansas oil and gas fields. It embraces all of Montgomery and portions of adjoining counties.

Geology.—The rocks of the district are of Coal Measures age and consist of limestones, alternating with heavier shales and sandstones. These dip gently northwestward about 15 feet per mile and are grouped in 7 formations, aggregating about 1,000 feet in thickness. A fuller statement of the geology occurs on pages 446–449 of this volume.

Cement resources.—The area of the quadrangle bids fair to become in the near future the home of important Portland-cement industries. Already two large plants are in process of construction, one at Independence, by the Western States Portland Cement Company, and one at Neodesha, by the American Portland Cement Company. The large amount of natural gas within the area available for fuel and the quantities of first-class limestone and shale, together with the regularity in composition of the limestones, render the field a very attractive one to cement manufacturers.

The Kansas State Geological Survey has made investigations in this area, and has published a brief report[a] on the same.

The materials suitable for making Portland cement in the area are practically identical with those existing so abundantly within the area of the Iola quadrangle, described in a former bulletin of the United States Geological Survey.[b]

The plant at Independence is located 1½ miles southeast of town, near the mouth of Rock Creek and the Verdigris River. It has been built on the Drum limestone, which here attains a thickness of nearly 100 feet. This limestone, which is to be used as one of the raw

[a] Univ. Geol. Survey Kansas, Annual Bulletin on Mineral Resources, 1902, pp. 44–56.
[b] Bull. U. S. Geol. Survey No. 238, pp. 63–69.

materials, here outcrops over an area of several square miles. It is semicrystalline, medium-grained, and highly fossiliferous. It has been tested by the company and found to be entirely satisfactory, the analysis showing it to be a very pure lime carbonate. Shale of good quality is also at hand in the formation that overlies the limestone, while fuel can be obtained from the great gas wells near by, and water from the Verdigris River.

The plant is connected with the Missouri Pacific Railway by three miles of branch line, built during the summer of 1904. During the same period a corps of more than a hundred men was steadily employed in erecting the plant, and by October some of the more important buildings were nearing completion and ground was being broken for others.

At Neodesha the limestone to be used caps the hill known as Little Bear Mound, about a mile northwest of town, where it has been found by the company's drill tests to have a thickness of 55 feet, and is known as the Iola-Allen. Here suitable shale is also present, underneath the limestone, and an abundance of oil and gas for fuel purposes is at hand. The company holds a contract with the city of Neodesha to supply natural gas from the city mains at 3 cents per 1,000 cubic feet. Here, too, the limestone has been tested by the company and found to be satisfactory. Lathbury & Spackman, of Philadelphia, were employed by the Kansas State Geological Survey to make a chemical examination and also an actual burning test of the limestone and shale from the site of the factory. They pronounced the limestone well adapted to the manufacture of Portland cement and the shale well proportioned and suitable for use with the limestone. After experimenting a product was made whose analysis proved to be well proportioned, as is shown by the following report:

TESTS OF PORTLAND CEMENT MADE FROM MATERIALS OCCURRING AT NEODESHA, KANS.

Fineness: Passing No. 100 sieve, 97.50 per cent; passing No. 200 sieve, 76.35 per cent.

Constancy of volume test: Normal pat, test Am. Soc. Civ. Engineers. Cold-water pat, good; air pat, good.

Setting time: Initial set, 20 minutes; final set, 55 minutes; water, 24 per cent; temperature of air, 78° F.; temperature of water, 74° F.

Accelerated test: Warm-water test, good; boiling-water test, good.

Tensile strength of standard briquettes (1 sq. in. section).

No. of briquette.	Composition.	Time. Water.	Time. In water.	Time. In air.	Time. Total.	Date made.	Date tested.	Strength. Briquettes.	Strength. Average.
		Per ct.	*Hrs.*	*Days.*	*Days.*				
20,580 1 2	Neat	24	24	.....	[a]24	May 26	May 27	225 250 240	238
20,590 1 2	Neat	24	24	6	7	May 26	July 2	485 495 500	490
20,595 6	1 cement, 3 sand.	12	24	6	7	May 26	July 2	340 320	330
20,590*a* 1*a* 2*a* 3*a* 4*a*	Neat	24	24	27	28	May 26	June 23	635 647 621 652 638	638
20,595*a* 6*a* 7*a* 8*a* 9*a*	1 cement, 3 sand.	12	24	27	28	May 26	June 23	425 432 430 435 427	430

[a] Hours.

As is usually the case, the shales to be used at Independence and Neodesha are more variable in nature than the limestones. In places they change rapidly in character, principally by a variation in the amount of sand present. The amount of calcium carbonate also is exceedingly variable, ranging from almost 20 per cent down to a very small amount; but with these variations the proportions of magnesia and of the alkalies remain fairly constant, and in no case has an excessive amount of magnesium carbonate been found. The following is an analysis[a] of the shale underlying the limestone at Neodesha:

[a] Univ. Geol. Survey Kansas, Annual Bull. on Mineral Resources, 1902, p. 50.

Analysis of shale at Neodesha, Kans.

Silica (SiO_2)	61.80
Alumina and iron oxide ($Al_2O_3+Fe_2O_3$)	22.7
Lime (CaO)	8.20
Magnesia (MgO)	.216
Alkalies (Na_2O+K_2O)	Trace.
Water (H_2O)	7.50
Total	100.416

The erection of a third cement plant at the west base of Table Mound, on the bank of Elk River, is reported to be in contemplation. Here the same limestone as at Neodesha is present, while the supplies of shale, water, and gas are also plentiful. The rocks exposed here consist of 45 feet of pure crystalline Piqua limestone overlying an 80-foot bed of shale, which in turn rests upon a 5-foot bed of the Iola-Allen limestone, underlain by 40 or more feet of shale. Both the Piqua and the Iola-Allen limestones are remarkably persistent over wide areas in the State, and wherever they may be found they are likely to be suitable for making Portland cement, as chemical examination is almost certain to show. Specimens of Piqua limestone taken at a number of places lying northwest of the quadrangle have been analyzed, with the following results:

Analyses of Piqua limestone from places in Kansas.

Towns.	Silica.	Oxide of iron and alumina.	Calcium carbonate.	Magnesium carbonate.	Sulphates.	Moisture.	Total.
Vilas	2.02	2.65	96.07	0.10			100.84
Ottawa	8.00	1.35	90.00	.12	0.02		99.49
Greeley	1.18	3.09	92.71	2.64			99.62
Lane	1.18	2.38	94.77	1.07			99.40
Do	3.82	[a].77	94.21	1.30			100.10
Do	3.94	1.20	93.61	1.20			99.95
Do	4.79	1.18	93.30	1.26			100.53
Garnett	4.30	.81	92.76	.95	.23	0.43	99.48
Do	.61	[a].51	97.32	.32	.43		99.19

[a] Alumina.

Conclusion.—A considerable extension of the Portland-cement industry may therefore be expected in eastern Kansas, though, of course, each new plant decreases the profits of manufacturing this product in this area. The limestone and shale used at these plants are satisfactory enough, but the real basis of the Kansas cement industry is the supply of cheap natural gas.

CEMENT RESOURCES OF NORTHEAST MISSISSIPPI.

By A. F. Crider.

The Selma formation of the Cretaceous is a thick series of chalks, chalky limestones, and more or less limy clays, which are well exposed in northern and eastern Mississippi. Much of this chalk is admirably adapted for use as a raw material in Portland-cement manufacture, and in Alabama a cement plant has been in operation for some years, using chalk from the Selma formation and an overlying residual clay.

The Selma chalk occupies much of the counties of Noxubee, Lowndes, Oktibbeha, Clay, Monroe, Chickasaw, Lee, Prentiss, and Alcorn, and smaller portions of adjoining counties.

Thickness.—The Selma chalk attains its maximum thickness in central Alabama, reaching a total of about 1,200 feet. Westward it decreases slightly in thickness, the well at Livingston, Sumter County, Ala., giving a total of 930 feet, while the well at Starkville, Oktibbeha County, Miss., taken in connection with surrounding outcrops, indicates a thickness of at least 700 feet. As the belt turns northward toward Tennessee, the Selma formation decreases rapidly in thickness, while at the same time the limestone beds contained in the formation become fewer and thinner, until in Tennessee the Selma is a thin series of somewhat calcareous clays, with only occasional beds of chalk.

Stratigraphy.—Owing to the rapidity with which it disintegrates when exposed to atmospheric action, surface outcrops give comparatively little information in regard to the stratigraphy of the Selma formation.

Fortunately a very precise section of the Selma chalk, taken at a point where it is almost of maximum thickness, is in existence. This is embodied in the record of a well drilled at Livingston, Sumter County, Ala., and is quoted by Dr. E. A. Smith in his Report on the Geology of the Coastal Plain of Alabama, pages 277–278. The well was located just south of the boundary between the Selma and Ripley formations, and reached a depth of 1,062 feet, so that it passed through the entire thickness of the Selma chalk and into the underlying Eutaw formation.

The section of this well is given below. The upper 20 feet are, according to Smith, probably in part Lafayette and in part Ripley. From a depth of 20 to 950 feet the well was in the Selma formation, while from 950 to 1,062 feet it was in the Eutaw.

Section of well at Livingston, Sumter County, Ala.

	Thickness.	Depth.
Lafayette and Ripley:	*Feet.*	*Feet.*
Sandy loam	1	
Coarse, dry sand	12	1 - 13
White quicksand	7	13 - 20
Selma chalk:		
Soft, blue limestone, many shells, and pyrite nodules	180	20 - 200
White limestone, harder, few shells or pyrite nodules	50	200 - 250
Hard, blue limestone, no shells or nodules	7	250 - 257
Bluish-white limestone, less hard, no shells or nodules	68	257 - 325
White limestone, very hard	55	325 - 380
Light-blue limestone, softer	47	380 - 427
Bluish-brown rock, small shells, some sand	58	427 - 485
Hard, white limestone	105	485 - 590
Soft, reddish-brown rock	2	590 - 592
Soft, deep-blue rock	20	592 - 612
Brownish-blue rock, moderately soft	78	612 - 690
Hard, gritty, blue rock	½	690 - 690½
Dark bluish rock, soft	9½	690½- 700
Soft, whitish limestone	250	700 - 950
Eutaw sands:		
Hard sandstone	6	950 - 956
Sand	10	956 - 966
Sand rock	1	966 - 967
Coarse greensand	38	967 -1,005
Sandstone	2	1,005 -1,007
Greensand	25	1,007 -1,032
Sandstone	2	1,032 -1,034
Coarse greensand	18	1,034 -1,052
Flint rock	1	1,052 -1,053
Very fine greensand	9	1,053 -1,062

Descriptions of localities.—During 1904 the Selma chalk was carefully mapped throughout the Tombigbee River basin in Mississippi, particular attention being paid to the district between the Alabama line and Columbus, because the transportation facilities in this area are more favorable to the erection of a cement plant than farther north in the State.

In the following pages descriptions will be given of the various localities visited during this work. Samples were taken from all of these localities, and many of these samples have been analyzed, the results being given below. The descriptions are given in order, going up the Tombigbee River from the Alabama-Mississippi line.

At the big elbow bend in Oaknoxubee River, one-fourth mile below the wagon bridge at Macon, the river has formed a bluff 75 feet high on the south side of the stream. The entire cliff is formed of the Selma chalk. It is a solid mass of white chalk, nonfossiliferous and apparently without bedding planes, but if the bluff is viewed at a distance the stratification of the material is shown by the unequal hardness of the strata, causing some to weather more rapidly than others. There is a marked dip to the south. All the smaller streams flowing into the Oaknoxubee have channeled their beds into the pure white limestone. A sample was collected from the bluff on the Oaknoxubee.

The following analysis of this sample was made by H. C. McNeil in the laboratory of the United States Geological Survey:

Analysis of Selma limestone, near Macon, Miss.

Silica (SiO_2)	9.09
Alumina (Al_2O_3) Iron oxide (Fe_2O_3)	7.47
Lime carbonate ($CaCO_3$)	80.99
Magnesium carbonate ($MgCO_3$)	0.00
Water	1.08

About 1½ miles northeast of the town of Dekalb, near the east edge of the area of the Lagrange formation on Sucarnooche Creek, is a bed of lignite 3 feet thick, which outcrops a few feet above the bed of the creek. This bed has been opened up with a view of developing the vein. A level was run into the hill 20 feet and considerable lignite taken out. It was found to be of excellent quality, and was burned in the office of the chancery clerk, Mr. Samuel O. Bell, at Dekalb. The following analyses were made, No. 1 by J. C. Long and No. 2 by R. T. Pittman:

Analyses of lignite, Dekalb, Miss.

	1.	2.
Fixed carbon	41.83	40.80
Volatile matter	46.82	41.48
Ash	7.94	17.64
Moisture	2.13	n.d.
Sulphur	1.28	1.57
Specific gravity	n.d.	1.33

The lignite is overlain by a bed of gray clay, and this by stratified red, yellow, and white sands, containing occasional bands of ferruginous sandstone. The Lafayette formation lies on these hills, reaching in places a thickness of 20 feet, and in this there is considerable sandstone.

Two and one-half miles east of Scooba, on the west bank of the creek, is the first outcrop of Selma chalk on the Scooba and Gainesville road. A sample of limestone taken from this outcrop was analyzed by W. S. McNeil, in the laboratory of the United States Geological Survey, with the following result:

Analysis of Selma limestone near Scooba, Miss.

Silica (SiO_2)	16.48
Alumina (Al_2O_3) / Iron oxide (Fe_2O_3)	6.97
Lime carbonate ($CaCO_3$)	74.34
Magnesium carbonate ($MgCO_3$)	.67
Water	.67

Two miles east of Scooba and one-half mile south is another outcrop of limestone more sandy than that 2½ miles east of Scooba. This is perhaps of Ripley age.

Between Portersville and Oak Grove, in southern Kemper County, on the west side of Pitticfaw Creek, the Lagrange Hills begin and extend westward. On the land belonging to Mr. M. L. Nailer a bed of lignite has been opened up and is reported to be 4 feet thick.

Sucarnooche Creek marks the west edge of the Midway group, from 2½ miles due east of Dekalb to about 3 miles north of Oak Grove. Here the Porters Creek area widens and its west edge swings in to within 2½ or 3 miles east of Oak Grove, then follows a southeasterly direction and crosses the Kemper and Lauderdale county line about 3½ miles west of the State line.

On the west side of Quilby Creek, where it runs southward along the State line, 7 miles east of Sucarnooche, the Selma chalk forms a small bluff. The prairie soil extends back for 2 miles farther west.

On the east side of the creek, about 100 yards in Alabama, the Selma chalk forms a bluff a little higher than on the opposite bank in Mississippi. Here what is taken to be the top of the Selma chalk is found. The top of the bluff is capped by a coarse-grained sandstone, cemented by lime carbonate. In it are lime concretions the size of a closed hand.

The upper beds of the Selma chalk also appear in the bluff on the east side of Quilby Creek, 7 miles east of Sucarnooche.

An outcrop of Selma chalk shows on Scooba and Fox Prairie road where it crosses the Bodea Creek, about 2 miles west of the State line.

A sample collected from this outcrop was analyzed in the laboratory of the United States Geological Survey by W. S. McNeil.

Analyses of Selma limestone, Bodea Creek, Mississippi.

Silica (SiO_2)	10.60
Alumina (Al_2O_3) Iron oxide (Fe_2O_3)	5.90
Lime carbonate ($CaCO_3$)	82.47
Magnesium carbonate ($MgCO_3$)	Trace.
Water	.82

Three miles north of Scooba the west border of the Selma chalk outcrops in a series of hills forming the south bank of Wahalak Creek. The bottom of the Wahalak here is about 1½ miles wide, the south bank retreating more rapidly than the north side. The creek has cut its channel into the Selma chalk, which outcrops almost continuously throughout its course. The limestone occurs up the creek about 6½ to 7 miles northwest of the town of Wahalak, but the clay belonging to the Porters Creek formation occupies the country on either side of the creek. The hill just east of Wahalak is of Porters Creek clay, which is not over 15 feet thick.

A sample of limestone was collected from the bed of Wahalak Creek about 1½ miles south of Wahalak. This sample was analyzed by W. S. McNeil in the laboratory of the United States Geological Survey, with the following results:

Analysis of Selma limestone near Wahalak, Miss.

Silica (SiO_2)	20.00
Alumina (Al_2O_3) Iron oxide (Fe_2O_3)	8.92
Lime carbonate ($CaCO_3$)	68.91
Magnesium carbonate ($MgCO_3$)	Trace.
Water	1.03

A sample of the Selma limestone was taken from the bed of Wahalak Creek 1½ miles south of the town, and another sample was taken on the range of low hills on the south side of Wahalak Creek, 1½ miles southeast of where the Mobile and Ohio Railroad crosses the creek.

At the top of the Selma chalk there is about 10 feet of a sand rock cemented with lime carbonate which contains numerous little bivalve shells. This is the same kind of stone as that found 7 miles east of Sucarnoochee. There is no evidence of any Midway limestone anywhere from Wahalak to the Alabama line, and this is the only place where the sandstone was seen in Mississippi.

The Midway or Flatwoods clay is well shown near Scooba, Miss. A sample collected there was analyzed by W. S. McNeil in the laboratory of the United States Geological Survey. The result is of interest because clays of this type occur everywhere near the western edge of the Selma limestone area, and such clays will be needed to reduce the percentage of lime carbonate found in some of the purer samples of Selma chalk.

Analysis of Midway clay, Scooba, Miss.

Silica (SiO_2)	61.92
Alumina (Al_2O_3)	19.47
Iron oxide (Fe_2O_3)	2.81
Lime (CaO)	.00
Magnesia (MgO)	1.98
Soda (Na_2O)	.50
Potash (H_2O)	.00
Loss on ignition	12.29

Samples of Selma chalk were taken from an old rock quarry on the southwest side of Bogue Chitto Creek, one-half mile east of Prairie Rock. This limestone differs from that along Oaknoxubee River, in vicinity of Macon, in that it is much harder. In the unweathered state of the Macon rock it is very soft and noncrystalline. One can easily stick a pick into it. But this limestone at Prairie Rock is a hard so-called "flint rock," crystalline in character, and is used for building purposes. The rock at Macon when exposed to the weather becomes as white as chalk; that at Prairie Rock weathers to a dirty gray and shows iron stains on the weathered surfaces. This is due to the oxidation of the iron sulphide (pyrites) which is found in small concretions in the fresh rock.

An analysis of the Prairie Rock limestone, made by W. S. McNeil in the laboratory of the United States Geological Survey, follows. It will be seen that the stone is a very pure limestone in spite of the manner in which it discolors on weathering:

Analysis of Selma limestone, Prairie Rock, Miss.

Silica (SiO_2)	1.13
Alumina (Al_2O_3) / Iron oxide (Fe_2O_3)	.68
Lime carbonate ($CaCO_3$)	98.36
Magnesium carbonate ($MgCO_3$)	Trace.
Water	.40

The rock breaks down easily when exposed to the weather and hence is not now used for extensive building purposes. It is, however, the only road material found in this section of the country. It has been used on the road across Bogue Chitto Swamp, but is unsatisfactory.

Men familiar with the country say that this hard limestone is only about 4 feet thick and occurs near the surface. Below this hard stratum comes the soft, whiter, "rotten limestone," which is, on an average, 20 feet thick. Below this comes the "blue rock," which holds water. In digging cisterns the farmers always dig down to the "blue rock," which requires no curbing.

There are two kinds of soils in the prairie section—the "post-oak" land and the prairie proper. The former is the highest land between the stream divides, which has suffered but little erosion. It is very level, sloping gently to the streams. This post-oak land is covered with a thin coating of Lafayette clayey sand, never over 10 feet thick, which has never been all carried away by erosion. The uncleared land produces post-oak and some black-oak timber. The soil is not so rich as the prairie soils and has been largely abandoned for cultivation.

The prairie land is that from which the Lafayette has been removed, and the black, rich loam, formed from the decomposition of the Selma chalk, comes to the surface. The limestone rarely outcrops except along the streams. This black prairie soil, when the country was first settled, was too strong for cotton. It produced a large stalk, but very little cotton. Until recent years all the cotton was planted on the poorer "post-oak" lands, and the prairie lands were put in corn. But after years of continuous crops of corn the prairie land became the best cotton land, and now the finest cotton grows on the prairie lands.

The following well sections are of interest in this connection:

Well sections near Columbus and Aberdeen, Miss.

	Feet.
(*a*) Well at ravine on land of J. Q. Poindexter:	
Selma chalk	250
Sand, water bearing, and principal source of water	475
Red clay	50
Depth of well	725
Water soft; rises to within 26 feet of surface.	
(*b*) Well 2 miles due east of ravine on Sebe Gavin's land:	
Depth of well	431
Water flows 16 feet above surface.	
(*c*) Well on Doctor Patty's land, near Bigbee Valley post-office:	
Depth of well	431
Water flows 20 feet above surface.	
Water found in sand, and soft.	

	Feet.
(*d*) Well at Bigbee Valley post-office, sec. 16, T. 16, R. 19 E.:	
Thickness of Selma chalk	200
Depth of well	460
Water flows 20 feet above surface.	
(*e*) Another well, sec. 21, T. 16, R. 19 E.:	
Sand	200
Depth of well (flows)	444
(*f*) Well at Cliftonville:	
Lime	300
Dark sand, dry	20
White sand, water bearing	20
Dark sand, dry	10
White sand, water bearing	40
Ferruginous sandstone	12
Depth of well	450
Greensand, source of water.	
(*g*) Well on A. G. Cunningham's land, 1½ miles west of mouth of James Creek:	
Thickness of limestone	100
Depth of well (water flows)	500
Well 75 feet above Tombigbee River.	
(*h*) Well at Pickinsville, Ala., on land of Will Rodgers:	
Thickness of limestone	100
Depth of well (water flows)	400

All the wells mentioned above except the first one were drilled by J. B. Cunningham, Cliftonville, Miss., and the records were obtained from him. The well drillers here fail to make any distinction between the lower Selma and the upper Eutaw, so their records can not be depended upon for obtaining the thickness of the Selma.

A sample of sandy limestone was obtained from mouth of James Creek, on Tombigbee River. Along the Tombigbee, at the mouth of James Creek, there is an exposure of a greensand clay, containing a large amount of lime. About 50 feet above the river, at a point 1½ miles west of the mouth of James Creek, another sample of limestone was collected. The limestone here is similar in color and general aspect to that on the Tombigbee, except that it has less greensand.

Farther west the limestone rarely shows at the surface. Its clayey character and its easy dissolution by weathering agents causes it to break down into a soil faster than it is carried away by erosion.

At Cliftonville, which is 75 feet above Tombigbee River, barometric reading, there is a hard cap rock 2 to 4 feet thick, found on top of the hills near the town. This is a hard "lime" rock similar to that found at Prairie Point.

Below this hard cap rock comes what is called the "blue rock." A sample of it seen at a well dug years ago shows it to be similar to that at Cunningham Hill, except that it has no sand in it.

Where the blue rock below this hard cap rock comes to the surface it forms a belt of the richest soil in the prairie region. The soil is very deep, black, and loose. More cotton and corn are raised to the acre here than any other section of the State. West of this the land becomes higher, and the Lafayette occupies the surface on the ridges.

About 6 miles north of Macon, on the Macon and Columbus road, the limestone begins to show at the surface in small gullies. The rock is harder than the blue rock along the Tombigbee, hence its more frequent occurrence.

A sample collected from this locality by the writer was analyzed by W. S. McNeil in the laboratory of the United States Geological Survey.

Analysis of Selma limestone from a point north of Macon, Miss.

Silica (SiO_2)	8.52
Alumina (Al_2O_3)	6.60
Iron oxide (Fe_2O_3) Lime carbonate ($CaCO_3$)	83.88
Magnesium carbonate ($MgCO_3$)	0.00
Water	1.00

Farther south, along the Macon and Columbus road, the limestone begins to show in every gully and on every hillside. At some places on level ground the soil is not over 12 inches deep. In this vicinity are the bald prairies—large areas of this white limestone without a particle of soil or a sprig of grass. A sample was taken 3 miles north of Macon.

A sample of Selma limestone was taken from north of Lime Creek, 5 miles east of Shuqualak, on Oaknoxubee River, where a bluff 50 feet high is composed of typical Selma chalk. The following analysis of this sample was made by W. S. McNeil in the laboratory of the United States Geological Survey:

Analysis of Selma limestone, near Shuqualak, Miss.

Silica (SiO_2)	8.06
Alumina (Al_2O_3) Iron oxide (Fe_2O_3)	5.94
Lime carbonate ($CaCO_3$)	84.61
Magnesium carbonate ($MgCO_3$)	0.00
Water	1.32

The Tombigbee at Columbus has cut its channel into the Eutaw sands, forming a bluff on the east side 90 feet high. The material composing the bluff here is sand, greenish when wet and gray when dry. It contains a small amount of lime carbonate. At the upper part of the bluff the sands become lighter in color, changing to a light golden yellow. This was the color of sand when deposited, and is not due to oxidation. Numerous little branching concretions, which are perhaps some kind of poorly preserved fossils, occur in the lower portion, near the water. The upper part of the sands contains two species of large oysters, which also occur in the Selma. The river at the town is now hugging the east bluff, and the bottom, which is 3 miles wide, is all on the west side. A short distance above the town, however, the reverse is true, the bluff being on the west side and the bottom on the east.

At the west edge of the bottom the heavy black prairie soils of the Selma chalk appear as soon as the low hills are reached. The bottom extends north to the little creek flowing northeast into the river 3 miles above the town.

At a distance of 4 miles above town, on the west side of the river, the bluff reaches about the same height above the river as the bluff at Columbus, and forms a perpendicular cliff a mile long, giving a fine section of the upper Eutaw and the base of the Selma. At the top of the bluff the low hills on the west come down to the river. The same heavy black prairie soils, which come within 3 miles of the river due west of Columbus, here come down to the edge of the bluff.

The following section of the bluffs was obtained where the road comes down to the river:

Section of bluff of Tombigbee River above Columbus, Miss.

	Ft.	in.
Lafayette at top.		
Selma:		
"Blue rock" of the Selma, which is a white to gray joint clay containing less sand at top than at bottom. In the unweathered condition the clay is a pale-blue color, with green and black sand	10	8
Greensand, highly calcareous, and containing numerous large oysters	9	5
Indurate ledge of greensand, calcareous, and containing same fossils as No. 9	9	0
Lighter colored sand, containing very few small fossils, but no large ones	8	2
Eutaw:		
Greensand, nonfossiliferous	6	6
Slightly fossiliferous, gray micaceous sand	5	5
Indurate ledge, slightly fossiliferous sand	4	10
Greensand, containing same large oysters as No. 9	3	4
Indurate ledge	2	8
Fossiliferous greensand to the water's edge	1	4

The prairie soil of the Selma extends to the river, north of Columbus, but is not found east of the river. From Columbus southward to the south side of McGrowers Creek, on the west side of the river, the Tombigbee bottom varies in width from 2 to 4 miles. South of this creek the bottom changes again to the east side and the Selma extends to the river.

At the mouth of James Creek the same joint clay as seen above Columbus occurs on the east bank of the creek about 10 feet above the water's edge.

About 8 miles east of Columbus, on the Columbus and Tuscaloosa road, the hills of the Tuscaloosa formation first appear. On the hill near the 8-mile post the highly stratified clay interbedded with various colored sands outcrops on the side of the road.

One mile south of Strongs, on the Illinois Central Railroad, on the Monroe and Clay line, the railroad has cut into the Selma clay to a depth of 15 feet.

Eutaw sands extend west of the town of Aberdeen for 2 miles. Here the post-oak lands begin, and the regular prairie soils one-half mile farther west. There are no outcrops of the Selma from Aberdeen to Prairie station. The first outcrop found southwest of Aberdeen is at Strongs. There are very few outcrops of the Selma chalk here or farther south.

The following four analyses of samples of limestone from various points in Oktibbeha County, Miss., were made by Prof. W. F. Hand, State chemist:

Analyses of Selma limestone, Oktibbeha County, Miss.

	1.	2.	3.	4.	Average.
Silica (SiO_2)	2.89	2.33	3.03	2.55	2.70
Alumina (Al_2O_3) Iron oxide (Fe_2O_3)	1.53	1.72	1.92	1.96	1.78
Lime carbonate ($CaCO_3$)	94.10	94.35	93.60	94.07	94.03
Magnesium carbonate ($MgCO_3$)	1.84	1.82	1.64	2.12	1.85
Water	.36	.44	.42	.52	.44

The following analysis is an old one made by Doctor Hilgard[a] on a sample of the Selma chalk from near Okolona, Chickasaw County, Miss. Of the material reported as "insoluble" probably about two-thirds was silica, the remainder being alumina and iron oxide.

Analysis of limestone from Okolona, Miss.

Insoluble (mostly silica, SiO_2)	10.90
Alumina (Al_2O_3)	1.96
Iron oxide (Fe_2O_3)	1.42
Lime (CaO)	[b] 45.79
Magnesia (MgO)	[c] .88
Alkalies (K_2O, Na_2O)	.57
Carbon dioxide (CO_2)	35.73
Water and organic	2.84

[a] Report on the Geology of Mississippi, p. 101. 1860.
[b] Lime carbonate ($CaCO_3$), 81.77.
[c] Magnesium carbonate ($MgCO_3$), 1.84.

For comparison, analyses of the raw materials and product of the Alabama Portland Cement Company are given below. The plant of this company is located at Demopolis, Ala., and the raw materials used are the Selma chalk and an overlying residual clay.

Analyses of cement materials and cement, Demopolis, Ala.

	1.	2.	3.	4.	5.	6.	7.	8.	9.
Silica (SiO_2)	13.32	9.88	7.64	55.64	20.54	20.25	19.99	19.99	19.56
Alumina (Al_2O_3) / Iron oxide (Fe_2O_3)	7.74	6.20	7.62	26.25	8.55	13.44	13.63	13.74	12.16
Lime (CaO)	41.41	43.19	45.20	.91	63.85	63.60	63.82	61.36	62.27
Magnesia (MgO)	.67	.51	.50	1.97	.66	1.03	.83	.61	.64
Sulphur trioxide (SO_3)	.27	n.d.	1.62	Tr.	n.d.	.41	1.16	n.d.	.54
Carbon dioxide (CO_2) / Water	33.26	34.50	36.06	13.80	1.34	......	......	......	[a]4.83

[a] Including alkalies.

1. Limestone; F. P. Dewey, analyst.
2. Limestone; analysis furnished by manager.
3. Limestone; R. S. Hodges, analyst.
4. Clay; R. S. Hodges, analyst.
5. Cement; R. W. Clark, chief chemist U. S. Geol. Survey, analyst.
6. Cement; A. W. Dow, analyst.
7. Cement; R. S. Hodges, analyst.
8. Cement; analysis furnished by manager.
9. Cement; analysis published in Cement Directory, 2d ed., p. 254.

PORTLAND-CEMENT RESOURCES OF NEW YORK.

By Edwin C. Eckel.

CEMENT-MAKING ROCKS.

The State of New York now ranks fourth in the production of Portland cement in the United States. The extensive series of limestones which outcrop within its borders and its excellent local markets for cement and cement products will probably enable it to improve its rank as a Portland-cement producer very materially within the next few years.

Of the many different limestone formations which outcrop in New York State, five are of such thickness, areal extent, and chemical composition as to be worth considering as sources of Portland-cement material. Many other limestones occur in the State, but these others may be disregarded here as being usually too thin, of improper chemical composition, or too badly located with regard to transportation routes, markets, or sources of fuel supply.

The five available limestones noted above, in their geologic order, are as follows:

Portland-cement rocks of New York.

5. Marls	Quaternary.
4. Tully limestone	Devonian.
3. Helderberg and Onondaga limestones	Silurian and Devonian.
2. Trenton limestone	Lower Silurian (Ordovician).
1. Chazy limestone	Lower Silurian (Ordovician).

All of these limestones except the first (Chazy) are at present utilized in Portland-cement manufacture in New York State.

The character and distribution of the five limestone groups above noted will now be described separately in the order in which they are listed above.

CHAZY LIMESTONE.

DISTRIBUTION.

The Chazy limestone is confined practically to the Lake Champlain Valley. It outcrops on the west shore of Lake Champlain, a few miles south of Crown Point village, and is also well shown in Crown

Point itself. It appears again on the lake shore about 5 miles south of Westport, near Essex village, and on Willsboro Point. Its most characteristic and extensive outcrops, however, are in the eastern part of Clinton County. It is shown well on Valcour Island, and on Isle la Motte, where it has been extensively quarried. On the mainland it occupies large areas north of Valcour and west of Plattsburg, where it is quarried. The largest single area is in the northeastern part of Clinton County, where it has been worked extensively for lime and building stone. This area extends almost without a break from the village of West Chazy to the lake shore and northward to the Canadian line near Rouse Point.

Local details concerning the distribution, thickness, etc., of the Chazy formation will be found in a paper by H. P. Cushing, entitled "Report on the Geology of Clinton County," in the Thirteenth Annual Report of the New York State Geologist, pages 473–490. This paper also contains geological maps of the county, showing the area covered by the limestone.

COMPOSITION.

The Chazy limestone is usually a very pure limestone, low in both magnesia and clayey matter. It is commonly bluish to grayish in color, and has a slightly crystalline appearance. Occasionally it carries notable percentages of silica, alumina, etc., but these argillaceous phases are rare. Of the analyses in the following table, Nos. 1 and 2 represent the purest type of the Chazy limestone, while Nos. 3, 5, and 6 contain more or less clayey matter. Analysis No. 4 is included as representing a highly argillaceous type, occurring in the same area as Nos. 3, 5, and 6; but this particular analysis is old and of doubtful value.

Analyses of Chazy limestone, New York.

<table>
<tr><th></th><th>1.</th><th>2.</th><th>3.</th><th>4.</th><th>5.</th><th>6.</th></tr>
<tr><td>Silica (SiO_2)</td><td>0.79</td><td>0.72</td><td>2.43</td><td>21.39</td><td>4.40</td><td>4.60</td></tr>
<tr><td>Alumina (Al_2O_3)</td><td>.14</td><td rowspan="2">.39</td><td rowspan="2">.41</td><td rowspan="2">3.61</td><td>7.10</td><td>4.10</td></tr>
<tr><td>Iron oxide (Fe_2O_3)</td><td>.12</td><td>3.50</td><td>1.90</td></tr>
<tr><td>Lime (CaO)</td><td>54.36</td><td>53.90</td><td>51.00</td><td>39.37</td><td>44.35</td><td>49.11</td></tr>
<tr><td>Magnesia (MgO)</td><td>.67</td><td>1.44</td><td>1.00</td><td>.52</td><td>2.00</td><td>.47</td></tr>
<tr><td>Carbon dioxide (CO_2)</td><td>43.45</td><td>43.92</td><td>n. d.</td><td>31.51</td><td>37.05</td><td>39.10</td></tr>
</table>

1. Chazy, Clinton County. Rept. New York State Geologist for 1897, p. 433.
2. Chazy Marble Lime Company, Clinton County. D. H. Newland, analyst. Bull. New York State Museum, No. 44, p. 755.
3. Willsboro Point, Essex County. T. G. White, analyst. Ibid., p. 782.

4–6. Willsboro Point, Essex County. E. C. Boynton, analyst. Ibid., pp. 782, 783.

The cost of fuel in the Champlain Valley and the distance from good local markets will probably prevent any great development of the cement industry in the Chazy district, though the limestone itself is well adapted to cement manufacture and good clays are obtainable.

TRENTON LIMESTONE.

DISTRIBUTION.

The Trenton limestone, including the Black River and Birdseye, or Lowville limestone, is widely distributed throughout New York State, appearing in the valleys of Lake Champlain, upper Hudson River, Mohawk River, and Black River, in all of which it is an important quarry stone. It occurs also in the southern part of the State, but the outcrops in that district are so small and scattered that they may be disregarded.

Along the shores of Lake Champlain the Trenton limestone is exposed at various points, being quarried more or less extensively on Isle la Motte, at Plattsburg, and on Larabees Point and Crown Point. The most important series of outcrops, however, are along Mohawk and Black rivers and in the vicinity of Glens Falls.

The belt which is quarried near Glens Falls enters the State from Vermont, in northern Washington County, and passes southward through West Haven and Whitehall, close to the line of the Delaware and Hudson Railroad. A short break in the area occurs at Fort Ann, beyond which the limestone belt passes south to Sandy Hill, then west to Glens Falls, where it again turns south to Saratoga. In all this distance it lies close to the railroads, and in places is also near the canal. It is extensively quarried for Portland cement at Glens Falls and for lime and building stone at Sandy Hill, Glens Falls, and other points.

In the lower Mohawk Valley the areas covered by the Trenton limestone are too irregular to be readily described.[a] It is sufficient to say that the Trenton outcrops extensively in the vicinity of Cranesville, Amsterdam, Tribes Hill, Yosts, Sprakers, Palatine Bridge, St. Johnsville, Dolgeville, and Little Falls. It is quarried at many of these points for lime or building stone. It should be noted, however, that another limestone—the Calciferous or Beekmantown limestone—also occurs at many of the points named, underlying the Trenton limestone. This Calciferous limestone, however, is usually a very impure rock, high in magnesia, and should therefore be carefully distinguished from the Trenton, which is normally very low in magnesia.

The most extensive area of Trenton limestone in the State remains to be described. This area lies mostly in Oneida, Lewis, and Jefferson

[a] The distribution of the Trenton limestone throughout much of its range in the Mohawk Valley and adjoining regions is described in detail in a paper by N. H. Darton on the "Geology of the Mohawk Valley," published in the Thirteenth Annual Report of the New York State Geologist, pp. 407–430.

counties, along the valleys of West Canada Creek and Black River. Commencing as a narrow belt near Middleville, Herkimer County, it passes northwestward, increasing to about 8 to 10 miles in width, and going through Trenton Falls, Prospect, Remsen, Boonville, Port Leyden, Lowville, and Copenhagen, at many of which points it is extensively quarried. The limestone belt here widens out greatly, being about 20 miles wide at Watertown, and extending along the St. Lawrence–Lake Ontario shore from near Clayton to near Port Ontario, a distance of over 50 miles. Within this broad area in Jefferson County the Trenton limestones are quarried at Cape Vincent, Chaumont, Clayton, Watertown, Theresa, and many other points.

COMPOSITION.

The Trenton limestone is usually a pure nonmagnesian limestone. It is dark gray to almost black in color, and is commonly highly fossiliferous.

The following analyses, which are representative of the various phases of the Trenton limestone, are arranged in geographic order along the outcrop of that limestone, beginning in Washington County, on the east, and ending in Lewis County, on the west.

Analyses of Trenton limestones, New York.

<table>
<tr><th>No.</th><th>Silica (SiO_2).</th><th>Alumina (Al_2O_3).</th><th>Iron oxide (Fe_2O_3).</th><th>Lime (CaO).</th><th>Magnesia (MgO).</th><th>Carbon dioxide (CO_2).</th></tr>
<tr><td>1</td><td>0.97</td><td>0.08</td><td>0.02</td><td>54.15</td><td>0.39</td><td>42.95</td></tr>
<tr><td>2</td><td>1.38</td><td colspan="2">0.58</td><td>55.26</td><td>.72</td><td>n. d.</td></tr>
<tr><td>3</td><td>.72</td><td colspan="2">1.50</td><td>54.28</td><td>.80</td><td>44.00</td></tr>
<tr><td>4</td><td>.70</td><td>1.00</td><td>.70</td><td>53.09</td><td>1.04</td><td>42.05</td></tr>
<tr><td>5</td><td>2.13</td><td colspan="2">1.26</td><td>53.19</td><td>Trace.</td><td>41.79</td></tr>
<tr><td>6</td><td>3.30</td><td colspan="2">1.30</td><td>52.15</td><td>1.58</td><td>40.98</td></tr>
<tr><td>7</td><td>1.10</td><td>.80</td><td>.50</td><td>53.17</td><td>.75</td><td>45.08</td></tr>
<tr><td>8</td><td>6.13</td><td>.79</td><td>.61</td><td>49.55</td><td>1.17</td><td>40.22</td></tr>
<tr><td>9</td><td>1.25</td><td colspan="2">3.00</td><td>52.78</td><td>..........</td><td>42.97</td></tr>
<tr><td>10</td><td>3.82</td><td colspan="2">1.08</td><td>52.46</td><td>..........</td><td>42.64</td></tr>
<tr><td>11</td><td>5.68</td><td colspan="2">2.76</td><td>52.12</td><td>..........</td><td>39.44</td></tr>
<tr><td>12</td><td>6.70</td><td>3.03</td><td>.21</td><td>49.92</td><td>Trace.</td><td>39.23</td></tr>
<tr><td>13</td><td>8.45</td><td>2.72</td><td>.84</td><td>47.38</td><td>1.63</td><td>39.01</td></tr>
<tr><td>14</td><td>2.59</td><td>1.21</td><td>.61</td><td>52.00</td><td>1.04</td><td>42.00</td></tr>
<tr><td>15</td><td>3.96</td><td colspan="2">1.70</td><td>51.11</td><td>1.80</td><td>42.14</td></tr>
<tr><td>16</td><td>3.09</td><td>1.15</td><td>.49</td><td>52.70</td><td>.78</td><td>42.26</td></tr>
<tr><td>17</td><td>1.44</td><td colspan="2">0.83</td><td>54.52</td><td>.49</td><td>43.39</td></tr>
<tr><td>18</td><td>6.50</td><td>1.67</td><td>.76</td><td>49.53</td><td>1.28</td><td>40.31</td></tr>
</table>

1. Keenan Lime Company, Smith's basin, Washington County. Twentieth Ann. Rept. U. S. Geol. Survey, pt. 6, p. 427.
2. Keenan Lime Company, Smith's basin, Washington County. Bull. New York State Mus. No. 44, p. 826.
3. Keenan Lime Company, Smith's basin, Washington County. H. Ries, analyst. Ibid., p. 827.
4. Harris quarry, near Whitehall, Washington County. Ibid.
5. Glens Falls, Warren County. J. H. Appleton, analyst. Seventeenth Ann. Rept. U. S. Geol. Survey, pt. 3, p. 801.
6. Glens Falls, Warren County. Mineral Industry, vol. 6, p. 97.
7. Glens Falls, Warren County. Bull. New York State Mus. No. 44, p. 825.
8. Hewitt quarry, Amsterdam, Montgomery County. Ibid., p. 749.
9. Hewitt quarry, Amsterdam, Montgomery County. J. M. Sherrerd, analyst. Twentieth Ann. Rept. U. S. Geol. Survey, pt. 6, p. 427.
10. Hewitt quarry, Amsterdam, Montgomery County. J. M. Sherrerd, analyst. Ibid., pt. 6, p. 427.
11. Hewitt quarry, Amsterdam, Montgomery County. J. M. Sherrerd, analyst. Ibid., pt. 6, p. 427.
12. Butler quarry, Ingham Mills, Herkimer County. Bull. New York State Mus. No. 44, p. 788.
13. Butler quarry, Ingham Mills, Herkimer County. Ibid.
14. Prospect, Oneida County. J. D. Irving, analyst. Ibid., p. 802.
15. Waters quarry, Lowville, Lewis County. Ibid., p. 792.
16. Roberts quarry, Collinsville, Lewis County. D. H. Newland, analyst. Ibid., p. 791.
17. Christy quarry, Leyden, Lewis County. Ibid., p. 791.
18. Snyder quarry, Port Leyden, Lewis County. D. H. Newland, analyst. Ibid., p. 791.

HELDERBERG LIMESTONE.

DISTRIBUTION.

Regarded as possible sources of Portland-cement materials, the most important series of limestone formations in New York State is that included in the upper and lower Helderberg groups. These two groups, each divisible into a number of well-marked formations, are separated throughout the greater part of their range by a comparatively thin bed of sandstone—the Oriskany sandstone—but for the purposes of this paper may be considered as one series of limestones. The Helderberg limestones, considered together, extend eastward from Buffalo, in Erie County, to Oriskany Falls, Oneida County. Here the belt turns about S. 30° E., to near South Bethlehem, Albany County. From this point the outcrops of the limestone trend almost parallel to and a little west of Hudson River, nearly to Kingston. The limestone belt then turns southeastward, passing along through Ellenville and Port Jervis into Pennsylvania and New Jersey.

The distribution of the Helderberg limestones is described at length in the following papers, in which maps and sections showing local details will be found:

Darton, N. H. Report on the Helderberg limestones: Thirteenth Ann. Rept. New York State Geol., pp. 197–228.

——— Report on the Geology of Albany County: Thirteenth Ann. Rept. New York State Geol., pp. 229–262.

——— Report on the Geology of Ulster County: Thirteenth Ann. Rept. New York State Geol., pp. 289–372.

COMPOSITION.

The composition of the Helderberg limestone is shown by the following analyses:

Analyses of Helderberg limestones, New York.

	Silica (SiO_2).	Alumina (Al_2O_3).	Iron oxide (Fe_2O_3).	Lime (CaO).	Magnesia (MgO).	Carbon dioxide (CO_2).
1	1.17	0.64		54.06	0.48	43.00
2	5.00	.60		51.78	.88	41.66
3	5.96	3.16	1.34	49.70	1.44	40.13
4	14.85	7.18	1.57	40.23	1.95	33.76
5	1.6	.7		54.32	.53	43.26
6	7.23	1.64		48.68	1.84	40.29
7	1.92	.36		52.53	.69	42.03
8	n.d.	n.d.	n.d.	35.25	8.94	37.52
9	n.d.	n.d.	n.d.	43.22	6.08	40.65
10	n.d.	n.d.	n.d.	48.82	1.48	39.99
11	5.53	1.50		50.25	1.00	40.49
12	2.48	.95		53.52	.46	42.54
13	5.56	1.55		50.47	.83	40.57
14	2.57	1.55		52.69	.84	42.33
15	5.66	2.14		50.25	1.11	40.70
16	5.46	1.35		50.80	1.01	41.02
17	5.82	1.38		50.93	.85	40.87
18	4.45	.30		50.06	2.74	42.36
19	4.91	.48	.53	51.82	1.16	41.90
20	4.31	.97		51.05	1.65	41.90
21	1.48	n.d.	n.d.	53.62	n.d.	n.d.
22	4.12	n.d.	n.d.	52.46	n.d.	n.d.
23	9.05	6.66	.99	44.72	1.98	37.33
24	5.12	1.45	.74	48.34	2.93	41.22
25	11.16	3.35	1.15	44.27	3.17	38.27
26	1.27	.73		54.51	.66	43.46
27	1.84	.63	1.82	51.40	2.23	41.19
28	1.89	1.01	.55	51.35	1.67	42.19
29	2.75	1.50	1.6	53.10	n.d.	n.d.
30	7.10	2.50	1.65	45.22	Trace.	39.10
31	3.87	1.07	1.34	54.11	Trace.	40.60

1. Fogelsonger quarry, Williamsville, Erie County. H. Carlson, analyst. Twentieth Ann. Rept. U. S. Geol. Survey, pt. 6, p. 427.
2. Howells quarry, Leroy, Genesee County. Bull. New York State Mus., No. 44, p. 784.
3. Strobel quarry, Leroy, Genesee County. Ibid.
4. Babcock quarry, Waterloo, Seneca County. Ibid., p. 819.
5. Alvord quarry, Jamesville, Onondaga County. F. E. Engelhardt, analyst. Ibid., p. 806.

6-12. Clinton, Oneida County. A. H. Chester, analyst. Ibid., p. 802.
13-17. Oriskany Falls, Oneida County. A. H. Chester, analyst. Ibid.
18. Putnam quarry, Oriskany Falls, Oneida County. Ibid., p. 803.
19. Manning quarry, Columbia, Herkimer County. Ibid., p. 788.
20. Cobleskill Quarry Company, Cobleskill, Schoharie County. C. F. McKenna, analyst. Twentieth Ann. Rept. U. S. Geol. Survey, pt. 6, p. 427.
21, 22. Howes Cave, Schoharie County. C. A. Schaeffer, analyst.
23-25. Callanan quarry, South Bethlehem, Albany County. Bull. New York State Mus., No. 44, p. 771.
26. Howes Cave, Schoharie County. C. A. Schaeffer, analyst. Twentieth Ann. Rept. U. S. Geol. Survey, pt. 6, p. 427.
27, 28. Hudson, Columbia County. Ibid., p. 427.
29. Holdredge quarry, Catskill, Greene County. H. Ries, analyst. Bull. New York State Mus., No. 44, p. 787.
30. Turner quarry, Wilbur, Ulster County. Ibid., p. 822.
31. Rondout, Ulster County. Ibid.

TULLY LIMESTONE.

DISTRIBUTION.

The thinness of the Tully limestone would probably allow it to be disregarded as a Portland-cement material if it were not for its advantageous distribution. It occurs only in central New York, and occupies a greater area than any other limestone in that part of the State. Its line of outcrop, moreover, crosses all the Finger lakes, on the shores of most of which the limestone is well exposed, and the belt is crossed by numerous railroad lines leading to the coal regions of Pennsylvania. With these advantages of position, even a relatively thin limestone bed is worth considering, and one Portland cement plant that uses the Tully limestone is already in operation.

The most western known exposure of the Tully limestone is near Reed Corners, Ontario County. From this point it runs southeastward through on near Gorham, Stanley, Halls Corners, and Dresden, disappearing below the waters of Seneca Lake opposite the village of Starkey. It reappears on the east shore of the lake about 5 miles south of Willard, and is exposed almost continuously along the lake shore as far north as Willard. Here it turns eastward through Hayt Corners, then southeastward near Sheldrake to the Cayuga Lake shore east of Covert, and thence southward along the west shore through Trumansburg to Glenwood. Its most available outcrops are, however, on the east shore of Cayuga Lake, which it follows closely from Portland Point north to opposite King Ferry. Turning northeastward the limestone outcrop leaves the lake and passes through Poplarridge, Sherwood, and Scipio. From this point to its most easterly known outcrop, which is near Smyrna, Chenango County, the outcrop of the Tully limestone is too irregular for ready description. It is sufficient here to indicate its course by saying that the principal villages and stations on or near the outcrop are, in order eastward, Cascade, Locke, Moravia, Miles, Glenhaven, Scott, Spofford, Borodino, Otisco Valley, Tully, Truxton, Cuyler, Deruyter, Georgetown, and Smyrna.

COMPOSITION.

The Tully limestone is low in magnesia, rarely carrying over 1½ per cent of magnesium carbonate. It commonly carries a rather large percentage of silica, alumina, and iron oxide, at times approximating to the composition of Lehigh cement rock. The analyses given below are fairly representative of its range in composition.

The limestone is immediately underlain by a series of shales which, as shown by the experience of the Portland-cement plant near Ithaca, are well adapted to mixing with the limestone.

Analyses of Tully limestone, New York.

	1.	2.	3.	4.	5.	6.
Silica (SiO_2)	9.72	6.30	7.88	5.7	4.0	15.0
Alumina (Al_2O_3)	4.20	3.35	4.01	2.1	26.0	23.0
Iron oxide (Fe_2O_3)	.48					
Lime (CaO)	47.11	50.25	48.10	49.56	33.6	30.0
Magnesia (MgO)	.66	.22	.53	.67	2.6	1.3
Carbon dioxide (CO_2)	n. d.	n. d.	n. d.	39.67	n. d.	n. d.

1. Top bed. Portland Point, Tompkins County. J. H. McGuire, analyst.
2. Middle bed. Portland Point, Tompkins County. J. H. McGuire, analyst.
3. Bottom bed. Portland Point, Tompkins County. J. H. McGuire, analyst.
4. Near Lansing, Tompkins County. H. Ries, analyst. Bull. New York State Mus. No. 44, p. 820.
5. Willard, Seneca County. Trans. New York Agric. Soc. for 1850, p. 611.
6. Hayt Corners, Seneca County. Ibid.

QUATERNARY MARLS.

DISTRIBUTION.

Small deposits of marl occur at many points in eastern and northern New York, filling old lake basins and now forming swampy tracts, overlain by much impure peat. So far as known, none of the deposits in this part of the State are of workable size.

In western and central New York, however, large marl deposits have been found at many points. They are, or have been, utilized in the manufacture of Portland cement at Montezuma, Cayuga County; Jordan and Warners, Onondaga County; Caledonia, Genesee County; Wayland and Perkinsville, Steuben County, and Cassadaga Lake, Chautauqua County. Other large deposits, as yet undeveloped, occur northwest of Canastota, Oneida County; at Cortland, Cortland County; Clifton Springs, Ontario County; Clarendon, Orleans County, and Bergen, Genesee County.[a]

[a] Bull. New York State Mus. No. 44, p. 767.

COMPOSITION.

The following analyses show the composition of the Quaternary marls of the State:

Analyses of Quaternary marls, New York.

No.	Silica (SiO_2).	Alumina (Al_2O_3).	Iron oxide (Fe_2O_3).	Lime (CaO).	Magnesia (MgO).	Carbon dioxide (CO_2).	Water organic, etc.
1	0.40	0.20	0.20	53.50	0.30	n. d.	([a])
2	1.10	1.50		54.54	Trace.	n. d.	----------
3	.49	.35		52.71	Trace.	n. d.	([b])
4	.50	2.00		52.70	1.09	42.61	----------
5	.42	1.08		52.36	1.01	42.26	[c]0.86
6	.54	.56		54.40	2.34	42.20	
7	.14	.36		53.16	1.50	n. d.	
8	.26	.10		52.86	.18	41.73	4.64
9	.26	.21	.01	50.98	.19	40.26	7.98
10	6.22	1.70	.86	47.86	.04	42.11	([d])
11	2.10	1.93		48.78	1.10	39.53	----------

[a] SO_3, 1.7 per cent.
[b] $CaSO_4$, 3.48 per cent.
[c] $CaSO_4$, 2.01 per cent.
[d] Alkalies, 2.20 per cent.

1. Iroquois Portland Cement Company, Caledonia, Livingston County.
2. 3 miles east of Mumford, Livingston County. Bull. New York State Mus., No. 44, p. 793.
3. 1 mile west of Bergen, Genesee County. J. A. Miller, analyst. Ibid., p. 785.
4. Mumford, Monroe County. (Calcareous tufa.) Ibid., p. 797.
5. Millen Portland Cement Company, Wayland, Steuben County.
6. Genesee Wayland Portland Cement Company, Perkinsville, Steuben County.
7. American Cement Company, Jordan, Onondaga County.
8, 9. Empire Portland Cement Company, Warners, Onondaga County.
10. Montezuma, Cayuga County. Mineral Industry, vol. 1, p. 52.
11. Canastota, Madison County. Bull. New York State Mus., No. 44, p. 794.

CEMENT MATERIALS OF THE VALLEY OF VIRGINIA.

By R. S. Bassler.

CEMENT-MAKING ROCKS.

For many years the argillaceous Trenton limestones of the Lehigh district of Pennsylvania have furnished the raw material for the manufacture of the greater part of the Portland cement output of the United States. Because of this enormous output the argillaceous limestones of this relatively small district have assumed great economic importance, and the occurrence of the same rock in adjoining States is of great interest to cement manufacturers.

In the early part of the field season of 1904 the writer spent six weeks in the Lehigh and Lebanon valleys of Pennsylvania in a general study of the paleontology and stratigraphy of the Ordovician strata, but particularly in mapping the distribution of the Trenton limestone or cement rock. Later in the season about three weeks were devoted to similar work in the southern half of the Valley of Virginia. The following preliminary report and accompanying maps are based largely upon this latter field work, but in their preparation free use has been made of the Staunton folio,[a] by N. H. Darton, and of an article by Charles Catlett entitled "Cement resources of the Valley of Virginia."[b] Acknowledgements are also due to Prof. H. D. Campbell, of Washington and Lee University, for the use of manuscript geologic maps prepared by him covering the region about Lexington and Natural Bridge, Va. Mr. Catlett has also kindly allowed the writer to make use of notes and preliminary analyses of the rocks in the vicinity of Harrisonburg and Staunton, Va.

In the present report only that part of the valley lying between Woodstock, in Shenandoah County, on the north and Natural Bridge, in Rockbridge County, on the south is considered.

[a] Geologic Atlas U. S., folio 14, U. S. Geol. Survey, 1894.
[b] Bull. U. S. Geol. Survey No. 225, 1904, pp. 457–461.

The raw materials occurring in the Valley of Virginia suitable for the manufacture of cement are magnesian limestone, argillaceous limestone, pure limestone, shales, and calcareous marls. Of these, the

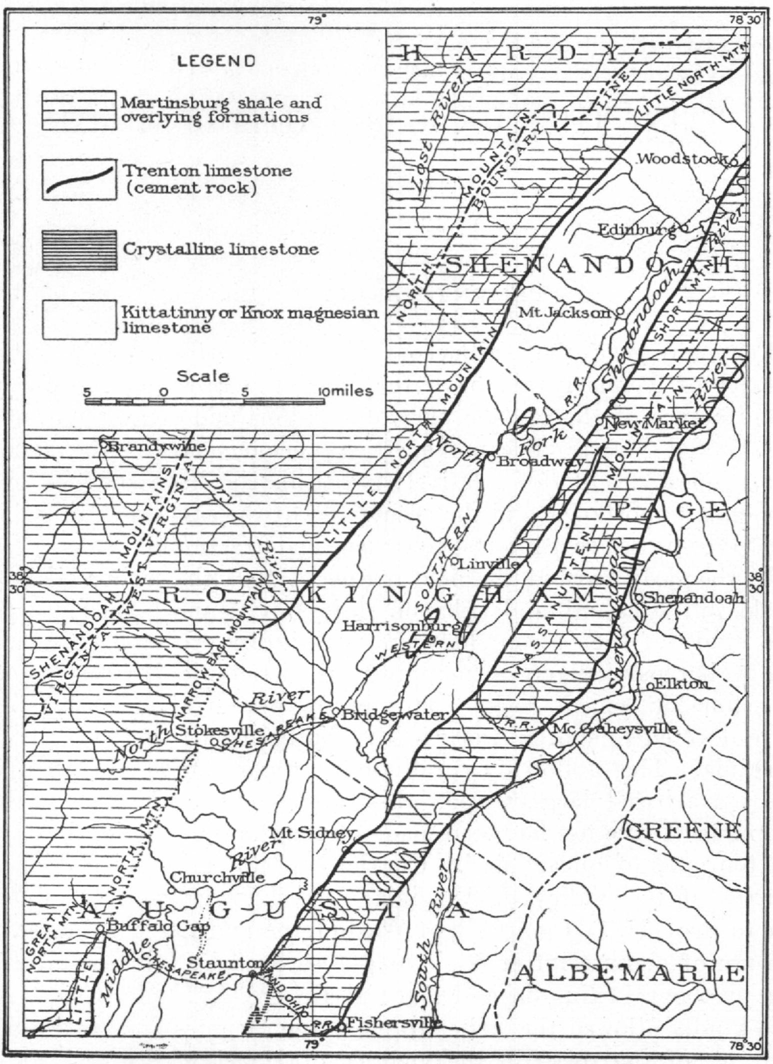


FIG. 23.—Map of the Valley of Virginia from Woodstock to Staunton. White area includes Knox limestone and underlying formations.

more important are the argillaceous and pure limestones. The magnesian limestones, as mentioned later, are now being used only in a single instance for the manufacture of a natural cement. The other materials cited may be utilized in the production of Portland cement.

GENERAL GEOLOGY.

The principal rock formations occurring in the Valley of Virginia are a great series of limestones termed the Shenandoah limestone and a series of shales named the Martinsburg shales. In general the entire valley is underlain by the Shenandoah limestone, while the shales usually outcrop along the base of the mountains bounding it. Both of these formations yield an abundance of the raw materials necessary for the manufacture of Portland cement.

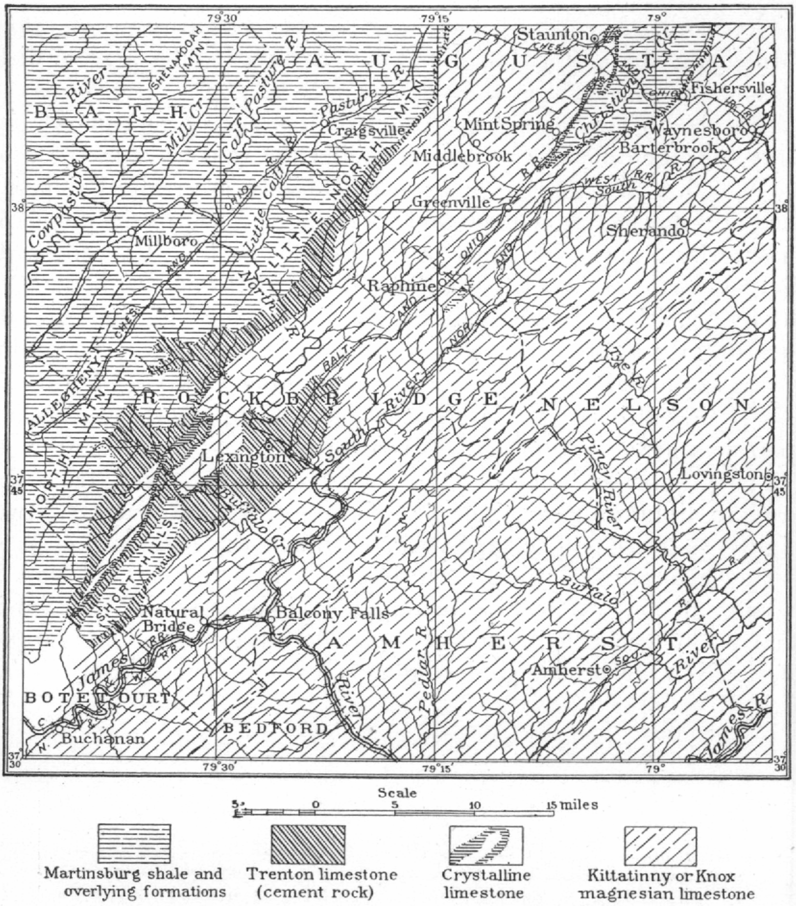


FIG. 24.—Map of the valley of Virginia from Staunton to Natural Bridge. Area marked by diagonal broken lines includes Knox limestone and underlying formations.

SHENANDOAH LIMESTONE.

Thickness, character, and subdivisions.—This formation has a very great thickness and is composed of several members, all of which have been grouped under the above general name. The chemical composition of its several divisions varies greatly, some of the limestones being highly magnesian, others being almost pure calcium carbonate, while a third group contains a considerable amount of clayey material. According to the character of the rock, and also in agreement with the fossil contents, four divisions may be recognized in the Shenandoah limestone, in ascending order, as follows: (1) Beds of magnesian limestone of Cambrian age from 1,000 to 2,000 feet in thickness; (2) 300 or more feet of cherty limestone bearing fossils of Beekmantown (Calciferous) age; (3) 60 to 100 feet of a coarsely crystalline, light-colored, highly fossiliferous limestone; (4) 200 to 350 feet of dark-colored argillaceous limestone, the Trenton cement rock. Members 1 and 2 are apparently uniformly developed throughout the valley, but 3 and 4, although having a wide distribution, are sometimes absent.

Cambrian limestone.—On account of the lack of continuous exposures and the difficulty in distinguishing the various beds, the thickness of this division has not been definitely ascertained, but it is certainly not less than 1,000 and may exceed 2,000 feet. Fossils are practically wanting in these rocks in this part of the valley, but farther north, notably at several localities in Pennsylvania and New Jersey, sufficient fossil evidence has been found to indicate that probably the entire division is of Upper Cambrian age. These limestones are underlain by a quartzite containing Lower Cambrian fossils, so that although the two formations are apparently conformable, there is a great time break between them.

The Cambrian limestones are massive bedded, vary from dark gray to light gray or light blue in color, and are nearly always highly magnesian in composition. Toward the base purple or silvery shales are sometimes seen, but as a rule the entire formation is one of heavily bedded magnesian limestones. The following analysis of specimens from New Jersey localities, copied from reports of the New Jersey Geological Survey, will probably apply equally well to Virginia:

Analyses of magnesian Cambrian limestone.

	1.	2.	3.	4.	5.	6.
Silica (SiO_2)	8.0	4.9	16.9	8.8	4.1	2.0
Alumina (Al_2O_3) / Iron oxide (Fe_2O_3)	5.3	6.5	1.0	.8	1.6	8.4
Lime (CaO)	26.3	27.3	28.3	29.4	30.3	32.4
Magnesia (MgO)	17.4	14.6	15.3	17.8	18.3	15.5
Carbon dioxide (CO_2)	41.1	44.8	38.9	42.8	44.1	42.5

1. Peapack, N. J.
2. Clinton, Hunterdon County, N. J.
3. Annandale, N. J.
4. Asbury, Warren County, N. J.
5. Peapack, N. J.
6. Pottersville, Somerset County, N. J.

On account of the high percentage of magnesia these limestones are of no value for the manufacture of Portland cement, but their composition does not preclude their use in the making of natural cement. For many years natural cement has been burned from the magnesian limestones of the lower part of this division at the plant at Glasgow, Rockbridge County: The product from this plant was used in building the locks of the James River and Kanawha Canal. The following analyses of this rock show its usual range in composition:

Analysis of magnesian limestone, Glasgow, Va.

	1.	2.
Silica (SiO_2)	17.21	17.38
Alumina (Al_2O_3)	Tr.	7.80
Iron oxide (Fe_2O_3)	1.62	
Lime (CaO)	24.85	34.23
Magnesia (MgO)	16.58	9.51
Carbon dioxide (CO_2)	37.95	30.40

1. C. L. Allen, analyst. The Virginias, vol. 3, p. 88.
2. E. C. Boynton, analyst. Gillmore: Limes, Cements, and Mortars, p. 125.

Occasionally, however, strata of pure limestone will be found interbedded with the more typical magnesian rock, and it is in this occurrence that the formation will prove of value in the manufacture of Portland cement. Such strata have been observed in various parts of the valley, but their occurrence is more or less sporadic. Because of this, and also on account of the geologic structure of the entire formation and the small percentage of pure limestones, these nonmagnesian strata can not be definitely mapped and must be determined by experiment in the field. In New Jersey and Pennsylvania the same arrangement of a few strata of nonmagnesian limestones interbedded with a great series of highly magnesian limestones obtains, and the former is the source of part of the limestone used in the Lehigh district to bring the cement rock up to the required percentage of calcium carbonate. Near Annville, Pa., these nonmagnesian limestones occur in greater quantities than usual, and much is quarried for shipment to cement plants. The following analyses of this rock are introduced for comparison with the Virginia pure limestones:

Analyses of pure limestones (Cambrian) from Annville, Pa.

	1.	2.	3.
Silica (SiO_2)	2.14	3.02	1.98
Alumnia (Al_2O_3) Iron oxide (Fe_2O_3)	1.46	1.90	.70
Lime carbonate ($CaCO_3$)	94.35	92.05	95.19
Magnesium carbonate ($MgCO_3$)	2.18	3.04	2.03

Beekmantown limestone.—The Cambrian magnesian limestones grade upward imperceptibly into another series of strata having essentially the same chemical composition but differing in that extensive layers of chert are interbedded with the limestones. The areas occupied by this division may usually be recognized by their topographic features, as the chert beds give rise to conspicuous hills or ridges. Chestnut Ridge, Sugar Loaf, and Betsey Bell are examples of this topography in the vicinity of Staunton, but similar ridges and knobs are encountered throughout the valley. The Beekmantown age of this series has been determined from gasteropod and cephalopod remains found at various points in the valley, but particularly in the vicinity of Lexington, Va. On account of this gradual passage of the Cambrian into the Beekmantown the determination of the thickness of the latter division is difficult. However, the characteristic fossils have been found 300 to 400 feet below the top of the cherty layers, so that their thickness is not less than the figures mentioned. The difficulty of separating these two divisions without fossil evidence is in accordance with a fact that has been often noted, namely, that whenever both are made up of limestone, sedimentation has apparently continued through upper Cambrian and Beekmantown times with no interruption.

Usually no pure limestone layers of any consequence have been noticed in this division, and this, as well as the unfavorable topography often accompanying its exposures, causes the rocks of this age to be of little value as a source of Portland-cement rock. Still, in a few instances, lenses of comparatively pure limestone have been found in this formation as well as in the underlying Cambrian. The following analysis of a sample of this rock from the vicinity of Staunton is typical:

Analysis of pure limestone (Beekmantown) from vicinity of Staunton, Va.

[Charles Catlett, analyst.]

Silica (SiO_2)	1.79
Alumina (Al_2O_3) and iron oxide (Fe_2O_3)	.74
Lime (CaO)	50.36
Magnesia (MgO)	1.79
Carbon dioxide (CO_2)	41.36
Alkalies, etc	3.97

Trenton limestones.—Under this general name two distinct series of limestone are here recognized—the older a formation of coarsely crystalline, highly fossiliferous rock, and the younger the well-known black argillaceous limestones or cement rock. This first series is well developed in the area south of Staunton, where it varies from 60 to 100 feet in thickness, while north of Staunton it is apparently missing altogether, for here only the cement rocks occupy the interval between the Beekmantown limestone and Martinsburg shales. At first sight these two would appear to be but phases of one and the same formation, but this idea is disproved by the development of both series in the vicinity of Lexington, Va. Fossils are abundant throughout both series, the first often being crowded with ramose bryozoa and masses of *Solenopora*, while brachiopods, ostracoda, and trilobites of Trenton age predominate in the second.

Although samples of these coarsely crystalline limestones run high in lime, the strata as a whole contain so much chert that they are of little value for mixture with the cement rock.

The youngest member of the Shenandoah limestone—the argillaceous Trenton—usually resembles the corresponding strata in the Lehigh district more in chemical composition than in its physical aspect. In Pennsylvania the cement rock is usually a dark-gray or black slaty limestone, which, on account of the shearing to which it has been subjected, breaks under the hammer into flat pieces with smooth glistening surfaces. As the rock loses its argillaceous character—i. e., as the percentage of lime carbonate in it increases—the slaty appearance is lost and a light-gray crystalline limestone is the result. In the Valley of Virginia, however, metamorphism seems usually not to have been so great and the aspect of the limestones varies according to their composition. For example, the rocks of the formation outcropping near Woodstock are little more than compact hardened strata of calcareous mud, while, on the other hand, the same horizon on the western side of the valley is occupied by tough, crystalline, dark-blue, or black limestones.

South of Staunton, especially in the vicinity of Lexington, the Trenton strata have been closely folded and compressed, with the consequent development of considerable metamorphic characters.

The result is that here the argillaceous limestones resemble those of the Lehigh district more than at any other point in the valley.

Analyses of these rocks are given under the detailed discussion of localities.

MARTINSBURG SHALES.

The highest formation in the valley proper, geologically speaking, is a great series of gray, light-brown, or black shales, varying in thickness from 1,000 to 1,500 feet. When the Trenton limestones underlie the shales the passage from the one formation to the other is often so gradual that no marked distinction can be observed. Even when the shales rest upon formations older than the Trenton argillaceous limestones their lower beds are often quite calcareous and may include thin layers of impure limestone. Although the calcareous portion of the shales may be found to burn into a cement when mixed with other material, it is probable that the main value of this series will rest in the noncalcareous portion for mixture with high-lime argillaceous rock. The following analyses show the composition of the lower calcareous part and also of the higher, more typical shales.

Analyses of Martinsburg shales.

	1.	2.	3.
Silica (SiO_2)	68.00	56.60	22.51
Alumina (Al_2O_3)	14.40	21.00	10.54
Iron oxide (Fe_2O_3)	5.40	5.65	3.26
Lime (CaO)	2.68	3.42	33.24
Magnesia (MgO)	1.51	2.30	1.54
Alkalies (K_2O, Na_2O)	.11	.50	--------
Carbon dioxide (CO_2)	2.30	2.20	29.07
Water (H_2O)	2.70	3.00	--------

1. Typical shales, 1 mile northwest of Colemanville, N. J. Geology New Jersey, 1868, p. 136.
2. Typical shales, Delaware Water Gap, N. J. Geology New Jersey, 1868, p. 136.
3. Calcareous shales 1½ miles east of Staunton, Va. Booth, Garret, and Blair, chemists.

CALCAREOUS MARLS.

Small deposits of calcareous tufa have been noticed in various parts of the valley, and these, if favorably located in sufficient quantity, would undoubtedly be of much value in cement manufacture. Of more importance, however, are deposits of calcareous fresh-water marl which have been found scattered throughout this region. In certain portions of Staunton, as has been noted by Mr. Catlett, the foundations of the houses are cut in marl 10 or 12 feet deep. The surface indications of these marls are usually so meager that no estimate of their quantity or extent can be determined from these alone.

GENERAL DISTRIBUTION OF ARGILLACEOUS TRENTON LIMESTONE.

On account of the geologic structure of the valley the argillaceous limestones are found in three well-defined belts. Two of these belts are formed by the outcropping edges of the syncline forming Massanutten Mountain, while the third follows the western edge of the valley. Exposures of the easternmost belt are found at numerous places along a northeast-southwest line from a point about 5 miles east of Woodstock to Fisherville. The next belt to the west parallels this and shows many outcrops along a similar line from Woodstock to Staunton. At several places along these lines of outcrop the argillaceous limestone is missing. The most pronounced areas where this has been observed are (1) the region just south of Massanutten Mountain, with McGaheysville on the eastern edge, and (2) the area south of Staunton, bounded by Staunton, Barter Brook, and Fisherville.

The third belt occurs along the western edge of the valley and parallels the other two. Here, however, these limestones are often cut out by the great overthrust fault of this portion of the valley. In this section the best exposures of these rocks are found along the eastern edge of Little North Mountain, especially in the vicinity of Dry River, north of Stokesville. The valley proper, as has been remarked before, is usually occupied by the dolomitic limestones, but occasionally synclines exposing the argillaceous limestones and shales are found. The most important of these from an economic standpoint occurs just west of Harrisonburg. In the vicinity of Lexington and Natural Bridge the Trenton limestones have been compressed into close folds and occupy considerably wider areas than farther north. The most important of these areas is that in which Lexington is located, the rest, as a glance at the map will show, being too far away from railroad facilities.

DETAILS OF LOCALITIES.

Below are briefly discussed the more favorable localities, showing good exposures of the argillaceous limestone, from Woodstock, in the northernmost part of the valley visited, to the vicinity of Natural Bridge. In indicating advantageous sites for cement plants, the writer means simply to imply that the cement rock and pure limestone deposits occur at the places mentioned, and that the transportation and other necessary facilities are at hand. Whether a good cement can be made from the raw materials found at these places is a matter which can be determined only by experimentation on a commercial scale. The argillaceous limestones, in most instances, have a composition very similar to good cement materials of other regions, but this does not necessarily indicate that they also will make first-class cement.

Woodstock and vicinity.—About 350 feet of argillaceous Trenton limestones are exposed just east of Woodstock, the town itself being situated upon the cherty limestones of Beekmantown age. These limestones and the overlying shales dip at an angle of about 45° to the southeast, and are the outcrops of the western edge of the great syncline forming Massanutten Mountain. Practically the same thickness of cement rock is exposed to the northeast and the southwest of Woodstock. As this line of outcrops is paralleled by the Southern Railroad, which is at no place more than 3 miles distant, numerous favorable sites for cement plants are offered. The most promising location, however, is in the immediate vicinity of Woodstock, since here the cement rocks outcrop on the western side of the North Fork of the Shenandoah River. Farther south the river flows between the railroad and the cement-rock outcrop, and would thus greatly increase the cost of a spur line.

Pure limestone for mixture with the cement rock can be found in the immediate vicinity, more probably in greatest quantity just west of the town. Limestone strata high in calcium carbonate and low in magnesia were found interbedded with the dolomites west of Woodstock, and more extended search will no doubt reveal an ample supply.

Good railroad facilities, both for obtaining the fuel supply and for shipping the finished material, are to be found at this place. Coal could be secured from the North via the Baltimore and Ohio and Southern railroads, and from the South via the Chesapeake and Ohio, the Valley Branch of the Baltimore and Ohio, and the Southern railroads. By the same lines the finished material could be shipped to the East and tidewater.

Some miles east of Woodstock this same succession of rock is encountered along the eastern edge of Massanutten Mountain. The cement rocks here occur along a northeast-southwest line, paralleling the belt along the western side of the mountain. Along this eastern belt the argillaceous limestones have practically the same composition as those exposed near Woodstock.

Broadway and Timberville.—Cuts along the Southern Railroad in the vicinity of these two towns show the presence of small syncline of shales and argillaceous limestone very similar in texture and composition to the same rocks found farther south about Harrisonburg.

Harrisonburg and vicinity.—A syncline showing the Trenton argillaceous limestones and Martinsburg shales occurs just west of Harrisonburg and extends northeast-southwest for a distance of some miles. The cement rock is especially well shown along the street just west of the Southern Railroad depot, but exposures of the shales and underlying argillaceous rocks may be seen all along the country roads going northwest, west, and southwest from the town. The thickness of the argillaceous limestones in this vicinity could not be ascertained with certainty because of the lack of continuous exposures, but it probably does not fall short of 200 feet. Fossils indicating the Trenton age of the strata were not uncommon in the rocks shown along the western edge of the town.

Pure limestone deposits are found in considerable quantity east and southeast of Harrisonburg. Exposures of this rock may be seen in a cut on the Chesapeake and Western Railroad just east of the crossing with the Southern Railroad. Here is found a pure gray limestone having the composition shown in analysis No. 1 of the table below.

From 75 to 100 feet of argillaceous limestones and calcareous slates are exposed in a cut on the Chesapeake and Western Railroad southwest of Harrisonburg and just west of the Southern crossing. Samples from this cut were analyzed by Charles Catlett, with the result shown in analysis No. 2.

About 1½ miles north of Harrisonburg the Southern Railroad passes through a cut about 20 feet high and 400 to 600 feet in length, exposing comparatively horizontal slaty limestone. This was found to have the composition shown in analysis No. 4.

Partial analyses of cement materials in the vicinity of Harrisonburg, Va.

[Charles Catlett, analyst.]

	1.	2.	3.	4.
Lime (CaO)	54.24	35.79	49.00	38.32
Magnesia (MgO)	.60	1.42	2.36	1.67
Alumina (Al_2O_3) } Iron oxide (Fe_2O_3) }	.60	3.32	.70	1.58
Insoluble	2.08	27.06	7.00	25.24

1. Pure gray limestone, cut on Chesapeake and Western Railroad just east of crossing with the Southern Railroad.
2. Calcareous slates, exposed in cut on Chesapeake and Western Railroad just west of crossing with the Southern Railroad.
3. Dark, friable limestones, exposed at crossing of railroads just south of Harrisonburg.
4. Calcareous slates, cut along Southern Railroad 1½ miles north of Harrisonburg.

Mount Jackson and New Market.—Numerous exposures of the argillaceous limestone may be seen in the foothills of Short Mountain, several miles east of Mount Jackson, and also in the immediate vicinity of New Market. Practically the same thickness of rock as that shown at Woodstock and vicinity is shown here, while the analysis of the rocks at both of these places indicates that in chemical composition at least they are quite similar to the best Lehigh rock.

Analysis of Trenton limestone, near Mount Jackson, Va.

Silica (SiO_2)	18.20
Alumina (Al_2O_3) and iron oxide (Fe_2O_3)	8.00
Lime carbonate ($CaCO_3$)	70.00
Magnesium carbonate ($MgCO_3$)	2.00
Water (H_2O)	3.00

Western edge of valley, north of Staunton.—The outcrops of the Trenton limestone along the western edge of this part of the valley are in general so remote from railroads that, in spite of the excellent rock shown at a few places, exploitation of this region is at present useless. Furthermore, throughout a considerable portion of this region the argillaceous limestones are cut out by overthrust faulting, the magnesian limestone resting upon the shales of still higher formations. But a single area can be mentioned in which the cement rocks are exposed within a reasonable distance of a railroad. Several miles north of Stokesville, the terminus of the Chesapeake and Western Railroad, and a few miles south of Little North Mountain, good outcrops of the rock are encountered. The quantity and quality of these limestones are such that, with the railroad facilities so near at hand, the rock will undoubtedly prove of economic importance. Shales are at hand for mixture with the cement rock when its percentage of lime is too high, while pure limestones, to increase the percentage when necessary, are found in sufficient quantity in the valley just to the east. Indeed, even with the present facilities, this is one of the most promising cement localities in the valley.

The composition of an average sample of the rock is shown by the following analysis:

Analysis of Trenton limestone from an exposure several miles north of Stokesville, Va.

Silica (SiO_2)	14.34
Alumina (Al_2O_3) and iron oxide (Fe_2O_3)	6.49
Lime carbonate ($CaCO_3$)	73.14
Magnesium carbonate ($MgCO_3$)	2.90
Water (H_2O)	4.00

Mount Sterling and vicinity.—From Staunton to Mount Sterling and thence for several miles northeast the Valley Branch of the Baltimore and Ohio Railroad either closely parallels or cuts through the belt of argillaceous limestone brought up on the western flank of the Massanutten Mountain syncline. The same rocks reappear on the eastern flank, 3 to 4 miles distant. The intervening country is occupied by Martinsburg shales, all of the younger rocks found on Massanutten Mountain having been removed by erosion. The favorable composition of the rock and the proximity of these two belts to railroads—the western to the Baltimore and Ohio and the eastern to the Shenandoah Valley—cause them to be worthy of attention. The following analysis of specimens from the eastern belt in the vicinity of Weyers Cave shows more magnesia than the average:

Analysis of Trenton limestone, near Weyers Cave, Va.

Silica (SiO_2)	14.62
Alumina (Al_2O_3) and iron oxide (Fe_2O_3)	6.90
Lime carbonate ($CaCO_3$)	67.92
Magnesium carbonate ($MgCO_3$)	4.69
Water (H_2O)	3.94

Staunton.—East and northeast of this place the Trenton limestones are well developed, and, together with the shales and pure limestones near by, offer abundant raw material for the manufacture of cement. The railroad facilities at Staunton are exceptionally good, for here a plant could obtain coal and ship its products over several lines. Ordinarily coal could be had on the most favorable terms over the Chesapeake and Ohio, but in times of labor disturbances in the New River field the fuel supply could still be obtained from the Fairmont region. The Trenton limestones in the vicinity of Staunton, as a rule, run unusually high in lime, so that shales or clays for mixture with them will be necessary. Unlimited quantities of shales may be found in connection with the limestone, but deposits of good clays are not so common. In this region the lower part of the shales are unusually calcareous, as the following analyses show, but higher up in the series the percentage of lime is very small:

Analyses of Martinsburg shales and Trenton limestone, vicinity of Staunton, Va.

[Charles Catlett, analyst.]

	1.	2.	3.	4.
Silica (SiO_2)	19.28	19.92	23.08	10.28
Oxides (Al_2O_3, Fe_2O_3)	9.86	10.76	10.08	4.36
Lime (CaO)	36.42	37.05	35.89	45.79
Magnesia (MgO)	1.08	1.72	.94	.79
Carbon dioxide (CO_2)	31.70	--------	--------	32.80

1–3. Calcareous shales showing variation in composition.
4. Trenton limestone.

Lexington.—In point of having an abundance of argillaceous limestones close at hand, Lexington is most favorably placed, as it is situated in the midst of a broad area of these rocks. In this part of the valley the Trenton limestones have been closely folded and overturned to the west, so that the exposures seem to show an extraordinary thickness. Occasionally the core of an anticline or syncline may be noted, and whenever it is possible to make accurate measurements the thickness of the formation is found not to exceed 350 feet. The composition of this rock is such that theoretically it ought to make a high-grade Portland cement, but, as noted by Catlett, it is a question whether the relatively high ratio of silica to iron and alumina, tending to increase the refractory character of the clinker, is offset by the finely divided condition and intimate mixing of the natural material. The following analyses show the variation in the composition of the rocks:

Analysis of Trenton limestones from Lexington, Va.

[Charles Catlett, analyst.]

	1.	2.	3.	4.	5.	6.
Silica (SiO_2)	0.73	9.31	11.86	12.92	17.42	22.60
Oxides (Al_2O_3, Fe_2O_3)	.79	3.47	1.76	3.88	4.70	7.06
Lime (CaO)	53.71	46.30	46.64	45.14	42.44	36.72
Magnesia (MgO)	.83	.86	.74	1.37	1.68	1.69
Carbon dioxide (CO_2)	--------	--------	38.32	37.20	35.62	32.52

Analysis of Trenton limestone, 5 miles east of Woodstock, Va.

Silica (SiO_2)	16.34
Alumina (Al_2O_3) and iron oxide (Fe_2O_3)	7.49
Lime carbonate ($CaCO_3$)	74.14
Magnesium carbonate ($MgCO_3$)	1.00
Water (H_2O)	2.00

PUBLICATIONS ON PORTLAND, NATURAL, AND PUZZOLAN CEMENTS.

The following list includes the principal publications by the United States Geological Survey, or by members of its staff, on cement materials:

CATLETT, C. Cement resources of the Valley of Virginia. In Bulletin U. S. Geol. Survey No. 225, pp. 457–461. 1904.

CUMMINGS, U. American rock cement. A series of annual articles on natural cements, appearing in the volumes of the Mineral Resources, U. S., previous to that for 1901.

DURYEE, E. Cement investigations in Arizona. In Bulletin U. S. Geol. Survey No. 213, pp. 372–380. 1903.

ECKEL, E. C. Slag cement in Alabama. In Mineral Resources for 1900, pp. 747–748. 1901.

——— The manufacture of slag cement. In Mineral Industry, vol. 10, pp. 84–95. 1902.

——— The classification of the crystalline cements. In Amer. Geologist, vol. 29, pp. 146–154. 1902.

——— Portland-cement manufacture. In Municipal Engineering, vol. 24, pp. 335–336; vol. 25, pp. 1–3, 75–76, 147–150, 227–230, 405–406. 1903.

——— The materials and manufacture of Portland cement. In Senate Document No. 19, 58th Congress, 1st session, pp. 2–11. 1903.

——— Cement-rock deposits of the Lehigh district. In Bulletin U. S. Geol. Survey No. 225, pp. 448–450. 1904.

——— Cement materials and cement industries of the United States. Bulletin U. S. Geol. Survey No. 243. 1905.

NEWBERRY, S. B. Portland cement. A series of annual articles on Portland cements, appearing in the various volumes of the Mineral Resources, U. S., previous to that for 1901.

RUSSELL, I. C. The Portland-cement industry in Michigan. In Twenty-second Ann. Rept. U. S. Geol. Survey, pt. 3, pp. 629–686. 1902.

SMITH, E. A. The Portland-cement materials of central and southern Alabama. In Senate Document No. 19, 58th Congress, 1st session, pp. 12–23. 1903.

——— Cement resources of Alabama. In Bulletin U. S. Geol. Survey No. 225, pp. 424–447. 1904.

TAFF, J. A. Chalk of southwestern Arkansas, with notes on its adaptability to the manufacture of hydraulic cements. In Twenty-second Ann. Rept. U. S. Geol. Survey, pt. 3, pp. 687–742. 1902.

CLAY, FULLER'S EARTH, ETC.

CLAY INDUSTRIES OF THE INDEPENDENCE QUADRANGLE, KANSAS.

By F. C. SCHRADER and ERASMUS HAWORTH.

SKETCH OF THE REGION.

Location.—The Independence quadrangle lies in the southeastern part of Kansas adjacent to Indian Territory and within the Kansas oil and gas fields. It has an area of nearly 1,000 square miles, embracing all of Montgomery County and portions of adjacent counties. Its chief towns are Independence, Coffeyville, Cherryvale, Neodesha, Caney, and Elk City.

Geology.—The rocks of the district are of Coal Measure age, and consist of limestones alternating with heavier shales and sandstones. In general they dip gently northwestward at the average rate of about 15 feet per mile, and exhibit but little evidence of disturbance. They include 7 formations and have a total thickness of about 1,000 feet.[a]

CLAY INDUSTRIES.

The clay resources of the quadrangle consist of numerous beds of shale, some of which attain a thickness of 80 feet or more, and are exposed over an area of many square miles. At present the most important and the most extensively developed beds are at Fredonia, Buxton, Caney, Buff Mound, Neodesha, Sycamore, Table Mound, Independence, Tyro, Cherryvale, Coffeyville, and northwest of Coffeyville. The abundance of natural gas in all parts of the field and these shales render the region peculiarly favorable for the development of clay industries, which include the manufacture of brick, roofing tile, and pottery.

Brick.—Brickmaking is one of the most important industries. The plants now working produce about 75,000,000 bricks a year, and have

[a] For a fuller statement on geology of region, see pp. 446–449, this volume.

a capacity considerably greater than this. Active operations are in progress at Coffeyville, Cherryvale, Independence, Caney, Sycamore, Neodesha, and Buff Mound. The material used at all these plants is practically the same, being common Coal Measure shales. At Coffeyville and in the region to the northwest are three plants operated by as many different companies. The plant at the southern edge of the town uses shale from the Parsons formation; the other two plants are northwest of town and use shale from the formation overlying the Parsons. This overlying shale also supplies the plant at Mound Valley, 5 miles east of the Independence quadrangle. At Cherryvale the six plants, operated by six different companies, are situated both northwest and south of the town, and use the Cherryvale shale, which occurs in the mounds that are so numerous in that locality. At Independence the brick plant is in the northwest part of the town, and the shale is brought by the Santa Fe Railroad from Table Mound, which stands on the banks of Elk River 4½ miles to the northwest. At Table Mound the shale bed has a thickness of 80 feet. At Caney the plant is north of town, at the foot of a large mound, from which the shale is obtained. At Sycamore the plant stands north of town, on the eastern side of the bluff from which the shale is quarried; and about midway between Sycamore and Neodesha, and similarly located with reference to the same escarpment, is the Neodesha plant, using the same shale as the Sycamore plant. This shale is also used by the Altoona or Buff Mound plant, located at the west base of Buff Mound, 4 miles north of Neodesha. Here the bed has a thickness of 60 feet. The pits of the Sycamore, Neodesha, Altoona, and Independence plants, together with those at Table Mound, are all excavated from the same shale, contained in the upper part of the Chanute shale, just below the Iola-Allen limestone.

All the plants of the quadrangle have many points in common. Though their machinery, kilns, and outdoor conveniences may differ, they are alike in that they make brick from practically the same grade of shale, which is quarried, crushed, tempered, and molded in substantially the same manner. There is a striking similarity also in the kind of brick manufactured. The chief product is common building brick. Next in abundance come vitrified brick, or pavers, followed by sidewalk brick and the different styles of dry-pressed or re-pressed ornamental brick.

Common brick.—In the manufacture of common building brick the shale is ground to a fine powder, is sufficiently tempered with water to make a nice mold, and is then forced through a die by auger motion. The rod or mass of clay forced out is carried by belt conveyor to a proper distance and cut into brick by machinery. For burning, the brick are usually built in a series of rectangular kilns 10 to 14 feet high, placed 6 to 10 feet apart, and are supplied with gas by lateral pipes which tap a common main laid through their midst. A large Bunsen burner attachment is placed at the kiln end of the lateral, so that the amount of air to be mixed with the gas is well regulated. It usually requires from six to nine days' firing to burn such a kiln of brick and from three to five days for the mass to cool after the gas is shut off. Owing to the iron oxides in the shale all the building brick in the area under consideration burn to a beautiful uniform brick-red color.

Vitrified brick.—Thus far the demand for building brick has been so great that some of the companies have confined their efforts entirely to the production of this class and have not made vitrified or paving brick. The latter are made, however, by all the larger companies. The only essential difference between making a building brick and a paving brick is in the firing. The latter requires a much higher temperature than the building brick—a temperature that will bring its entire mass to a state of incipient fusion. To accomplish this a special style of kiln is necessary. The one usually employed is some form of the circular down-draft kiln, with a low, dome-shaped roof and open-draft spaces connecting from the floor with the chimney. Gas mixed with air is admitted on the side, similar to the method already described for rectangular kilns. Upon entering the kiln it is deflected upward to the concave roof and then reflected down through the mass of brick to the opening in the floor and out through proper conduits and chimneys. It usually requires about two days' longer firing to burn a kiln of vitrified brick than one of common brick.

Dry-pressed brick.—The essential differences in the methods of manufacturing common building brick and dry-pressed brick are the amount of water used and the enormous amount of pressure to which the latter are subjected. For molding common building brick and vitrified brick a sufficient amount of water is added to produce a stiff mud, but with the dry-pressed brick the amount of water added is so small it can scarcely be noticed in the clay.

This use of a small amount of moisture keeps shrinkage and warping in the dry-pressed brick at a minimum and is one of the reasons for the superiority of this brick.

The operations of the Federal Betterment Company at Cherryvale show that where there is no culling or discarding dry-pressed brick can be placed on the market almost as cheaply as others.

Of the plants enumerated only seven produce dry-pressed brick, namely, the two each at Cherryvale and Coffeyville, and those at Independence, Caney, and Sycamore.

Roofing tile.—A plant for the manufacture of roofing tile, owned by the Western Roofing Tile Company, is operated at Coffeyville.

It is situated beside the Missouri Pacific Railroad, in the southwestern part of the city. It manufactures red tile of ordinary shape and also a number of different kinds of fancy-shaped tile of varying colors, as demand or occasion may require. It makes also a great variety of ornamental patterns for cornices, gables, finals, etc., and is well equipped for such work. The company is fortunate in having a clay that burns to a rich, deep, uniform red of pleasing tint. Although the industry dates only from 1903, the company has secured an excellent start and is already shipping roofing tile as far east as St. Louis and as far north as Iowa.

Pottery.—A large pottery plant, operated by the Coffeyville Pottery and Clay Manufacturing Company, stands at the northeast edge of the town. It makes practically all kinds of stoneware, such as crocks, jars, jugs, etc., and during the greater part of the year it produced about 40,000 gallons of hollow ware per month, using, upon the average, 4 pounds of clay per gallon.

THE CLAY DEPOSITS OF WASHINGTON.

By Henry Landes.

INTRODUCTION.

The value of the clay products of Washington in 1903 amounted to nearly $1,000,000. The value of such products in 1898 was only one-quarter as much, thus showing a very large gain in six years. In a State as lately settled as Washington it is not surprising that common bricks represent more than one-half the value of the clay products. As the towns have grown into cities and the small cities have become larger and wealthier the use of pressed and ornamental brick, ornamental terra cotta, and similar products has increased very rapidly. With the growth of the municipalities there has come a demand for permanent improvements and larger and larger quantities of vitrified brick and sewer pipe are used each year. The great increase in the number of farms has caused a sharp rise in the demand for draintile. The discovery of clays of a good grade has led to the manufacture of stoneware and higher grades of pottery to supply the local demand.

Statistics of clay products of Washington for 1903.

	Quantity.	Value.	Average value per thousand.
Common brick	72,825,000	$557,147	$7.65
Pressed brick	3,421,000	65,755	19.22
Vitrified brick	4,555,000	67,314	14.78
Fire brick		13,932	
Draintile		10,883	
Sewer pipe		171,133	
Stoneware		14,100	
Ornamental brick, terra cotta, fireproofing, hollow building tile, and miscellaneous		28,001	
Total		928,265	

Value of the products of clay in Washington, 1898–1903.

1898	$250,988
1899	591,277
1900	625,459
1901	944,798
1902	905,231
1903	928,265

DISTRIBUTION OF DEPOSITS.

The igneous and sedimentary rocks from which clays are usually derived are common in the State. Of the igneous rocks granite and basalt are perhaps the most common. Granite is found very generally in the northern and northeastern parts of the State, while basalt is the country rock in all the southeastern sections. Of the sedimentary rocks, shales afford the chief sources of clays. They occur very commonly west of the Cascades, especially in the Puget Sound basin. Large deposits of clay are found within the extensive glaciated areas. It is sufficient to say that there is scarcely a region of any extent in which clays suitable for the manufacture of common brick may not be found. From time to time better grades of clay are discovered, and beyond a doubt the State contains deposits of clay which may be used in the manufacture of the finest wares.

While deposits of clay occur at very many points, it is only in the more thickly settled parts of the State that they have received any attention or have been developed in the least. At the present time there are three principal centers for the manufacture of clay products, which may be designated the Seattle district, Spokane district, and Sopenah district.

In the immediate vicinity of Seattle are extensive beds of clay suitable for making common and hollow brick, draintile, and similar products. At Taylor and at Kummer, a few miles southeast of Seattle, are extensive deposits of clay very well adapted to the manufacture of pressed brick, sewer pipe, fire brick, and vitrified brick.

At Clayton, about 30 miles north of Spokane, are large deposits of clays which have been developed, and ornamental brick, terra cotta, stoneware, and other clay products are manufactured. At Meade, between Spokane and Clayton, is a bank of clay from which common bricks are made. At Freeman and Mica, two towns south of Spokane, are beds of clay of excellent quality which have been worked for some time.

At Sopenah, on the Northern Pacific Railway, are extensive outcrops of shale which yield clay of good quality for the manufacture of sewer pipe, draintile, and different varieties of brick. East of Sopenah for a number of miles are similar deposits of clay. This is one of the most extensive clay districts of the State.

Besides the localities mentioned above, there are other places where the demand for clay products has led to the opening and exploitation of beds of clay, though on a less extensive scale. Among the most important are Tacoma, Chehalis, North Yakima, Aberdeen, Wenatchee, Pullman, and Palouse.

DESCRIPTIONS OF CLAY DEPOSITS.

Seattle district.—In the vicinity of Kummer, on the line of the Columbia and Puget Sound Railway, are extensive deposits of clay, some of which have been developed for a number of years. The most prominent ones are those owned by the Denny Clay Company. This company manufactures no clay products at this place, but ships all of the clay to its principal works at Van Asselt, near Seattle. The clay beds are interstratified with layers of sandstone and with seams of coal. The strike of the series is about north and south (magnetic). The dip is to the east at an angle of 52°. A section across the coal and clay beds that are used is given below:

Section at clay and coal mine at Kummer.

	Ft.	in.
Sandstone.		
Coal	3	8
Sandstone	60	0
Coal and bone	2	4
Arenaceous clay	60	0
Coal	2	0
Bone	2	0
Coal	2	0
Sandstone	30	0
Blue shale	10	0
Coal	2	10
Sandstone	80	0
Clay (used for sewer pipe)	18	0
Coal	2	6
Coarse yellow sandstone	20	0
Bluish shale and sandstone	100	0
Coal	4	6
Clay (used for sewer pipe)	20	0
Carbonaceous clay	10	0
Flint clay (used for fire brick)	7	0
Coal and bone	2	3
Sandstone.		

At Kummer the common methods of coal mining are employed in obtaining the clay, the room-and-pillar scheme being followed. The flint fire clay is brownish black, very fine grained, and hard. It breaks with a marked conchoidal fracture, and the edges of a broken piece are usually very sharp. The sewer-pipe clays are fine grained, break with sharp edges, but do not possess the conchoidal fracture of the fire clays. They are brown to black in color, and contain some carbonaceous matter. The presence of nonmarine shells within the clays, in connection with other facts, tends to prove their estuarine or fresh-water origin.

The coal which is mined in connection with the clay is all shipped to the factory at Van Asselt, where it is used in burning the clay wares. Relatively pure sand is obtained from the beds of sandstone noted in the section above. The sand is shipped to the factory and used with the clay in the manufacture of certain articles.

In mining clay, coal, and sand at Kummer tunnels have been driven into the various beds and seams at points about 20 feet above the high-water mark of Green River. From the river bank the materials are drawn up an incline over 600 feet in length to the top of the plateau. At this place they are dumped into cars and carried to Van Asselt.

About 2 miles west of the town of Kummer, at the base of one of the bluffs of Green River, several beds of clay have been found and some pits opened. As far as developments show, the beds are comparatively thin and lie almost flat. The clays exhibit several varieties of color, some being red, some blue, and some pure white. Much of the clay is very fine grained, free from grit, and possesses marked plastic qualities. These pits have been opened by the Auburn Pottery Company, and the clay is hauled by wagon to Auburn, about 10 miles away.

At Taylor, on one of the branch lines of the Columbia and Puget Sound Railway, are extensive deposits of clay, which have been used for some time by the Denny Clay Company. The clays are part of the coal-bearing series, and both clay and coal are taken from the same tunnel. The strata have a northwest-southeast strike and a dip to the southwest of 82°. In the old workings clay is taken from one stratum, having a width of 18 feet. This clay is compact and hard, and is in three colors—white, buff, and purple. At the new workings a tunnel of 1,000 feet has been driven which has crossed several layers of clay, coal, and sandstone. The tunnel shows the following section:

Section in new tunnel at Taylor.

	Feet.
Glacial sediment	15
Sandstone	60
Coal (No. 1)	5
Purple clay	18
Sandstone	45
Clay (No. 1)	18
Sandstone	60
Clay (No. 2)	16
Sandstone	75
Coal (No. 2)	7

	Feet.
Sandstone	150
Coal (No. 3)	5½
Clay (No. 3)	24
Coal (No. 4)	8
Sandstone (white)	70
Clay (No. 4)	12
Sandstone	150
Coal (No. 5)	4
Flint clay (No. 5)	7
Sandstone	

The beds of coal are all workable and are of good quality. None of the coal that is mined is sold, but all is used in burning the clay. Of the clay beds only Nos. 1 and 2 are being worked at the present time. No. 1 clay is fine grained, massive, and when broken shows sharp edges and an uneven fracture. No. 2 clay is almost black and breaks with a conchoidal fracture. It is heavy, massive, and compact. No. 3 clay is dark, almost black, and contains a little bituminous matter. It is hard, compact, and heavy. No. 4 clay is dark gray, massive, and breaks irregularly. It is more plastic than the associated clays. The major portion of the clay that is mined is used at the plant near by in the manufacture of vitrified bricks, but a portion of it is shipped to Van Asselt.

Among the coal-bearing strata in the vicinity of Renton are beds of shale which are of value, and one of these has been developed by the Renton Clay Company. The bed of clay which is used is about 25 feet thick and lies very nearly flat. It outcrops upon a hillside, and, since only a little stripping is necessary, the clay is obtained by quarrying rather than by the usual mining methods.

Along Duwamish River, south of Seattle, are a number of clay deposits, which have been utilized chiefly in the manufacture of common and hollow brick and draintile. Some of the clay beds contain marine shells, indicating a slight rise within comparatively recent times. As far as observed, the maximum height of the clay beds above tide is about 50 feet. Except for the oxidized portions which make up the first 10 or 15 feet of the clay, the remainder of it is of a deep bluish color, usually fine grained and plastic, but now and then containing thin lenses of sand and occasionally small pebbles. While it contains sufficient fluxes to give it a fairly low melting point, it makes a common brick of extraordinary hardness and strength.

At other places in the vicinity of Seattle are clays of glacial origin having great extent. The glacial sediments about Puget Sound are as a rule very thick. With the beds of till, stratified sands, and gravel are occasional layers of clay, which are of value for the making of common brick. The clay is usually bluish and comparatively free from sand. Now and then sand and gravel appear, but ordinarily not in sufficient amount to impair the quality of the brick. The extent of such deposits is very great, and at the more favorable localities brick industries have been developed.

Spokane district.—At Freeman, in the southern part of Spokane County, several clay pits have been opened by the Washington Brick, Lime, and Manufacturing Company, of Spokane. The general classes of clays are found here—a clay derived from basalt and one derived from granite and certain associated rocks. Two large pits have been opened, and the dividing line between the granite area on the east and the basalt field on the west passes between the two clay deposits, so that both kinds of clay are taken out. The clay above the basalt is about 60 feet in thickness, the upper 25 feet only being worked. The lower part of the clay is doubtless of residual origin, but the upper portion has clearly been blown about by the winds and displays an eolian character. The clay is of a deep reddish-brown color, and much of it is distinctly jointed. It contains more or less grit and occasionally thin layers of sand or small pebbles.

The adjacent clay pit is located in rocks composed primarily of granite, gneiss, and pegmatite dikes, with some mica-schist. All these rocks have been profoundly affected by weathering. They have been made so soft and incoherent that they may easily be taken out with a pick and shovel. A test hole to the depth of 80 feet showed the rocks to be of the same nature to that depth. In the face of the quarry, which is vertical and about 20 feet high, the rocks show that they have suffered no displacement as a result of weathering, occupying perfectly normal positions. The very marked excess of weathering over erosion is due chiefly to the fact that the country is comparatively level or very gently rolling and the annual rainfall is low. Upon the walls of the quarry a wonderful array of brilliant colors is shown, mainly due to varying degrees of oxidation. The chief colors are varying shades of red, with yellows, browns, blues, and pure whites. From the pegmatite dikes, which are rich in feldspar, clays of good quality are obtained, but the materials taken from the pit are scarcely differentiated in use, some of them being used with the clay of basaltic origin in the manufacture of common brick, while some is used in the manufacture of fire brick and fireproofing.

At Mica are extensive deposits of clay which have been derived from granite, gneiss, pegmatite, schist, etc. These deposits lie at the foot of Mica Mountain, near the contact of the granites and allied rocks with the basalt of the plain. The clay beds are in part residual, but under the influences of gravity and surface wash some of the clay has been shifted from its original position and deposited farther down the slope. The residual clay is variegated in color, and exhibits the iron minerals in varying stages of decomposition and oxidation. The transported or washed clay is pure white in appearance, and has been derived chiefly from the feldspars of the granite and pegmatite dikes. This clay is very fine grained and free from grit. It has a greasy feel, is plastic, and in water slakes quickly. The clays at Mica are used chiefly by the American Fire Brick Company in the manufacture of sewer pipe and fire brick.

Between Mica and Spokane, especially in the neighborhood of Chester, are deposits of clay similar in appearance, character, and origin to those of Mica. At a few points some test pits have been dug in them, but for the most part they are wholly undeveloped. A company has lately begun the manufacture of clay goods at Chester, and it is likely that similar industries will soon be established at near-by places.

About 3 miles from the center of Spokane, along Latah Creek, is a deposit of clay which has been used in making common bricks. The clay varies in color from an almost pure white to buff or brown, with occasional streaks of an orange hue. It is usually massive, but often shows a fine lamination. It breaks with a conchoidal fracture and with sharp edges. It is fine grained, possesses a gritty feel, and has all through it very small flakes of muscovite mica. The clay has evidently been derived from a granitoid rock, although basalt is the only country rock in the immediate neighborhood. A casual inspection of the deposit failed to bring to light the origin of the clay. Elsewhere about Spokane, between extrusive sheets of basalt there are beds of clay of lacustrine origin. The clay in question may represent such a deposit with the basalt removed from above it, or it may be a part of the extensive deposits of glacial origin which line the valley of Spokane River throughout almost its entire length.

At Clayton there are extensive deposits of clays which have been utilized for a number of years. They are used chiefly by the Washington Brick, Lime, and Manufacturing Company in the manufacture of terra cotta, pressed, vetrified, sidewalk, and common bricks, fire proofing, roof tiles, drain tiles, and sewer pipe. The clay is also used by the Standard Stoneware Company in the manufacture of stoneware and flower pots. The clay deposits are located upon an extensive plain, almost level or gently rolling, and from test pits and drill holes they are known to cover several thousand acres. The beds lie almost flat and are usually covered by only a thin coating of soil. Some of the clay is clearly of residual origin, being derived from the decomposition of granite, which is the bed rock of Clayton and vicinity. The clay, or more properly sand, thus produced varies in color from white to red. The feldspar has been changed to kaolinite; the quartz has been set free, and the iron-bearing minerals have been thoroughly decomposed and their soluble constituents been lost by leaching. Pits have been opened in the decayed granite to a depth of 15 feet or more, and the rock to this depth is sufficiently soft to be easily removed with pick and shovel. Adjacent to the residual clay and sand deposits are beds of clay which are without doubt of granitic origin, but which have been laid down in their present positions by water action. These clays are in part a pure white and in part a light yellow in color. Sometimes the two colors occur alternately in thin bands. The yellow clay is very soft and contains some silica in very fine grains. The white clay is very finely laminated, usually soft, and sometimes breaks with a conchoidal fracture. It possesses marked plastic properties, and for some years has been used in pottery work.

Sopenah district.—In the valley of Cowlitz River, especially about and east of Sopenah, the existence of large bodies of clay has been known for some time. The deposits which have been worked thus far all lie very near Sopenah and the clay has been used chiefly by the Little Falls Fire Clay Company in the manufacture of sewer pipe, fire brick, common brick, and draintile. The clay beds form part of an extensive series of sedimentary rocks of Eocene age, mainly clays and sandstones. Within the clays shells of marine animals are commonly found, and in adjacent sandstone beds such shells occur in great abundance. Several pits have been opened in the clay beds, the necessary stripping of soil amounting to about 5 feet. For a distance of about 12 feet below the surface the clay is usually jointed and is of a red or a reddish-brown color. Below the weathered zone the color of the clay is a light gray, sometimes approaching blue. In all the clay flakes of muscovite mica occur, and occasionally some sandy layers are encountered. It has been found in working the clay that the weathered part is more desirable than the unweathered part, since the fusion point of the latter is rather low. In practice it has been found also that better sewer pipe can be made by adding sand to the clay than by using the clay alone.

Outcrops of clay deposits have been noted at a number of places in the vicinity of Chehalis. The clays are residual and comprise a part of the coal-measure series of the region. They lie in thick beds, dip gently, and are very easy of access. The quality of the clays has been but slightly investigated. A plant for the manufacture of common brick has lately been installed at Chehalis. The clay used is taken from the surface, only a few inches of soil and vegetable matter being removed. It is light brown, and contains some fine sand and minute flakes of muscovite mica.

Whitman County.—Large deposits of clay are found along Palouse River, especially near the town of Palouse and to the east of it. The clay occurs in distinct layers and is therefore of sedimentary origin.

It closely resembles kaolin and has doubtless been derived from a granite or other rock containing much feldspar. The clay bed being worked lies about one-half mile from Palouse River. It has a thickness varying from 15 to 20 feet and is overlain by 10 to 15 feet of soil. The clay is mostly white, soft, fine grained, and free from grit. It has a greasy feel, is very plastic, and when placed in water slakes rapidly. The clay is used chiefly in the manufacture of stoneware at the plant of the Palouse Pottery Company.

Yakima County.—Alluvial deposits of clay occur in the valley of Yakima River near North Yakima. The bed of clay that has been opened up is only about 3 feet in thickness. It lies at the surface and is underlain by beds of coarse gravels and bowlders. The clay is dark brown and contains much vegetable matter. It is sandy, soft, and incoherent, and can be used only in the manufacture of common brick.

THE BENTONITE DEPOSITS OF WYOMING.

By C. A. Fisher.

Introduction.—The variety of clay known as bentonite was first described in 1898 by the late Prof. W. C. Knight,[a] of the Wyoming State School of Mines. The first name given to this product was taylorite, in honor of Mr. William Taylor, of Rock Creek, Wyo., who brought the clay to notice. It was discovered later, by Mr. Knight, that the name taylorite was preoccupied, consequently bentonite[b] was proposed, after the Benton formation, in which the most extensive deposits of this peculiar variety of clay are found. This formation has a wide distribution throughout the Northwest, particularly in Wyoming. The deposits in the northeastern part of the State, in the vicinity of Newcastle, were first described in detail by Mr. N. H. Darton.[c] During the last season the writer found some thick deposits in the northern part of the Bighorn basin, in Bighorn County, Wyo.

Physical properties.—Fresh bentonite usually has a yellowish-green color, but assumes a light cream tint on exposure. It is a fine-textured, soft, massive variety of clay which is unctuous to the touch and which, on the addition of water, forms an emulsion. The material is characterized by its unusual absorbent qualities, having the capacity of absorbing three times its weight of water. In a comparative test it is reported to have taken up twice as much glycerin as infusorial earth. When fresh from the quarry, it breaks with conchoidal fracture, but upon exposure loses this property and crumbles to a light yellowish powder resembling corn meal. It was formerly classed with fire clays, but owing to its fluxing properties is unfit for this purpose.

This mineral is a hydrous silicate of alumina, a clay possessing peculiar physical properties. The specific gravity of this clay, when fresh, is 2.18. Its resemblance to ehrenbergite of Germany has been pointed out by Mr. Knight. The composition of the clay from dif-

[a] Eng. and Min. Jour., vol. 63, pp. 600–601.
[b] Eng. and Min. Jour., vol. 66, p. 491.
[c] Darton, N. H., Geologic Atlas U. S., folio No. 107, U. S. Geol. Survey, 1904.

ferent localities varies somewhat, but in general is quite uniform. The following table gives several analyses of bentonite, made at the Wyoming State School of Mines.

Analyses of bentonite from Wyoming.

	Peach Creek.	Crook County.	Weston County.	Natrona County.
SiO_2	59.78	61.08	63.25	65.24
Al_2O_3	15.10	17.12	17.62	15.88
Fe_2O_3	2.40	3.17	3.70	3.12
MgO	4.14	1.82	3.70	5.34 + CaO
CaO	.73	2.69	4.12	
NaOKO		.20 NaO		
SO_3		.88	1.53	
H_2O	16.26			9.17
Sp. gr	2.180		2.132	

Uses.—This clay has been used in various ways, chiefly in the manufacture of some of the higher grades of soap, the clay giving to the soap a certain weight and body which is considered desirable. It has also been found valuable as a packing for a special kind of horseshoe and as a diluent for certain powerful drugs sold in powdered form. Small quantities are used as an adulterant in making candy, after the alkali associated with it has been removed. In this condition it closely resembles terra alba, which is generally used. Owing to its high absorption, its use in the manufacture of dynamite has been suggested. There are also other uses suggested, such as for loading paper and for adulterations of various other kinds.

Distribution.—Bentonite has been found extensively in Wyoming. It has been reported from Crook, Johnson, Weston, Converse, Natrona, Carbon, Albany, Laramie, and Bighorn counties. The accompanying map (fig. 25), compiled from various sources, will show approximately the location of the larger areas of the Benton formation in Wyoming.

Benton group.—The rocks of the Benton group are the most widespread and constant in character of all the sedimentary deposits of the Great Plains region. Throughout Wyoming, however, considerable variation is noted in passing from east to west. In northeast Wyoming, on the west flank of the Black Hills, the maximum thickness is reached. Here the group consists of three members—a basal series of dark shales, comprising the Graneros, in which bentonite occurs; a medial limestone, known as the "Greenhorn limestone," and an upper shaly series with sandy layers, known as the "Carlile formation." The Graneros is composed chiefly of shale, but contains occasional layers of sandstone, and about halfway from the base beds of harder gray shale and sandstone, which weather light gray and form bare ridges of considerable prominence. Mr. N. H. Darton has called this series the "Mowrie beds," from Mowrie Creek, near Buffalo, Wyo., where they attain their greatest development. The Greenhorn is an impure limestone near the middle of the Benton, which forms low but distinct escarpments, while the Carlile consists of a shaly series, with sandstone layers near the base and a band of large fossiliferous concretions at the top, characterized by the occurrence of *Prionotropis woolgari* and *Prionocyclas wyomingensis*.

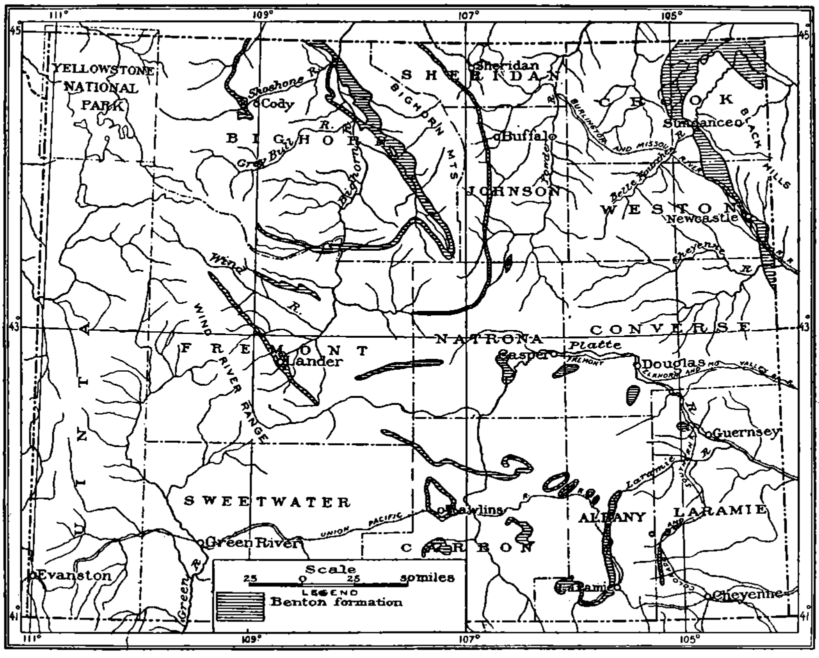


FIG. 25.—Sketch map showing distribution of the Benton formation in Wyoming.

The above subdivisions, so obvious in the Black Hills and Laramie Mountains, are not all recognizable farther west in the region of the Bighorn Mountains, owing mainly to the absence of the Greenhorn limestone, while the basal member of the Graneros is here represented by a much greater thickness of beds. It is in this region of greater development of the Graneros shales that the thickest deposits of bentonite have been found.

Occurrence and development.—Bentonite occurs at various horizons in the Benton group. In one locality, near Newcastle, Wyo., this clay occurs in passage beds at the top of the Niobrara.

The extensive deposits of bentonite discovered by the writer in the northern part of the Bighorn basin are on Dry Creek about 8 miles east of Frannie, Wyo. The Benton formation here consists of a basal member of rusty-brown, sandy shales 200 feet thick, overlain by 500 feet of very black shale, in the upper part of which occurs several horizons of bentonite. Immediately above these beds there is a very characteristic series, about 150 feet thick, of hard, lighter-gray shales and sandstone of the Mowrie beds. Next above occur about 300 feet of light-gray shales, alternating with sandy beds of no great thickness. This series is capped by 60 feet of gray, coarse-grained, cross-bedded sandstone, which in turn is overlain by another shaly series, 200 feet thick, containing concretionary bands and constituting the uppermost member of the Benton. The bentonite occurs in the black shales of the lower part of the Graneros shales, a short distance below the Mowrie beds, which here are well developed. The deposits have a total thickness of 11 feet, distributed throughout a vertical range of 100 feet. The thickest layer is about 7½ feet thick. Below the bentonite series beds of dark shale abound, and above are lighter shales, containing bands of iron concretions. The material is a gray, fine-grained, massive clay, of green and yellow tints, apparently of good quality throughout. The thin seams of gypsum generally associated with the clay in other localities are present, though not conspicuous. These deposits, when seen at a distance, appear as dull-gray bands on the face of the barren slopes of the Benton shales. The following section will show the approximate position of the different deposits at this place:

Section of a portion of the Benton formation on Dry Creek.

	Feet.
Bentonite	2
Dark fissile shale	12
Bentonite	7½
Shale	30
Bentonite	1½
Shale	30

Near the head of Dry Gulch, about 5 miles north of Cowley, Wyo., a 1½-foot layer of bentonite is found near the top of the Benton formation. The following section shows the materials associated with the bentonite:

Section at head of Dry Gulch.

	Feet.
Black shale capped by brown sandstone	6
Bentonite	1½
Black fissile shale	20

The Benton group is well developed in the Bighorn basin, being represented by 1,200 to 1,500 feet of beds. At many localities in the north half of the basin bentonite deposits were observed, usually occurring in the shales about 100 feet below the Mowrie beds.

The mining of bentonite has been carried on in Wyoming since 1888, although the output has at no time been large. Prior to 1896 Mr. William Taylor had shipped 5,400 tons from his quarry near Rock Creek station. This material was sold at $25 per ton, making a total value of $13,500. In 1897 Doctor Linscott opened a new bank of clay, apparently identical with the Taylor product, 6 miles south of Rock Creek, on the south slope of the Spring Creek anticline. The beds in this vicinity are said to extend for several miles. Later in the season Messrs. Edgar and Thole began operations on the deposits near Newcastle, Wyo. The production of the Linscott quarry for 1897 amounted to 150 tons and that of Edgar and Thole to 20 tons. The extent of the clay in Weston County is considerable, the formation extending north and west from Newcastle, apparently nearly to Moorcroft. The railroad passes along this exposure, making it possible to operate banks at several stations between these points. The material at present has a market value of about $5 a ton. This industry is of but little importance at present; but it is believed that a thorough investigation of the clay with a view to ascertaining its utility might prove profitable.

GEOLOGICAL SURVEY PUBLICATIONS ON CLAYS, FULLER'S EARTH, ETC.

In addition to the papers listed below, references to clays will be found in the publications listed under the head of "Cements," on page 545.

BRANNER, J. C. Bibliography of clays and the ceramic arts. Bulletin No. 143, 114 pp. 1896.

ECKEL, E. C. Stoneware and brick clays of western Tennessee and northwestern Mississippi. In Bulletin No. 213, pp. 382–391. 1903.

GOLDING, W. Flint and feldspar. In Seventeenth Ann. Rept., pt. 3, pp. 838–841. 1896.

HILL, R. T. Clay materials of the United States. In Mineral Resources U. S. for 1891, pp. 474–528.

——— Clay materials of the United States. In Mineral Resources U. S. for 1892, pp. 712–738. 1893.

RIES, H. Technology of the clay industry. In Sixteenth Ann. Rept., pt. 4, pp 523–575. 1895.

——— The pottery industry of the United States. In Seventeenth Ann. Rept. pt. 3, pp. 842–880. 1896.

——— The clays of the United States east of the Mississippi River. Prof. Paper No. 11. 1903.

SHALER, N. S., WOODWORTH, J. B., and MARBUT, C. F. The glacial brick clays of Rhode Island and southeastern Massachusetts. In Seventeenth Ann. Rept., pt. 1, pp. 957–1004. 1896.

VAUGHAN, T. W. Fuller's earth deposits of Florida and Georgia. In Bulletin No. 213, pp. 392–399. 1903.

WILBER, F. A. Clays of the United States. In Mineral Resources U. S. for 1882, pp. 465–475. 1883.

——— Clays of the United States. In Mineral Resources U. S. for 1883–1884, pp. 676–711. 1885.

WOOLSEY, L. H. Clays of the Ohio Valley in Pennsylvania. In Bulletin No. 225, pp. 463–480. 1904.

SALT, GYPSUM, ETC.

ZUNI SALT DEPOSITS, NEW MEXICO.

By N. H. Darton.

Forty miles south of the pueblo of Zuni, in the west central portion of New Mexico, there is a deposit of salt which is not only of great geologic interest, but promises to prove of considerable economic importance. The locality is 80 miles south of Gallup, on the main line of the Santa Fe Railroad, and about the same distance west of Magdalena, on a branch of the same railroad system. This deposit has been a source of supply for the Indians and Mexicans for several centuries, and of late the salt is hauled to ranches in a wide surrounding district. The present output averages only about a thousand tons a year, valued at about $2.50 a ton. A small colony of Mexicans at the locality collect the salt in a very crude manner. Ordinarily, persons desiring a supply go to the place and help themselves.

The deposits occur in a lake occupying a portion of the bottom of a deep depression in a plain of Cretaceous sandstone. This depression is about a mile in diameter, and has walls of sandstone, in part capped by lava, averaging 150 feet in height. The lake is about 4,000 feet long, east and west, and about 3,000 feet wide, and is apparently shallow. The water contains about 26 per cent of salt, mostly chloride of sodium. The region is arid and the evaporation causes the crystallization of the salt, especially in the shallow waters. On the south side of the lake extensive bodies of the salt rise a few inches above the surface of the water.

The lake is fed by a spring or springs that rise beneath the water near the southern margin of the lake. Whether or not the spring water is saturated with salt was not ascertained. The springs are believed to rise from red beds, which lie at no great distance below the bottom of the depression and are usually saliferous to a moderate extent. On the south side of the lake rise two recent cinder cones, one of which contains a crater, having in its bottom a salt pool in which the water stands at the lake level. The water in this pool is somewhat less saline than that in the lake.

Apparently the lake at one time filled the entire depression, but it has shrunk to its present size by evaporation and the deposition of wash from the adjacent slopes, mainly on the south. No excavations have been made on the bottom of the lake or on its shores, but undoubtedly there are extensive bodies of salt below, probably more or less mixed with mud.

A large amount of salt could be obtained by properly conducted solar evaporation of the lake water. By washing the salt with a small amount of the lake water the more soluble foreign salts are removed and almost pure chloride of sodium remains.

SALT AND OTHER RESOURCES OF THE WATKINS GLEN DISTRICT, NEW YORK.

By E. M. Kindle.

INTRODUCTION.

The Watkins Glen and Catatonk quadrangles embrace an area of about 2,000 square miles, extending from the New York-Pennsylvania State line into the southern margin of the Finger Lake region, and include the greater part of Tompkins, Tioga, Chemung, and Schuyler counties and a small portion of Cortland and Broome counties. The region is primarily a farming country, and its mineral resources are few and of small importance as compared with its agricultural wealth.

The most important mineral deposits occurring in these quadrangles are the beds of salt.

SALT.

Location of deposits.—The salt deposits of this area belong to a broad east-west belt of salt-producing territory, extending from western Wyoming County eastward into Madison County, a distance of about 150 miles. There is no definite information as to the southern limit of the salt beds, because the rapidly increasing depth at which they lie south of the developed region has prevented deep wells from reaching the salt horizon. It is probable that they extend a considerable distance to the south of the 200 or more wells and shafts now used in exploiting them. The salt beds doubtless underlie all of the northern part of the quadrangles under consideration. The salt industry has been developed, however, at only two localities, Ithaca and Watkins, where physiographic and economic conditions are most favorable for it.

The deeply excavated valleys of Lake Cayuga and Lake Seneca enable the driller to start several hundred feet nearer the salt than on the higher lands away from the lakes, while both water and railway transportation are available for the manufactured product.

Topography.—This region comprises a series of rather steep hills and ridges and their intervening valleys. The hills reach a maximum elevation of a little more than 2,000 feet. With two exceptions all of the larger valleys lie between the 800- and 1,200-foot contours. These exceptions are Lakes Cayuga and Seneca, which lie respectively

380 and 443 feet above tide. The lake valleys are very deeply filled about their heads with drift and lake clays, the filling at Ithaca having a maximum thickness of 400 feet and at Watkins of more than 1,000 feet. Wells located about the heads of these lakes have the advantage, therefore, not only of starting 400 feet or more nearer the salt than in other valleys of the region, but pass in the upper part of their course through the comparatively soft and easily drilled clays and gravels of the Ithaca and Watkins deltas.

General geology.—The surface rocks of this region comprise the sandy shales and thin-bedded sandstones of the Chemung and Nunda formations. There is a general southerly inclination of the rocks, interrupted by a series of broad, low folds with east-west trend. The salt beds occur in the Salina formation and comprise a series of beds of rock salt interbedded with green and reddish shales. In thickness the beds of salt vary from more than 50 feet to less than 5 feet. Some of the saline horizons are represented by salt crystals disseminated through the shale beds, but the thicker beds are composed of nearly pure rock salt.

At Ithaca the top of the salt has been reached in the Remington well at a depth of 2,137 feet, or 1,737 feet below sea level. The log of the old test well records the first salt at a depth of 2,244 feet, or 1,844 feet below tide. At Watkins the wells reach the salt at a depth of about 1,800 feet, or about 1,350 feet below sea level. Only two wells have been drilled which pass through the entire thickness of the salt beds. These are the Ithaca test well and the Hill well at Watkins.

The portions of these records which include the salt deposits are here given. The mouth of the George G. Hill well is located about 665 feet above tide. Its record of the salt deposits is as follows:

Log of the George G. Hill salt well at Watkins, N. Y.

	Feet.
1. Gray "shale"	1,880–2,005
2. Salt (1)	2,005–2,270
3. Limestone with occasional layers of shales	2,270–2,310
4. Salt (2)	2,310–2,338
5. Brown shale	2,338–2,378
6. Salt (3)	2,378–2,450
7. Brown shale	2,450–2,507
8. Salt (4)	2,507–2,517
9. Brown shale	2,517–2,537
10. Salt (5)	2,537–2,560
11. Brown shale	2,560–2,630
12. Salt (6)	2,630–2,680
13. Limestone and shales	2,680–2,810
14. Salt (7)	2,810–2,820
15. Very hard limestone	2,820–2,920
16–22. "Slate," limestone and shale	2,920–3,315

This record shows the salt at Watkins to be distributed through 815 feet of the Salina formation.

The following record, which was kept by Prof. C. S. Prosser, includes only the Salina portion of the old Ithaca well. The well started at 396 feet above tide.

Log of Ithaca test well, Ithaca, N. Y.

	Feet.
1. Magnesian limestones, calcareous shales, and some gypsum	1,900–2,244
2. Rock salt (1)	2,244–2,268
3. Shale	2,268–2,274
4. Rock salt (2)	2,274–2,328
5. Shale	2,328–2,340
6. Rock salt (3)	2,340–2,357
7. Shale	2,357–2,388
8. Rock salt (4)	2,388–2,409
9. Shale	2,409–2,476
10. Rock salt (5)	2,476–2,518
11. Shale	2,518–2,542
12. Rock salt (6)	2,542–2,590
13. Shale	2,590–2,650
14. Rock salt (7)	2,650–2,654
15. Shale	2,654–2,672
16. Rock salt (8)	2,672–2,714
17. Shale	2,714–2,720
18. Greenish and dark-gray shale	2,720–2,900
19. Rock salt (9)	2,900–2,906
20. Some salt crystals, the last seen	2,906–2,912
23. Green shales	2,912–2,922
24. Salt crystals, the last seen	2,922–2,944
25. Mottled red and green shales	2,944–3,130
26. Last sample	3,130–3,185

It is seen from the above that the salt deposits are distributed through 700 feet of strata and include nine distinct beds at Ithaca. Only the uppermost of the salt beds are utilized for the manufacture of salt.

Development.—The presence of salt in this region was first shown by the drilling of the Ithaca test well in 1885. No attempt to develop the salt commercially was made at Ithaca for ten years. In 1896 the manufacture of salt was begun at Ithaca by the Ithaca Salt Company. A plant with a daily capacity of 800 barrels was erected in the north part of Ithaca, just east of the inlet. The plant is now in active operation.

A second plant was put in operation about two years ago by the Remington Company. It is located on the east shore of Lake Cayuga, three-fourths of a mile north of Ithaca. Three wells have been sunk by this company. The works are now in active operation.

In 1893 the pioneer well in the Seneca Lake basin was drilled at Salt Point, near Watkins, for the Glen Salt Company. Other wells were drilled for this company at the same locality later, and a plant having a daily capacity of 1,000 barrels was put in operation by it in 1894.

More recently the Watkins Salt Company and the Union Salt Company have erected plants for the manufacture of salt in the village of Watkins. Each of these operates from three to four wells.

The vast amount of salt in western New York has led at times, to overdevelopment of the industry, with resulting small profits to the manufacturer. The National Salt Company undertook to remedy this condition a few years ago and obtained control of most of the plants. By closing unnecessary factories prices were temporarily improved. This led to fresh competition from new factories, and a consequent overproduction. As a result of the low prices which followed, the National Salt Company passed into the hands of a receiver in the summer of 1902. The Ithaca Salt Company and the Glen Salt Company were operated by the National Salt Company. The Remington and the Watkins Salt companies remained independent manufacturers.

At present three companies are in actual operation at Watkins—the Watkins Salt Company, the Union Salt Company, and the Glen Salt Company. Two companies are in operation at Ithaca—the Remington and the Ithaca Salt companies.

Manufacture and output.—The salt is extracted from the wells by forcing a flow of water through them, which returns to the evaporating sheds a strong brine. Grainers and open pans are generally used in reducing the brine to salt. The vacuum process is used by the Glen City Company, of Watkins.

The total output for the year 1904 of the several companies operating at Ithaca and Watkins was 207,475 tons.

NATURAL GAS.

Natural gas in small quantities has been obtained from several of the deep wells which have been drilled in the quadrangle. The "test well" just south of Ithaca encountered a small flow of gas in the lower Helderberg limestone horizon. One of the salt wells in Ithaca struck a flow of gas at a depth of 1,545 feet. A well which was drilled ten years ago to a depth of 2,100 feet at Wellsburg encountered gas at two horizons. The upper one, which was in the Chemung, at a depth of 137 feet below the surface, is said to have furnished a flame several feet in height for several days. In the

Catlin well, 4½ miles northwest of Horseheads, a small flow of gas appeared at a depth of about 1,265 feet near the base of the Munda.

Near West Candor, in the Owego quadrangle, a well was drilled to a depth of 1,350 feet about fifteen years ago. Only a trace of gas was found, and no oil, which was the object sought. A deep well was drilled in Owego a few years ago with similar results.

The only wells which have produced gas of commercial value are located at Watkins. One of these has supplied most of the heat for a large hotel for a number of years. The other is the Hill well which struck gas at 1,550 feet in a sandstone probably of Oriskany age. Before shooting, the gas produced a flame 2 feet high. After shooting, the gas pressure is reported to have risen to 100 pounds per square inch. The gas is used for both heating and lighting purposes. Nearly all the business places in the village are supplied from it.

Another well was begun during the summer of 1904 at Watkins for the purpose of securing a larger supply of gas.

It is worthy of note that the Watkins wells, which are the only ones in the entire region producing gas of commercial value, are located just at the axis of one of the broad, low folds which was discovered during the areal survey of this region. It happens that this fold is the lowest of those recognized in the region. The chances of success of future explorations for gas in this region would be greatly increased if they were made along the axes of some of the other larger folds. Structure is only one of the elements controlling the occurrence of gas. The presence or absence of other elements is not ascertainable from surface indications; consequently the success of a well favorably located with reference to structural features can not be positively predicted, since the texture of the rock at horizons elsewhere gas producing may or may not be favorable to its accumulation. It is evident, however, that the chances of success are greater if the well is located where one of the elements controlling gas accumulation is known to be present than if it were located without regard to structural features.

QUARRIES.

Quarries in the vicinity of each of the larger towns and cities supply the local demand for foundation work and the rougher kinds of building stones. The beds quarried are the thin-bedded sandstones of the Nunda and Chemung formations. Small quantities of paving flags are produced at some of the quarries in the Sherburne flagstone beds. The sandstones, however, are not generally satisfactory for this purpose. Considerable quantities of crushed stone are used for street paving in Elmira and Ithaca.

A dark-gray sandy shale has been extensively quarried 1¼ miles northeast of Horseheads for the manufacture of brick. The shale is mixed with glacial clay in the proportion of two parts of the former to one of the latter. The output of the factory is about 50,000 bricks per day.

At Elmira a large brick factory is operated which makes a high-grade brick from the valley clay combined with the sandy shales furnished by the quarries just east of the city.

The same quarries which furnish brick shale at Elmira supply thin-bedded sandstone, which is used extensively for foundation work in the city and to a small extent for other purposes.

SALT, GYPSUM, AND PETROLEUM IN TRANS-PECOS TEXAS.

By G. B. Richardson.

INTRODUCTION.

In the summer of 1903 a rapid reconnaissance was made of that part of trans-Pecos Texas which lies north of the Texas and Pacific Railway, the primary object being to examine conditions of occurrence of underground water.[a] The opportunity was taken to note deposits of salt, petroleum, gypsum, and sulphur in this little-known region, and the fragmentary facts observed are here recorded. The region is so little known that a brief description of the topography and stratigraphy of that part of it in which these deposits occur is also given.

TOPOGRAPHY.

The accompanying sketch map[b] (Pl. IV) illustrates the general occurrence of the deposits to be described, which are situated in eastern El Paso and northern Reeves counties. This area lies partly in the Great Plains and partly in the Cordilleras, the dividing line between the counties marking the approximate boundary of the physiographic provinces. The dominant topographic feature of the region is the highland belt comprising the Guadalupe-Delaware Mountains, that extend in a northwest-southeast direction, separating the lowlands of Toyah basin on the east from Salt basin on the west.

The Guadalupe-Delaware Mountains constitute an eastward-sloping monocline and present a steep scarp to the Salt basin. This escarpment is especially prominent in the northern part of the area, where it rises almost 5,000 feet above the adjacent plain. Southward the difference in elevation decreases to about 1,000 feet.

The Guadalupe Mountains extend into Texas from New Mexico, crossing the State line about 45 miles west of Pecos River. Here the

[a] In cooperation with the University of Texas Mineral Survey.

[b] For more detailed map, see Richardson, G. B., Report of a reconnaissance in trans-Pecos Texas: Bull. No. 9, University of Texas Mineral Survey, 1904.

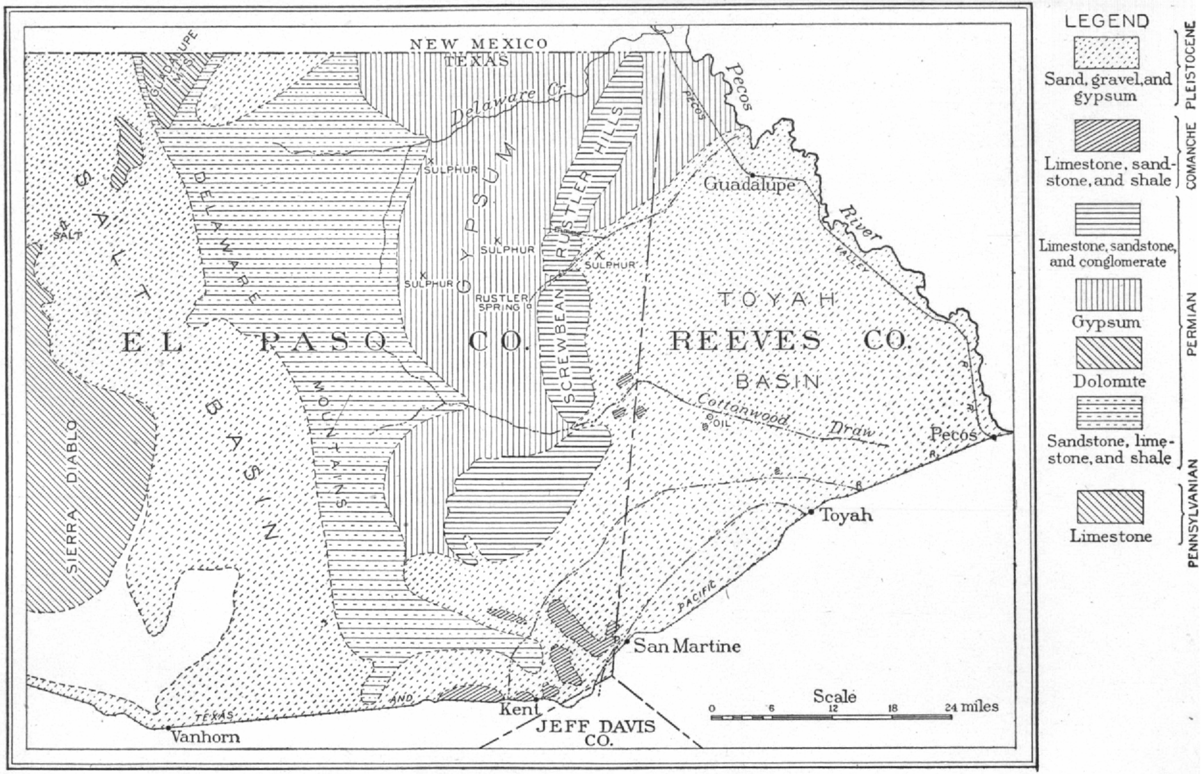
mountains are 10 miles wide, but they converge in a wedge-shaped form and abruptly terminate about 10 miles south in a precipitous cliff called Guadalupe Point. El Capitan Peak, having an elevation of approximately 8,500 feet,[a] is one-fourth of a mile north of Guadalupe Point, and is thought to be the highest point in Texas.

The Delaware Mountains are the southern extension of the Guadalupes. They extend northwest-southeast uninterruptedly for about 40 miles, beyond which they are considerably dissected and form an irregular, unnamed highland mass which reaches almost to the Texas and Pacific Railway. These mountains constitute a typical cuesta. They have a southwestward-facing scarp approximately 2,000 feet high, from the crest of which the surface slopes gradually northeastward, conforming approximately with the dip of the underlying rocks. Along the western face of the escarpment there is a belt of dissected foothills, but no drainage way cuts across the escarpment in the Delaware Mountains proper. At the southern extremity of the mountains the escarpment becomes indistinct, and a longitudinal valley extends parallel with the axis of a low anticlinal fold.

The streams that drain the Delaware Mountains are mainly consequent and flow down the slope of the monocline. Delaware Creek and the valleys at the heads of Salt and Cottonwood draws are the chief waterways, although no stream except Delaware Creek below Delaware Springs is perennial. Some lateral valleys are developed which trend approximately parallel to the strike of the rocks, Wild Horse Draw being a typical example. Near the crest of the mountains the valleys are steep and narrow, but eastward they broaden out.

Salt basin, which is one of the prominent débris-filled intermontane valleys of the trans-Pecos country, lies west of the Guadalupe-Delaware Mountains. It has the characteristic northwest-southeast trend and is over 150 miles long. The area under consideration includes 70 miles of the linear extent of the Salt basin, which here ranges from 8 to 20 miles in width, averaging about 15 miles. The Salt basin is a typical closed basin, with no drainage outlet. The center is about 25 miles north of Van Horn, at the base of the Diablo Mountains, where the elevation is below 3,600 feet. The rise is very gradual both to the north and to the south. Northward from the center of the basin to the State line the slope of the surface is only about 2 feet in a mile, and the basin appears to be flat in its longer extent and to rise only to the adjacent highlands on the northeast and southwest. The surface is not a level plain, but is characterized by numerous hillocks and local depressions. The former are often composed of wind-blown material, and the latter are locally called "lakes," though only one contains a considerable body of water. This

[a] Barometric determination.



GEOLOGIC SKETCH MAP OF THE TRANS-PECOS REGION, TEXAS.

is the shallow lake which is near the center of the basin, and is about 3½ miles long and one-half mile wide. Most of the local depressions are marsh areas that contain water only for a short time during the rainy season.

The Sierra Diablo, marking the eastern scarp of the Diablo Plateau, which is an extensive region lying beyond the area here considered, delimits the Salt basin on the west. These mountains extend about 25 miles from north to south, and are flanked on the south, east, and northeast by an abrupt escarpment, which is steepest on the east, where it rises over 2,000 feet above the Salt basin. The mountains are capped by massive limestone that dips westward at a low angle, with which the general slope of the surface corresponds. Very little of the drainage passes directly eastward into the Salt basin, the principal outlets being to the south, west, and northeast.

At the eastern base of the Guadalupe-Delaware Mountains there is a gently undulating, east-sloping plain that is underlain by gypsum. Within Texas this area is approximately 50 miles in length and averages 15 miles in width, though at the State boundary it is 25 miles wide. The general flatness is relieved by occasional isolated, rounded hills that are capped by limestone. The gypsum plain is traversed by Delaware Creek near the State line and farther south by Horseshoe and Cottonwood draws. These waterways occupy broad valleys, in which narrow gorges locally have been intrenched.

Eastward a narrow range of low hills intervenes between the gypsum plain and Pecos Valley. These are the Screwbean-Rustler hills, which extend southwestward from the mouth of Delaware Creek, a distance of about 40 miles, in a belt averaging 5 miles in width. They rise 3,600 to 3,700 feet above sea level and 150 to 250 feet above the adjacent plains. They are capped by limestone, and when viewed from an elevation show an even-topped sky line. Erosion has dissected these hills somewhat, and Horseshoe and Cottonwood draws flow through them in relatively narrow valleys.

In the vicinity of Kent and San Martine, at the western end of the Toyah basin, are a number of detached, rounded and irregularly shaped hills that rise from 100 to 200 feet above the surrounding level. These hills are composed of low-lying Cretaceous rocks, which are the erosion remnants of a former connected mass.

The Toyah basin is that part of the Pecos Valley lying between the vicinity of the Texas-New Mexico boundary and the escarpment of the Stockton and Edwards plateaus, 50 to 70 miles south of the Texas and Pacific Railway, the east-west limits of the basin being, respectively, the scarp of the Staked Plains and the mountains to the west. This large area is underlain to a great but unknown depth by unconsolidated materials which may be in part lake deposits.

The portion of the Toyah basin within the area described is a broad plain that rises gradually westward. The elevation is 2,500 feet at Pecos and about 3,600 feet at the western border near San Martine. Though in general flat, the basin can be characterized as consisting of broad, gently undulating valleys separated by intervening low divides. At the western margin a number of arroyos emerge from the hills, but few waterways maintain their channels completely across the basin. Cottonwood Draw is a conspicuous example. This is a comparatively large drainage way that heads in the Delaware Mountains, but midway across the Toyah basin it becomes lost in the flat. Pecos River, which flows perennially, meanders in a broad flood plain, into which it has cut a shallow channel. The flood plain slopes gradually away from the river, and locally the border between the flood plain and the Toyah basin is marked by a low gravel bluff.

STRATIGRAPHY.

The rocks of the area here described are sedimentary and belong chiefly to the Carboniferous, Cretaceous, and Quaternary systems.

The Sierra Diablo is capped by over 1,000 feet of massive gray limestone, including a few thin layers of interbedded drab shale. These rocks contain numerous fossils belonging to the Pennsylvanian series of the Carboniferous. A coarse conglomerate marks the base of the Carboniferous rocks, which overlie unconformably a complex group of sediments of probable pre-Cambrian age that need not be described here. The Carboniferous rocks of the Sierra Diablo lie almost flat, with a low westward dip. They are delimited on the east by a fault of considerable but undetermined throw that is marked by the scarp of the mountains toward Salt basin.

Salt basin is strewn with unconsolidated "wash" derived from the contiguous highlands. Adjacent to the periphery the materials are coarse textured and are more or less cemented by lime. Toward the center of the basin the deposits are finer, and consist largely of sand and clay. Low, marshy areas south of the New Mexico-Texas boundary are commonly floored with gypsum containing traces of other salts. No very deep wells have been put down in the Salt basin, the deepest recorded being 343 feet at Wild Horse. It may be surmised, however, that these unconsolidated deposits extend to a depth of 1,000 feet and more, as in the Hueco basin near El Paso.

The Pleistocene deposits of Salt basin conceal the relation of the Pennsylvanian strata of the Sierra Diablo to the rocks of the Guadalupe-Delaware Mountains. The scarp of the latter marks a belt of disturbance. At the western limit of the range an unsymmetrical anticline is developed, of which the elevated, gently east-sloping limb terminates at the scarp. To the west, low-lying foothills expose the steeper-dipping western limb. Faulting of undetermined throw appears to be associated with this fold.

In the Guadalupe-Delaware Mountains are developed a considerable thickness of Permian strata, which do not occur west of Salt basin. In the Guadalupe Mountains the following generalized section is plainly exposed.

Section of rocks in Guadalupe Mountains.

	Feet.
Massive white magnesian limestone	1,800
Interbedded buff sandstone and gray limestone	2,000
Blue-black limestone, locally shaly	200

Farther south, in the Delaware Mountains, the upper white limestone is missing, the rocks exposed belonging to the middle formation, sandstone predominating in the northern and limestone in the southern part of the mountains. As mentioned above, the structure of the range is a low east-dipping monocline. These rocks contain an abundant and unique Permian fauna, which is being studied by Dr. G. H. Girty.

Midway between the mountains and Pecos River lies a broad belt of bedded gypsum, which rests unconformably on the rocks exposed in the Delaware Mountains and apparently maintains the prevailing low eastward dip. The width of the belt averages about 15 miles, though at the New Mexico-Texas boundary it is 30 miles. This gypsum belt begins 15 miles north of the Texas and Pacific Railroad and extends into New Mexico.

The gypsum is unconformably overlain in the Screwbean-Rustler Hills by buff sandstone, which is wholly conglomeratic, and white magnesian limestone, aggregating about 200 feet in thickness. Only a few indeterminable fossils were found in these rocks, which, with the gypsum, are provisionally assigned to the Permian. They likewise, with minor undulations, conform to the general low eastward dip, at least as far as Toyah basin, where they are covered by Pleistocene deposits.

Outlying exposures of horizontal or gently inclined calcereous shale, thin-bedded limestone, and occasional beds of sandstone belonging to the Washita group of the Comanche Cretaceous, occur surrounded by the Toyah basin deposits in low hills in the western part of the basin, and also adjacent to Pecos River, about 20 miles south of the State boundary.

Toyah basin, like Salt basin, is strewn with unconsolidated material derived from the bordering highlands. At Toyah a well 832 feet deep has been bored in these deposits without reaching bed rock, the depth to which is not known. Practically all of the surface coverings of the basin are of recent age, being now in process of formation. A considerable part of the basin deposits doubtless is Pleistocene, but whether some of the basal material is of Tertiary age is unkown.

SALT.

The presence of salt in the Salt basin has long been known to Mexicans, who, in the early days of the occupation of the country, are said to have traveled for it from distant parts of Chihuahua. The first wagon road to the deposit, however, was not built until 1863. Not long after its construction the salt was "located" and claimed, and an effort was made to collect a charge for the salt, which formerly was free to all. This provoked trouble, which was made an issue in a personal fued between two politicians, and finally, in 1877, resulted in riot and bloodshed at San Elizario. Quiet was restored only by the intervention of the United States Army.[a]

This deposit of salt is situated on the west side of the Salt basin, about 15 miles southwest of El Capitan Peak and a little more than 50 miles north of Vanhorn. The deposit is locally known as the salt lake. It occupies a slight depression, and is one of several so-called lakes similarly situated in this part of the Salt basin.

Unconsolidated, earthy gypsum forms the floor of most of these lakes and surrounds and connects them. Borax and potash have been found in one of the dry lakes. Strontium occurs in the gypsum that surrounds the Salt lake, and there are traces of lithium in the deposits. Outside the area occupied by these depressions the materials of the Salt basin generally are clay and fine sand, and toward the margin the surface is strewn with coarser débris from the contiguous highlands.

Although some salt occurs in a few of the other "lakes," only one is known to contain it in important quantities. This is roughly elliptical in outline and has an area of about 45 acres. Viewed from a distance it presents the appearance of a pond covered with ice or snow, so white is the layer of salt on its surface.

During the dusty, dry season the salt becomes impure, but after a rain, and especially in localities where the surface salt has been lately removed, beautiful hopper-shaped crystals are formed. An analysis of some of these, by S. H. Worrell, of the University of Texas Mineral Survey, gave the following results:

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[a] House Ex. Doc. No. 93, 45th Cong., 2d sess., El Paso Troubles in Texas, 1878.

Analysis of salt crystals from Salt basin, El Paso County, Tex.

Chlorine	59.5
Sodium	38.6
Calcium	.1
Magnesium	.2
Sulphur tetroxide	1.2
Water	1.0
Total	100.6

The analysis shows that the crystals are almost pure halite, mixed with small amounts of calcium and magnesium sulphates.

No wells have been sunk to test the character of the underlying deposits, but a shallow hole shows the following section:

	Inches.
Salt	1
Gypsiferous sand	¼
Black clay with sulphurous smell, impregnated with salt	6
Green-drab clay	24

A qualitative analysis of these substances, by Mr. S. H. Worrell, shows the presence of silica, alumina, lime, magnesia, soda, sulphur trioxide, carbon dioxide, and traces of potash and lithium, but no borax.

Borax, however, occurs in at least one locality near by. An evaporation crust on a lake about 2 miles southeast of the Salt lake, examined by Mr. E. M. Skeats, of El Paso, has the following composition:

Insoluble sulphates of calcium, magnesium, and sodium	73.0
Sodium chloride	18.3
Borax	8.7
Total	100.0

No test was made for potash. From this analysis it appears desirable to further prospect in this locality.

The layer of salt which covers the surface of the "lake" is said occasionally to attain a thickness of from 4 to 6 inches, but measurements made in 1903 show an average of only about 1 inch. This is the commercially valuable deposit, for the crystals of halite referred to above are comparatively rare. The salt is grayish-white, coarsely crystalline to granular, and deliquescent. Occasionally wind-blown impurities occur on the surface of the deposit. An analysis of a typical specimen, by Mr. S. H. Worrell, is as follows:

Analysis of common salt from El Paso County, Tex.

Silica	0.6
Alumina	0.6
Iron	Trace.
Magnesia	Trace.
Lime	Trace.
Potash	None.
Sodium sulphate	1.4
Sodium chloride	97.3
Total	99.9

The ground-water level here is very near the surface. The test hole above referred to rapidly filled with water which contained considerable gas, apparently hydrogen sulphide. An analysis of this water, by Mr. S. H. Worrell, shows it to contain 9,990 parts of solids per 100,000, consisting chiefly of sodium chloride.

When the surface layer of salt is removed its place is taken by this brine, which evaporates and deposits salt, so that within a few weeks after stripping an area a new deposit of salt replaces that which was removed. The supply is popularly believed to be inexhaustible.

These facts imply that the salt is derived from an underground source, either from disseminated salt or from a concentrated deposit with which the ground waters come in contact. The depth below the surface and the extent of such deposits are unknown.

This salt is extensively used by ranchmen, some of whom come from Fort Davis, a distance of over 100 miles. Considerable salt from the "lake" is also freighted to the pan amalgamation works at Shafter, 150 miles distant. The salt is sold by the load. A two-horse load costs $1 and a six-horse load $3. No careful records are kept of the amount hauled away, but certainly immense quantities have been used, and apparently there is as much in sight as there was forty years ago.

PETROLEUM.

The presence of petroleum in commercial quantities in parts of trans-Pecos Texas—in Pecos, Reeves, and eastern El Paso counties—has been suspected for several years.[a] Indications are numerous. Bituminous limestones, sandstones, and shales that give a strong odor on being struck with a hammer outcrop in many places. The occurrence of globules of oil in water from various wells, of a few oil seeps, and especially of small quantities of petroleum in oil prospects, tends

[a] Phillips, W. B., Texas petroleum: Bull. No. 1, University of Texas Mineral Survey, 1901.

Phillips, W. B., Sulphur, oil, and quicksilver in trans-Pecos Texas: Bull. No. 2, University of Texas Mineral Survey, 1902.

Hill, R. T., the Beaumont oil field and notes on other oil fields of the Texas region: Jour. Franklin Institute, vol. 154, p. 226, 1902.

to confirm the suspicion that oil in paying quantities actually exists here. But as yet this hope has not been realized.

In Bulletin No. 2 of the University of Texas Mineral Survey, Doctor Phillips calls attention to the presence of oil and asphalt in small quantities near Fort Stockton. Since the publication of that bulletin a well 1,200 feet deep has been put down in search of oil in that vicinity, and though a little petroleum and gas and considerable sulphur were reported, oil in paying quantities was not found. The well struck highly mineralized artesian water, which flows about 25 barrels a day. The geology of the surrounding area has not yet been studied.

Another unsuccessful deep well was sunk in search of oil about 4 miles west of Carlsbad, N. Mex., in 1902. A log was not kept, but the well was sunk chiefly through limestone to a depth of 1,500 feet, and only a little gas and oil were reported.

In 1855–1857 Capt. John Pope put down two wells in search of artesian water about 10 miles east of the mouth of Delaware Creek. The deepest was sunk 1,050 feet, apparently mostly through red beds. No hydrocarbons were reported, and the undertaking was a failure.

In the region with which this paper is concerned a number of wells have been drilled in this supposed oil belt. The deepest of these, the Aden well, on the east slope of the Delaware Mountains, about 35 miles northeast of Vanhorn, was sunk in 1902 in search of water. No signs of oil were reported from this well, which was put down 916 feet, mostly in Permian limestone.

Another deep hole is the artesian well at Toyah, 832 feet deep, which is said to have gone all the way through unconsolidated materials. The water contains considerable hydrogen sulphide, but no hydrocarbons were reported.

A number of wells have been drilled in the unconsolidated deposits of Toyah basin, in the immediate vicinity of Pecos, where artesian water is found at depths between 100 and 300 feet. The occasional presence of traces of oil in this water is reported. In 1901 a well was drilled 6 miles southeast of Pecos to a depth of 282 feet in the basin deposits. A small amount of gas was struck at 155 feet; traces of oil were found at 217 feet, and several other traces of oil were encountered between 240 and 282 feet.

Petroleum has been found also in two other wells in the Toyah basin, the Casey and Ross wells, respectively 12 and 15 miles northwest of Pecos. The quantity is so small that the oil is cased off, and the wells are used for watering stock. Traces of oil are found in the Tinnin well, near Cottonwood Draw, about 20 miles northwest of Toyah; in the Burnt Spring, northwest of Toyah, and at a few other localities. Also, a small amount of natural gas was found in a 21-foot bore hole in the sulphur area northeast of Rustler Spring.

In spite of these various indications, very little oil had been found in trans-Pecos Texas until early in 1903, when Mr. J. D. Leatherman reported oil about 15 miles northwest of Toyah, in the Toyah basin. This oil is said to occur in unconsolidated materials, but it has not yet been regularly removed, and the yield of the well has not been determined. The well went through 20 feet of surface material, mostly gypsum, 20 feet of gravel, and 150 feet of bluish clay containing a few sand streaks. Oil, which rose to within about 30 feet of the surface, is reported to have been found at 170 feet. Considerable gas accompanies this oil.

Oil from the Leatherman well was for sale in the winter of 1903–4, at Pecos, where it was used for lubricating windmills. An analysis of this, by Mr. O. H. Palm, of the University of Texas Mineral Survey, follows:

Analysis of oil obtained 15 miles northwest of Toyah.

Specific gravity: 20° C. (68° F.), 0.9090, equivalent to 24° Baumé. Barometer: 29.2 inches.

Color: Dark brown. Odor: Sweet.

Viscosity: Engler test—20° at 25° C.—73° F.

Cooling test: Oil flows at minus 16° C.—3° F.

Flash point: 74° C.—165.2° F. Burning point: 110° C.—230° F.

Heating power: 19,440 B. T. U.=Calories: 10,800 on water free oil.

Distillation yielded the following fractions (29.2 inches pressure):

Results of distillation of oil obtained 15 miles northwest of Toyah.

No.	Temperature.		Percentage by volume.	Specific gravity.	Baumé.	Color.
	Centigrade.	Fahrenheit.				
	°	°				
1	125–150	257–302	6.10	0.7404	59	Colorless.
2	175–200	347–392	1.20	.7590	54.5	Straw yellow.
3	225–250	437–482	7.80	.8360	37	Light yellow.
4	250–275	482–527	8.20	.8543	34	Do.
5	275–300	527–572	7.40	.8620	32	Yellow.
6	325–350	617–662	50.00	.8843	28	Pale red.
Residue: 14 per cent by weight			14.00			Black asphalt.
Loss			5.30	Naphtha (fraction 1), 6.10 per cent by volume.		
Total			100.00	Burning oil (2, 3, 4, 5), 24.60 per cent by volume.		
Sulphur: 1 per cent.				Heavy oil (6), 50 per cent by volume.		

The heavy oil has a very low viscosity, due to the fact that the crude oil decomposed rapidly during the distillation. A sickening odor was given off during the entire fractionation.

Judging from the analysis, this oil appears to be similar in some respects to the Beaumont product. The Toyah sample has not been studied enough, however, to determine many of its characteristics. Its flash point is rather low, but it has a good calorific value, and, if found in profitable quantity, its chief use probably will be as a fuel.

In the fall of 1903 a well was sunk by a California company about 1¼ miles southwest of the Leatherman well, with poor results. The log of this well is as follows:

Log of California company's well No. 1.

Material.	Thickness.	Depth.
	Feet.	*Feet.*
Surface, mostly gypsum	27	27
Gravel	40	67
Coarse gravel, water at base	4	71
Blue clay	9	80
Hard sand	45	125
Blue clay	14	139
Brown clay	95	234

Nevertheless, it was decided by those in charge to make a decisive test in this vicinity, and winter quarters were erected and a new site chosen near the other wells. Work is said to have been in progress during the early part of 1904, but little information has been made public beyond the statement that some oil was found. In January, 1905, it was reported that the well had been abandoned.

The Leatherman and California oil wells are situated in the Toyah basin, in the midst of a broad, very gently undulating flat. Cottonwood Draw, occupying a scarcely perceptible swale, is near by. In the immediate vicinity of the wells, and extending far eastward in both a northern and a southern direction, pulverulent, earthy gypsum covers the surface. At the wells this gypsum is from 18 to 27 feet thick. In this immediate vicinity the gypsum is impregnated with native sulphur, which will be referred to below. Outside of this gypsum area the Toyah basin is covered by loose detritus of igneous rock, sandstone, and limestone. This material is wash from the adjacent highlands, the igneous rock coming from the Davis Mountains, to the southwest.

At about 1½ miles southwest of the wells is a small area of broken gray limestone, and from 5 to 7 miles west, extending in an approximately north-south belt, are low outcrops of coarse and fine textured sandstone, with interbedded limestone, which are almost buried by the surrounding basin deposits. These are outlying Cretaceous rocks, belonging to the Washita group of the Comanche series.

The "wash" of Toyah basin extends farther west, to the Rustler Hills, in which sandstone (Permian?) and limestone outcrop. Westward these strata are succeeded by the belt of bedded gypsum, and finally by the sandstones (Permian?) and limestones in the Delaware Mountains. These rocks in general dip low to the east, but their structure, depth, and extent in the Toyah basin are unknown because of the cover of wash and the erosion that occurred previous to the deposition of the basin deposits.

Reviewing known conditions in the area covered by the reconnaissance in 1903, the following may be noted concerning the possible abundance of petroleum. There occurs here a great mass of little-disturbed sedimentary rocks, some of which are bituminous. There are beds of porous rock to serve as reservoirs. Locally the strata are gently folded, and small amounts of petroleum are widely disseminated. On the other hand, there is very little shale in this region to act as an impervious cap to prevent the escape and to aid in the accumulation of oil. However, there is considerable limestone, which sometimes is an effective barrier. There is no general system of folds to provide for storage and the accumulation of pools, but the beds are characteristically lenticular, and there may be lenses of porous rock saturated with oil that is preserved by contiguous impervious beds. Besides chances for oil in the older rocks, there are possibilities, in the wide extent of the unconsolidated materials of Toyah basin, for a combination of favorable conditions for collecting disseminated petroleum and for its storage. Only the drill can determine whether oil exists here in paying quantities.

GYPSUM.

Within Texas the bedded gypsum referred to above covers an area of about 600 square miles. This great gypsum field remains commercially untouched. The nearest part of the deposit lies about 15 miles from the Texas and Pacific Railroad, and adjacent to the New Mexico-Texas boundary another part of the area lies contiguous to the Pecos Valley Railway.

This gypsum is a massive, white, granular variety. It is comparatively pure, and a characteristic sample, analyzed qualitatively by Mr. W. T. Schaller, shows it to be of no unusual composition. Considering its great extent the gypsum is remarkably homogeneous, yet it varies somewhat. On the surface generally it is disintegrated and earthy. In places it is grayish or dark in color, owing to the presence of organic matter, and at other places it is stained red by iron oxide. Locally, disseminated selenite is abundant. Some sections show occasional thin beds of banded gray limestone in the gypsum. Deposits of native sulphur are also associated with it.

The thickness of this formation is not known, but it is considerable. A well at the old sulphur works about 6 miles north of Rustler Springs shows a thickness there of a little over 300 feet, though the base of the gypsum is not known to have been reached. Good sections, exposing sometimes 50 or 60 feet of gypsum, occur along Delaware Creek and Cottonwood Draw. Such sections commonly show the rock to be considerably cracked and jointed.

This gypsum is also cavernous, and there are many underground channels in it. A conspicuous one heads in a small draw about 6 miles southeast of Sayles's ranch, 35 miles northwest of Toyah. The opening of the cavern is circular, with a diameter of about 5 feet, and it has been explored for a distance of a quarter of a mile. A peculiar variety of bunch grass (*Bouteloua breviseta*), called "yeso" grass, grows on the gypsum, which also bears a stunted growth of junipers.

GEOLOGICAL SURVEY PUBLICATIONS ON GYPSUM, SALT, BORAX, AND SODA.

The more important publications of the United States Geological Survey on the natural lime, sodium, and potassium salts included in this group are the following:

ADAMS, G. I., and others. Gypsum deposits of the United States. Bulletin U. S. Geol. Survey, No. 223, 123 pp. 1904.

BOUTWELL, J. M. Rock gypsum at Nephi, Utah. In Bulletin 225, pp. 483–487.

CAMPBELL, M. R. Reconnaissance of the borax deposits of Death Valley and Mohave Desert. Bulletin No. 200. 23 pp. 1902.

——— Borax deposits of eastern California. In Bulletin No. 213. pp. 401–405. 1903.

CHATARD, T. M. Salt-making processes in the United States. In Seventh Ann. Rept., pp. 491–535. 1888.

DAY, W. C. Potassium salts. In Mineral Resources U. S. for 1887, pp. 628–650. 1888.

——— Sodium salts. In Mineral Resources U. S. for 1887, pp. 651–658. 1888.

ECKEL, E. C. Salt and gypsum deposits of southwestern Virginia. In Bulletin No. 213. pp. 406–416. 1903.

——— Salt industry of Utah and California. Bulletin U. S. Geol. Survey No. 225. pp. 488–495.

HILGARD, E. W. The salines of Louisiana. In Mineral Resources U. S. for 1882, pp. 554–565. 1883.

ORTON, E. Gypsum or land plaster in Ohio. In Mineral Resources U. S. for 1887, pp. 596–601. 1888.

PACKARD, R. L. Natural sodium salts. In Mineral Resources U. S. for 1893, pp. 728–738. 1894.

PEALE, A. C. Natural mineral waters of the United States. In Fourteenth Ann. Rept., pt. 2, pp. 49–88. 1894.

YALE, C. G. Borax. In Mineral Resources U. S. for 1889–1890, pp. 494–506. 1902.

SULPHUR AND PYRITE.

PYRITE DEPOSITS OF THE WESTERN ADIRONDACKS, NEW YORK.

By Edwin C. Eckel.

Several important pyrite deposits, which have long been worked, are located in St. Lawrence County, N. Y. As these deposits are of considerable economic interest because of their location, intermediate between the Appalachian pyrite bodies and those of Ontario, the following brief notes on the subject are presented. The principal mines and prospects were visited by the writer in June, 1904, while engaged in an examination of the red hematite deposits which occur in the same area, though in entirely different geologic relations.

The Stella mine is located about 2 miles southeast of De Kalb Junction, on the road to Hermon.

The country rock is a light-gray gneiss, which is usually rather fine grained, but which in places contains coarser bands. It is well foliated, the foliation planes near the mine showing a strike of N. 20° to 30° E., and dipping 20° to 30° to the northwest. This rock is probably a sheared igneous rock of pre-Cambrian age. Near the Stella mine it is well shown in little ridges east and west of the vein, a small depression marking the location of the ore body.

At the mine this gray gneiss incloses a band of fine-grained, dark-colored schist 15 to 20 feet in width. Though this schist band is at this point parallel to the foliation of the gneiss, it is probably an intrusive rock of much more recent age than the gneiss.

The pyrite at the Stella mine occurs as a series of overlapping lenses in this schist. Each lens may average 12 feet in thickness and 200 to 250 feet in extent along the dip and strike. At the main slope the strike of the schist and pyrite belt is N. 20° E., and its dip is 23° to the northwest.

The mine has been opened by a slope 700 feet long, which runs down on the dip of the ore body to a depth of 285 feet.

The lump ore, as shipped, contains from 34 to 35 per cent sulphur. The average mill ore contains from 26 to 27 per cent sulphur. By concentration this is brought up to 44 or 45 per cent. An average sample of mill ore would give about the following analysis:

Average sample of mill ore from Stella pyrite mine, St. Lawrence County, N. Y.

Sulphur	28
Iron	29
Silica	32
Lime and manganese	1.5
Zinc	.3
Copper	.2

At the time of the writer's visit the mill was being remodeled, and New Century jigs were being substituted for Hartz jigs. The practice had been, after picking out ore of sufficiently high grade to be marketable as lump, to crush the remainder to 1½ inch, then by rolls to one-fourth inch. The material from the rolls was passed through two sets of screens (one-fourth inch and one-eighth inch, respectively) in turn, giving two sizes of product which were sent to two different sets of jigs.

About 4 miles northeast of the Stella mine, at Pyrites or High Falls, the second producing mine is located. Here a 12-foot slope has been run down for 230 feet on the dip of the ore body, while 160 feet of lateral drifts have been opened. The ore body at this point dips 46° to the west. As at the Stella mine, the ore is inclosed in fine-grained schist, but the country rock at High Falls is not the normal gray gneiss of the region, but a coarse, well-foliated gabbro. An old slope showed a body of pyrrhotite 7 or 8 feet thick on the hanging wall, but the new workings are entirely in pyrite.

About 1½ miles south of Richville a small opening is being made on the west side of the Rome, Watertown and Ogdensburg Railroad tracks. The ore here occurs in a body of schist near its contact with crystalline limestone. The schist is fine grained, dark gray to black, and bordered on the west by a series of thinly foliated light-gray gneisses. The pyrite body at present exposed occurs in the schist about a foot from the limestone, and is 7 feet thick at the surface.

NATIVE SULPHUR IN EL PASO COUNTY, TEX.

By G. B. Richardson.

For several years[a] native suphur has been known in El Paso County, Tex. Some prospecting and development work has been done and two carloads of sulphur have been shipped, but very little is yet known of the extent and value of these deposits.

The sulphur occurs associated with gypsum in northeastern El Paso County, both east and west of the Screwbean-Rustler Hills. A sketch map of the district appears opposite page 574 and an outline of the local topography and stratigraphy is given on pages 573 to 578 of this bulletin.

The prospect nearest to a railroad occurs in the western part of Toyah basin, about 15 miles southwest of Guadalupe station, on the Pecos Valley road.

Another sulphur prospect, but of less value, is about the same distance northwest of Toyah, on the Texas and Pacific Railroad. Other prospects occur scattered over the gypsum belt at various distances up to 25 miles from the first-mentioned locality. There would be little difficulty in constructing a railroad into the sulphur fields, for the country is open and rises gradually westward across the nearly flat Toyah basin and through valleys in the Screwbean-Rustler Hills into the gypsum plain beyond.

This country is fairly well supplied with water from shallow wells, but all of it is strongly mineralized. The water averages almost 300 parts per 100,000 of dissolved salts, of which about two-thirds is calcium sulphate. Fuel can be furnished for a limited time by a growth of stunted junipers. Moreover, there is a hope that petroleum or gas in profitable quantities will be found in this region.

The most extensive prospecting has been done in the vicinity of Maverick Spring, which is in the Toyah basin, about 9 miles northeast of Rustler Spring, near the eastern base of the Screwbean-Rustler Hills. Several shallow prospect holes have been dug here and an area of considerable size has been scraped. Sulphur occurs at or near the surface in a bare, flat, gypsum-covered area strewn with well-

[a] Skeats, E. M., and others, Bulletin No. 2, University of Texas Mineral Survey, 1902.

rounded quartz pebbles that average about one-half inch in diameter. The gypsum is impure and earthy, and besides predominating granular gypsum consists of small selenite crystals, with which are associated some sand, occasional quartz pebbles, and bits of organic matter. Apparently this gypsum is of secondary origin, derived from the near by bedded deposits in several ways, including evaporation of ground water solutions of calcium sulphate and transportation by wind and streams. The quartz pebbles can be traced to conglomeratic sandstone in the Screwbean-Rustler Hills.

Sulphur occurs here in different ways. Sometimes it is surficially developed on the gypsum as a thin amorphous film. Again it is rather minutely disseminated throughout the mass of gypsum. One broad strip exposes a bed of brownish earth about 3 feet thick, highly impregnated with undeterminable organic matter, having a peculiar sulphurous odor and containing considerable disseminated minute sulphur crystals. Small sulphur crystals also occur locally in linear vein-like arrangement through the earthy gypsum. A cut in this vicinity exposes about 2 feet of rather compact amorphous sulphur, which also contains small pebbles.

This is the only locality where considerable prospecting has been done, though no sulphur has been shipped from it. Mr. E. M. Skeats reports a pit section 41 feet deep in gypsum, sand, and gravel, situated about 5 miles northwest of Maverick Spring. Samples were taken every few feet, an average of which gave 26 per cent of free sulphur, though some tests went as high as 46 per cent. Mr. Skeats reports the presence of free sulphuric acid in the waters associated with the sulphur deposits, and he mentions that a 21-foot bore hole struck a mixture of gas which burned for several days.

The most extensive development work has been done about 6 miles north of Rustler Springs, in the bedded gypsum belt. It is reported that four or five years ago 100 men or more were employed here for several months. A number of acres were stripped, a furnace was erected for treating the ore by the superheated steam process, and two or three carloads of refined sulphur were shipped from Guadalupe. The strippings show at the surface from 2 to 3 feet of porous, earthy gypsum, containing a few rounded pebbles of quartz, overlying the ore, which averages about 4 feet in thickness. The ore is a brownish, porous substance, containing disseminated sulphur crystals. An analysis by Mr. George Steiger, of the United States Geological Survey, shows that the bulk of the ore is silica, with a little alumina, and that no calcium, sulphuric acid, or carbon dioxide is present. This ore contains considerable organic matter of an undetermined nature and 18.36 per cent of free sulphur. Geodes consisting of hollow spherical masses of gypsum, lined with small sulphur crystals, have been reported from this vicinity.

About 10 miles northwest of Rustler Spring, just east of the Toyah-Guadalupe road, a low gypsum hill is capped by 20 feet of gray limestone lying practically flat. Several hundred feet have been stripped along the southern side of the hill, exposing a good section. Amorphous yellow sulphur occurs, disseminated in irregular streaks and patches in the gypsum, occasionally rudely following the bedding, and again crossing it, not following any regular course. The sulphur-impregnated zone averages about 3 feet in width. The contact between the gypsum and the limestone is extremely irregular. The gypsum and the limestone are intimately intermingled and porous, which suggests local derivation of the gypsum from the limestone adjacent to the contact.

A test pit 1½ miles northeast of this locality shows 6 feet of gypsum, containing disseminated sulphur, underlain by 3 feet of bituminous limestone.

South of Delaware Creek, about 4 miles southeast of Delaware Spring and 18 miles northwest of Rustler Spring, is a prominent three-peaked hill of limestone underlain by gypsum. A cavern over 100 feet deep shows surficial alteration of the limestone into white, porous gypsum, with which thin coatings of native sulphur are associated. The odor of hydrogen sulphide is easily detected in the cavern, and apparently the alteration of the limestone and the origin of the sulphur are due to that gas.

Sulphur also occurs in small quantities, disseminated in gypsum, about 10 miles north of Rustler Springs, near Stinking Seep; and on the north side of Cottonwood Draw, about 16 miles northwest of Toyah, contiguous to the oil wells in Toyah basin, a small area has been scraped, exposing some sulphur sparingly disseminated in secondary gypsum. A few other localities are also known where sulphur is present at the surface associated with gypsum, but little prospecting has been done at these places.

These are practically all of the known occurrences of sulphur in this region. Sulphur is found throughout a wide area, and locally it is fairly well concentrated, but very little is known of the extent and value of these deposits. Judging from the occurrences noted above, there is not a great quantity of sulphur in sight. Apparently, however, economical mining on a small scale would yield some profit, and in this way the deposits might well be further explored. The value of this field can be determined only by persistent prospecting.

Concerning the origin of the sulphur, the most significant facts seem to be its association with gypsum and organic matter and the occurrence of hydrogen sulphide. There has been no recent volcanic activity in this region.

The association of sulphur, gypsum, and organic matter suggests their genetic relationship, inasmuch as sulphur can be formed by the reduction of gypsum. The origin of sulphur has been accounted for by considering that organic matter reduces gypsum to calcium sulphide, which, being acted on by carbonic-acid waters, yields calcium carbonate and hydrogen sulphide, and from the latter sulphur is formed by oxidation. Gypsum, however, is a stable compound, and though it can be reduced by the application of heat its reduction at ordinary temperatures, except through the life activity of algæ or bacteria, has not been established. Possibly such favorable conditions existed during the formation of some of the sulphur under consideration, which apparently was formed at or near the surface.

Hydrogen sulphide, though its source is not clear, is widespread throughout the area under consideration, and it is a familiar fact that native sulphur is formed by the oxidation of this gas. By such a reaction sulphur is now being deposited in Delaware Creek, where water from a sulphur spring mingles with water from Delaware Springs. The surficial rust-like coating of sulphur on gypsum near Maverick Spring may be accounted for by the oxidation of hydrogen sulphide contained in water trickling over the gypsum. Throughout this region, each occurrence having its own characteristics, in the final reaction the sulphur may have been formed by the oxidation of hydrogen sulphide, but the ultimate source of this gas needs further investigation, both in the field and in the laboratory.

GEOLOGICAL SURVEY PUBLICATIONS ON SULPHUR AND PYRITE.

ADAMS, G. I. The Rabbit Hole sulphur mines, near Humboldt House, Nev. In Bulletin No. 225, pp. 497–500. 1904.

DAVIS, H. J. Pyrites. In Mineral Resources U. S. for 1885, pp. 501–517. 1886.

ECKEL, E. C. Gold and pyrite deposits of the Dahlonega district, Georgia. In Bulletin No. 213, pp. 57–63. 1903.

MARTIN, W. Pyrites. In Mineral Resources U. S. for 1883–84, pp. 877–905. 1886.

ROTHWELL, R. P. Pyrites. In Mineral Resources U. S. for 1886, pp. 650–675. 1887.

SPURR, J. E. Alum deposit near Silver Peak, Esmeralda County, Nev. In Bulletin No. 225, pp. 501–502. 1904.

PHOSPHATES AND OTHER MINERAL FERTILIZERS.

PUBLICATIONS ON PHOSPHATES, ETC.

The following papers relative to phosphates, gypsum (land plaster), and other mineral materials used as fertilizers have been published by the United States Geological Survey or by members of its staff. Further references will be found under the head of "Gypsum" in the list on page 586 of this volume.

ADAMS, G. I., and others. Gypsum deposits in the United States. Bulletin U. S. Geol. Survey No. 223, 127 pp. 1904.

DARTON, N. H. Notes on the geology of the Florida phosphates. In Am. Jour. Sci., 3d series, vol. 41, pp. 102–105. 1891.

ECKEL, E. C. Recently discovered extension of Tennessee white phosphate field. In Mineral Resources U. S. for 1900, pp. 812–813. 1901.

——— Utilization of iron and steel slags. In Bulletin U. S. Geol. Survey No. 213, pp. 221–231. 1903.

——— The white phosphates of Decatur County, Tenn. In Bulletin U. S. Geol. Survey No. 213, pp. 424–425. 1903.

ELDRIDGE, G. H. A preliminary sketch of the phosphates of Florida. In Trans. Am. Inst. Min. Eng., vol. 21, pp. 196–231. 1893.

HAYES, C. W. The Tennessee phosphates. In Sixteenth Ann. Rept. U. S. Geol. Survey, pt. 4, pp. 610–630. 1895.

——— The Tennessee phosphates. In Seventeenth Ann. Rept. U. S. Geol. Survey, pt. 2, pp. 1–38. 1896.

——— The white phosphates of Tennessee. Trans. Am. Inst. Min. Eng., vol. 25, pp. 19–28. 1896.

——— A brief reconnaissance of the Tennessee phosphate field. In Twentieth Ann. Rept. U. S. Geol. Survey, pt. 6, pp. 633–638. 1899.

——— The geological relations of the Tennessee brown phosphates. In Science, vol. 12, p. 1005. 1900.

——— Tennessee white phosphate. In Twenty-first Ann. Rept. U. S. Geol. Survey, pt. 3, pp. 473–485. 1901.

——— Origin and extent of the Tennessee white phosphates. In Bulletin U. S. Geol. Survey No. 213, pp. 418–423. 1903.

IHLSENG, M. C. A phosphate prospect in Pennsylvania. In Seventeenth Ann. Rept. U. S. Geol. Survey, pt. 3, pp. 955–957. 1896.

MEMMINGER, C. G. Commercial development of the Tennessee phosphates. In Sixteenth Ann. Rept. U. S. Geol. Survey, pt. 4, pp. 631–635. 1895.

Moses, O. A. The phosphate deposits of South Carolina. In Mineral Resources U. S. for 1882, pp. 504–521. 1883.

Orton, E. Gypsum or land plaster in Ohio. In Mineral Resources U. S. for 1887, pp. 596–601. 1888.

Penrose, R. A. F. Nature and origin of deposits of phosphate of lime. Bulletin U. S. Geol. Survey No. 46. 143 pp. 1888.

Stubbs, W. C. Phosphates of Alabama. In Mineral Resources U. S. for 1883–84, pp. 794–803. 1885.

Wilber, F. A. Greensand marls in the United States. In Mineral Resources U. S. for 1882, pp. 522–526. 1883.

MICA, GRAPHITE, ABRASIVE MATERIALS, ETC.

PUBLICATIONS ON MICA, GRAPHITE, ABRASIVE MATERIALS, ETC.

The following list includes a number of papers, published by the United States Geological Survey or by members of its staff, dealing with various nonmetallic mineral products not treated separately in the present bulletin:

BREWER, W. M. Occurrences of graphite in the South. In Seventeenth Ann. Rept. U. S. Geol. Survey, pt. 3, pp. 1008–1010. 1896.

CHATARD, T. M. Corundum and emery. In Mineral Resources U. S. for 1883–84, pp. 714–720. 1885.

ECKEL, E. C. The emery deposits of Westchester County, N. Y. In Mineral Industry, vol. 9, pp. 15–17. 1901.

EMMONS, S. F. Fluorspar deposits of southern Illinois. In Trans. Am. Inst. Min. Eng., vol. 21, pp. 31–53. 1893.

FULLER, M. L. Crushed quartz and its source. In Stone, vol. 18, pp. 1–4. 1898.

——— The occurrence and uses of mica. In Stone, vol. 19, pp. 530–532. 1899.

HAYES, C. W., and ECKEL, E. C. Occurrence and development of ocher deposits in the Cartersville district, Georgia. In Bulletin U. S. Geol. Survey No. 213, pp. 427–432. 1903.

HIDDEN, W. E. The discovery of emeralds and hiddenite in North Carolina. In Mineral Resources U. S. for 1882, pp. 500–503. 1883.

HOLMES, J. A. Corundum deposits of the Southern Appalachian region. In Seventeenth Ann. Rept. U. S. Geol. Survey, pt. 3, pp. 935–943. 1896.

——— Mica deposits in the United States. In Twentieth Ann. Rept. U. S. Geol. Survey, pt. 6, pp. 691–707. 1899.

JENKS, C. N. The manufacture and use of corundum. In Seventeenth Ann. Rept. U. S. Geol. Survey, pt. 3, pp. 943–947. 1896.

KEITH, A. Talc deposits of North Carolina. In Bulletin U. S. Geol. Survey No. 213, pp. 433–438. 1903.

KEMP, J. F. Notes on the occurrence of asbestos in Lamoille and Orleans counties, Vt. In Mineral Resources U. S. for 1900, pp. 862–866. 1901.

PARKER, E. W. Abrasive materials. In Nineteenth Ann. Rept. U. S. Geol. Survey, pt. 6, pp. 515–533. 1898.

PHILLIPS, W. B. Mica mining in North Carolina. In Mineral Resources U. S. for 1887, pp. 661–671. 1888.

PRATT, J. H. The occurrence and distribution of corundum in the United States., Bulletin U. S. Geol. Survey No. 180. 98 pp. 1901.

Raborg, W. A. Buhrstones. In Mineral Resources U. S. for 1886, pp. 581–582. 1887.

——— Grindstones. In Mineral Resources U. S. for 1886, pp. 582–585. 1887.

——— Corundum. In Mineral Resources U. S. for 1886, pp. 585–586. 1887.

Read, M. C. Berea grit. In Mineral Resources U. S. for 1882, pp. 478–479. 1883.

Turner, G. M. Novaculite. In Mineral Resources U. S. for 1885, pp. 433–436. 1886.

——— Novaculites and other whetstones. In Mineral Resources U. S. for 1886, pp. 589–594. 1887.

Ulrich, E. O., and Smith, W. S. T. Lead, zinc, and fluorspar deposits of eastern Kentucky. In Bulletin U. S. Geol. Survey No. 213, pp. 205–213. 1903.

MISCELLANEOUS.

ECONOMIC VALUE OF HOT SPRINGS AND HOT-SPRING DEPOSITS.

By Walter Harvey Weed.

GENERAL USES OF WATERS OF HOT SPRINGS.

The commercial value of natural hot waters for bathing establishments is well recognized in the more settled parts of the country; but their usefulness for the heating of dwellings, for greenhouses, and other buildings is less generally recognized. As mineral water the outflow of hot springs is often valuable, and the increasing use of carbonic-acid gas gives a considerable value to springs from which this gas issues in any considerable amount. Where the waters are highly charged with mineral salts this material is recoverable by evaporation, the value of the product varying, of course, with its nature. So far as known, there are no workable borax springs in the United States comparable with those of Tuscany (Italy), but the ferrous-sulphate and alum-bearing waters of the Sun River Hot Springs, Montana, furnish a residue that is sold at a high price. At Glenwood, Colo., similar waters are bottled, and at several resorts waters carrying alkaline sulphates and chlorides are locally concentrated or their mineral salts extracted.

The utilization of natural hot waters for the purposes mentioned in the preceding paragraph is, however, of relatively slight importance compared with their value for curative purposes. Since the earliest age of man such waters have been held in especial esteem and used for drinking and bathing. At many places the hot waters are vastly more valuable for this than for any other use, and in the older, more settled parts of the country are fully utilized for this purpose. This feature is, however, not deemed appropriate for presentation in the present place.

The hot waters of Boise, Idaho, derived from artesian wells, are utilized for heating and for domestic purposes and yield considerable revenue to the company controlling them, while the uniformity of heat and the constancy of supply day and night for domestic uses are of great value to the consumer.

At various other points the waters are used for heating the hotels and cottages built about hot springs, as, for example, at Boulder Hot Springs, Mont.

At Gregson Springs, Mont., the waters are used to heat greenhouses. Perhaps the most striking example of this is seen at the Upper Geyser basin, Yellowstone Park, where the ingenious keeper of the hotel supplied himself throughout the winter, and the guests in summer, with fresh vegetables grown in a greenhouse erected over a small spring of boiling water. The exuberant growth of the plants in this house proved a marvel to all visitors.

HOT SPRING DEPOSITS.

The waters of hot springs, particularly those of high temperature, invariably carry more or less mineral matter in solution. While the soluble salts, such as sodium sulphate, are carried off by the waters, frequently an incrustation is formed in the fissure or tube from which the waters issue, or on the surface about the spring where the water overflows. The most common deposit is travertine, or calc-sinter, or calc-tufa (carbonate of lime); less commonly it is siliceous sinter, also known as geyserite. If the hot-spring fissure is coated or filled by similar material, veins are formed, which are in numerous cases known to be slightly metalliferous.

Though the formation of ore deposits by the agency of hot springs is well recognized by mining men, examples of such deposits now actually forming are comparatively rare. The Sulphur Bank, California, cinnabar deposits and Steamboat Springs, Nevada, are two noted localities in the United States. The deposits of Boulder Hot Springs and Anaconda Hot Springs, Montana, are of scientific interest, though the precious-metal content is minute. An interesting example occurs in Java, where the hot springs of Gunung Kendeng district contain iodide of copper, from the waters of which copper is obtained by evaporation, the product being 5,161 pounds in 1899.[a] Tin-bearing sinters, formed by hot springs, are worked in the Malay Peninsula, and the hot waters of several Japanese mines are known to contain considerable amounts of various metals.

The Steamboat Springs, Nevada, have recently attracted renewed attention because of the discovery that the alluvial gravels underlying the hot spring sinters are encrusted and cemented by stibnite and pyrite, the antimony ore being in considerable abundance. It has recently been described by Lindgren.[b]

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[a] Stevens Copper Handbuch, vol. 4, 1904, p. 156.

[b] Bull. Am. Inst. Min. Eng., Mar., 1905, p. 275.

The deposits of the Boulder Hot Springs have been described in detail by the writer and appear identical in character with the silver and gold bearing quartz veins so abundant throughout the region between Butte and Helena, Mont.[a]

In the rhyolite about the Monarch Geyser, Norris basin, Yellowstone Park, veins of gold-bearing pyrite are formed by hot waters. Indeed, the Yellowstone Park offers a most inviting field for the study of the relations between hot springs and ore deposition. Several springs at the Hot Lake group, Lower basin, are depositing considerable amounts of manganese oxide, and at the Ocher Springs deposits of limonite (red oxide of iron) are being formed, while the deposition of realgar and orpiment (the red and yellow sulphides of arsenic) at the Norris basin, has already been described.[b]

THE LIMONITE AND TRAVERTINE DEPOSITS OF THE ANACONDA HOT SPRINGS, MONTANA.

For a number of years the limonite deposits found on the foothills between Mill Creek and the city of Anaconda were quarried and the ore shipped to the East Helena smelter. In 1902 the property was investigated by Mr. H. V. Winchell, chief geologist of the Anaconda Copper Company. He kindly took the writer over to see the property, and called attention to its unique character. It is now owned by and forms an important source of flux for the Washoe copper smelter, which lies but a half mile or so to the north.

The Anaconda Hot Springs are 3 miles from Anaconda, on the hillside south of the great Washoe smelting plant and west of the Deer Lodge Valley. The area of former and existing hot-spring action covers the slope north of Mill Creek and west of the main valley, the old travertine terraces of this place being formerly as extensive as the famous ones of the Mammoth Hot Springs of the Yellowstone Park. Prolonged degradation has removed the larger part of the Anaconda deposit and destroyed all the terracing. The underlying rocks are tilted Mesozoic limestones, which are probably of Jurassic age, but which have not been identified by fossils. Their eroded surface is covered by rhyolitic tuffs, on which the travertine cap was laid down.

The existing waters are tepid, inert, and feebly charged, and are incapable of adding to the great deposit of travertine that once covered the slopes. Several old cones still exist, and from an isolated one to the northwest of the main area a small quantity of warm water overflows. There is another cone to the extreme southwest,

[a] Weed, W. H., the Boulder Hot Springs, Mont.: Twenty-first Ann. Rept. U. S. Geol. Survey, pt. 2, 1900, p. 227.

[b] Weed and Pirsson, Am. Jour. Sci., 3d series, vol. 42, 1895, p. 401.

but the main outflow is from the open quarries and underground workings, where a deposit of limonite is extracted for a flux.

This limonite deposit is extensive, covering many acres. It comes to the surface in some places, but elsewhere lies beneath the travertine sheet, of which it is clearly a replacement formed by the existing springs.

The travertine has the surficial aspect of an ordinary limestone. Even in the cuts along the switch line to the new smelter, where 20 feet of curved and platy superimposed sheets of calcareous tufa are exposed, the travertine is easily mistaken for limestone unless compared with the similar old deposits of the Yellowstone Park. Aside from the water-filled cone just noted, there are no recent deposits to give a clue to its origin. The old basins and terraces are gone, soil and vegetation cover a large part of the area, and the travertine is no longer loose and friable, but hard and dense, though in part still porous.

The chief economic interest lies in the iron ore. The existing waters are distinctly ferruginous and are warm (100° ±). They deposit limonite in their channels and in the drainage trenches, and are evidently replacing the travertine by limonite (not siderite) at a depth of 10 to 20 feet below the surface. The limonite not only forms a sheet, but sac-shaped masses, prongs, and tongues project into the travertine along joint cracks, etc. This ore is very low in silica, carries 2 per cent or more of lime (gradations to travertine being, of course, common), and, according to assays, often carries 50 cents to $1.50 in gold per ton. It is the chief source of flux for the great Washoe copper smelter.

GYPSUM VEINS AND WATERS OF HUNTERS HOT SPRINGS, MONT.

The gypsum veins at Hunters Hot Springs, Mont., are, so far as known, devoid of metallic contents, but are of considerable scientific, and possibly economic, importance. Gypsum is often found in mineral veins, but has usually been considered as an alteration product, due to oxidizing waters, which become acid from decomposing sulphides, and react on carbonate of lime. That the gypsum at Hunters Hot Springs is of primary origin and is due to deposition by hot waters in open fissures appears certain.

One of the best-known hot-spring resorts of Montana is situated on the hills north of the Yellowstone River, about 20 miles east of Livingston. The locality is easily accessible from a station on the Northern Pacific Railroad, and is improved by hotels and bath houses. The area is part of the foot-slope region of the Crazy Mountains, whose snow-covered peaks rise to heights of 11,000 feet at a distance of only 10 miles to the north.

The country in the immediate vicinity of the springs is relatively gently rolling, there being a succession of hills and long ridges, with intervening swales, carrying intermittent streams. The Sheep Cliffs, or Sheep Mountain, an abrupt sandstone cliff capped by intrusive trap sheet, lies about 4 miles to the west. The gentle foothill region of the Crazy Mountains is, in this vicinity, somewhat barren in aspect, having a scanty growth of grass, with occasional low sagebrush. At the immediate vicinity of the springs the main drainage channel carries flowing water, and a fine growth of cottonwoods forms a pleasant park. With the exception of the alluvial-filled stream bottoms, the country has too scanty a soil to be useful for agriculture.

The rocks in this neighborhood are all part of the Livingston formation, which is composed of dark-colored, poorly assorted sandstone-like rocks made up mainly of volcanic débris, and represents the finer material ejected from the volcanoes of the region to the south, which were active in early Eocene time. These rocks have been folded, and the hot-spring fissures are on the summit of an anticlinal fold with a northeast axis, while the igneous masses of the Crazy Mountains send out innumerable dikes, some of which reach almost to the vicinity of the springs. These dikes are radial from the mountains, and if extended to the springs would cut across the folded rocks at an acute angle with the axis of the main anticline. In fact, a fault observed in the canyon of the Yellowstone appears to extend northward, passing almost through the location of the springs.

These hot springs are connected with reefs or veins composed of gypsum, with stilbite. The more prominent of these reefs are seen in the ridges to the northwest of the springs, which are now dry, but the existing hot waters come from a similar vein, and their complete resemblance and connection with the older and now dry veins is quite apparent. These veins occupy fractures traversing upturned beds of arkose, grits, sandstones, and shales, all of them dark-colored rocks which, as already noted, are composed of volcanic, andesitic débris, forming a part of the Livingston series, a post-Laramie fresh-water formation. The veins outcrop in white reefs, which form a conspicuous feature of the grassy slopes, and are in strong contrast to the dark-colored rocks of the ridges. There are three of these reefs. The two westernmost are about a quarter of a mile apart, and approach each other to the north. The middle vein, which is the largest, has a course of N. 60° W. The vein to the west of it runs nearly northwest, while the eastern vein is parallel to the middle one. As just noted, the rocks are upturned, the dip varying from 5° to 20°, and vary in strike as the beds curve about sides of the anticlinal dome. There is considerable difference in elevation along the veins, owing to the relief of the ground.

The largest vein is well exposed on the steep eastern slopes of a little valley about three-fourths of a mile west of the springs. Its prominent white outcrop forms in some places a wall that rises 3 to 6 feet above the general surface of the ground, but it is more generally weathered down to a few inches above the general surface. The vein is almost continuously traceable for 1½ miles, from a point a mile south of the wagon road to a point half a mile north of it. In this distance there are a few short gaps in the exposure, in which débris and dirt washed down the hillsides cover the vein. Throughout this length of 1½ miles the vein is remarkably uniform in direction, though presenting gentle minor sinuosities. The width varies from 1 to 5 feet. The filling consists mainly of gypsum, which in weathering breaks along cleavage planes and presents a curious, glittering appearance when seen at a distance. This gypsum is seamed by veinlets of stilbite, which often form rosette-like masses. Included fragments of the gritty sandstone wall rock often occur in the vein, and these fragments are commonly surrounded by stilbite, resembling the so-called cockade or ring ores of mineral veins. The stilbite also occurs frequently in cracks in the adjacent country rock, forming little veinlets parallel to and alongside the main vein. The only other mineral seen in the vein is calcite, and this is not common, though when it is found it occurs in considerable quantity, but is readily distinguished by its opaqueness from the more waxy-looking gypsum which surrounds and incloses it. These reefs are the most conspicuous feature of the country west of the hot springs. Their origin is clearly to be ascribed to hot waters, and the nearest reef is about one-fourth of a mile west of the existing springs. So far as could be determined the veins are barren of metallic minerals.

The Hunters Hot Springs comprise a number of vents, the waters issuing from veins similar to those just described. The waters come from the central portion of a shallow basin inclosed by low rocky slopes or bounding walls of a small creek valley, whose upper course is marked by groves of cottonwoods. The springs in the upper group issue from a fissure in the rocks and are surrounded by a grassy marsh. Owing to artificial excavations, the fissure has been exposed, but at present the waters are confined in a basin or pool lined with lumber, the outflow flowing through a trough to the bath houses. There is a copious emission of gas, mainly CO_2, but in part sulphureted hydrogen. The fissure line is exposed for a distance of perhaps 20 feet.

The lower group of springs issues from a fissure that also traverses the barren dark purplish sandstones or grits of the Livingston formation. The crevice is in part filled by a deposit of gypsum, which varies from 2 to 3 inches in width and resembles the veins already noticed. The flow from these lower springs is copious, has a sulphurous taste, is remarkably soft, and, as far as observed, does not form a surface deposit outside of the fissure, not even in the channels lined with brown and red algæ, a growth which is abundant in the overflow and forms silk-like skeins in the easternmost spring. The water is palatable and is largely drunk by the guests at the hotel.

It is probable that the rock walls of the fissures from which the waters of the Hunters Hot Springs now issue have long since been leached of the more readily soluble material. The rocks are composed of small fragments of andesite, the fine dust of a volcanic eruption washed into the waters of a great lake which at one time covered this region and extended westward to the flanks of the Bridger Mountains. As the hot waters come up through these rocks, it would be expected that the older deposit would contain an abundance of silica, but no such deposit has been found. The material consists mainly of sulphate of lime. The stilbite, which is a monoclinal zeolite, though a contemporaneous deposit, is mainly the product of the later or dying stages of hot-spring action. The temperature of the water is 148° F. No official analysis has been made, but the accompanying analysis, made for the owners of the springs by Mr. Harry Snyder and published on their letter heads, is given herewith:

Analysis of water from Hunters Hot Springs, Montana.

Temperature	° F	148
Mineral matter	grains	16.28
Silica	per cent	17.03
Alumina	do	2.82
Lime	do	.75
Magnesia	do	.75
Chlorine	do	3.62
Potash	do	1.60
Soda	do	44.02
Combined carbon dioxide	do	15.51
Combined water	do	10.25
Sulphates	do	.88
Lithium		Trace.
Gases in solution:		
Free carbon dioxide	per cent	49
Dissolved oxygen	grams per liter	.0416

As stilbite contains 57.4 per cent silica, 16.3 per cent alumina, 7.7 per cent lime, and 1.4 per cent soda, with 17.2 per cent water, it is probable that the spring water is now depositing this mineral, and not gypsum, but this could not be verified.

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