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IRON OXIDE MINERAL PIGMENTS OF THE UNITED STATES

BY

HEWITT WILSON

With contributions by
JELKS BARKSDALE, HENRY H. SYMONS, C. McK. LAIZURE
RICHARD W. SMITH, BENJAMIN L. MILLER
and FREDERICK A. BURT

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CONTENTS

Page

Page

Part III—Continued

Part V—Continued

Part V—Continued

ILLUSTRATIONS

IRON OXIDE MINERAL PIGMENTS OF THE UNITED STATES[1]

By HEWITT WILSON[2]

INTRODUCTION

PURPOSE OF INVESTIGATION

No national investigation of the mineral pigments of the United States has ever been undertaken. Pennsylvania[3] and Georgia[4] made reports on this subject 20 years ago, and California[5] has kept a continuous record of prospects and mines and the production of her mineral pigments, but in most of the other States mineral pigments have been neglected. The United States Bureau of Mines issued two reports in 1929—one describing some possible mineral-earth colors in the Pacific Northwest[6] and the other summarizing the production and uses of ocher and similar pigments.[7] No statistics covering the total output of the United States have been available since 1915, but the estimated domestic production of natural pigments probably exceeds $3,000,000 annually; artificial pigments add to this amount.

Many persons interested in mineral pigments agree that the French ocher, Italian sienna, Spanish red oxide, and Turkish umber cannot be duplicated in the United States as to hue or uniformity of standards. Is this true? Although time and funds were not available to permit investigation of the size and uniformity of American deposits a preliminary study was made of the color of numerous mineral earths. Color is the factor of greatest importance in deciding the value of a pigment. The extent and uniformity of the most promising deposits can be determined later, and modern mining and purifying methods will control uniformity.

SUMMARY

This report reviews the occurrence of mineral pigments and allied iron ores and the nomenclature and common methods of classifying and testing many commercial mineral pigments used in this country. Tests for color, tinting strength, fineness of grain, oil absorption, and content of iron oxide were made on 274 samples of

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[1] Work on manuscript completed April 1931.

[2] Engineer, nonmetallics, U.S. Bureau of Mines, Northwest Experiment Station, Seattle, Wash.

[3] Miller, B. L., The Mineral Pigments of Pennsylvania: Topog. and Geol. Survey of Pennsylvania Rept. 4, 1911, 101 pp.

[4] Watson, T. L., A Preliminary Report on the Ocher Deposits of Georgia: Geol. Survey of Georgia Bull. 13, 1906, 78 pp.

[5] Reports of the California Division of Mines and Mining.

[6] Wilson, Hewitt, Ochers and Mineral Pigments of the Pacific Northwest; Occurrence, Possible Methods of Preparation, and Testing of Ochers, Siennas, and Colored Clays: Bull. 304, Bureau of Mines, 1929, 74 pp.

[7] Santmyers, R. M., Ocher and Ochery Earths: Inf. Circ. 6132, Bureau of Mines, 1929, 20 pp.

both used and unknown minerals having possible pigment value. Most of the samples were obtained through various State geological surveys which either shipped them direct or advertised this study in local papers and trade journals. Most of the materials were received crude and required washing or grinding. The sand and grit in the soft, claylike samples were removed by differential settling in water, followed by concentration, drying, and pulverization. Hard iron ores were ground in water in pebble mills.

Most materials had no commercial value because of poor color, poor tinting strength, and low content of iron oxide.[8] Forty-six samples from new deposits had possible commercial value for ocher or sienna of some grade—18 for burnt sienna, 13 for mineral browns, 5 for umbers, and 10 for miscellaneous pigments. Clear, bright-yellow ocher or sienna is the rarest of these iron oxide pigment materials. Natural red earths are generally inferior in depth of chroma and clearness of hue to the artificial red produced by calcination of iron oxide. The red-brown earths, however, are plentifully distributed over the whole country and occur in far larger quantities than the yellow-brown earths. Six yellow-ocher samples—2 from Alabama, 2 from Illinois, 1 from Mississippi, and 1 from Washington—gave a clear color similar to that of imported French ochers and hence justify further investigation with respect to mining and marketing. Undoubtedly some good orange-yellow pigments will be uncovered in Alabama, Illinois, Mississippi, Nevada, Utah, and Washington. The remaining 40 ochers, classed as having commercial possibilities, may give local service in their own districts where exact duplication of French ocher is not necessary.

Many pigments tested are hybrid mixtures which lie between the commercial classes and cannot be substituted directly in the formulas of paint and pigment manufacturers. However, considerable confusion in nomenclature and hue results when the products of different dealers and manufacturers of natural earth pigments are compared, particularly the larger variety of colors introduced in the market from American deposits to duplicate some well-known European pigment but differing widely from that for which it was named This practice not only discredits American pigment but shows a lack of ingenuity in devising new names and in marketing a useful material.

Chemically precipitated pigments have successfully invaded the natural pigment industry and give an American product of excellent color and fineness and high tinting strength. The higher prices of the concentrated artificial pigment can be reduced to that of the natural materials by accurate dilution with a silica, gypsum, or clay base. Exhaustion of natural resources therefore presents no cause for alarm in estimating the future supply of pigment materials.

PRODUCTION

The United States Geological Survey discontinued its canvass of the production of natural pigments in 1915. Table 1 summarizes Survey data between 1911 and 1914.

The United States Bureau of the Census prepared a special summary of the natural and synthetic pigment production of the United States

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[8] The descriptions of 34 samples tested in the study were eliminated from this report because of inferior pigment qualities and of 37 others because their source could not be ascertained from the persons submitting the samples.

from 1914 to 1929. These data are given in table 2 and figures 1, *A* and *B*, and 2, *A*.

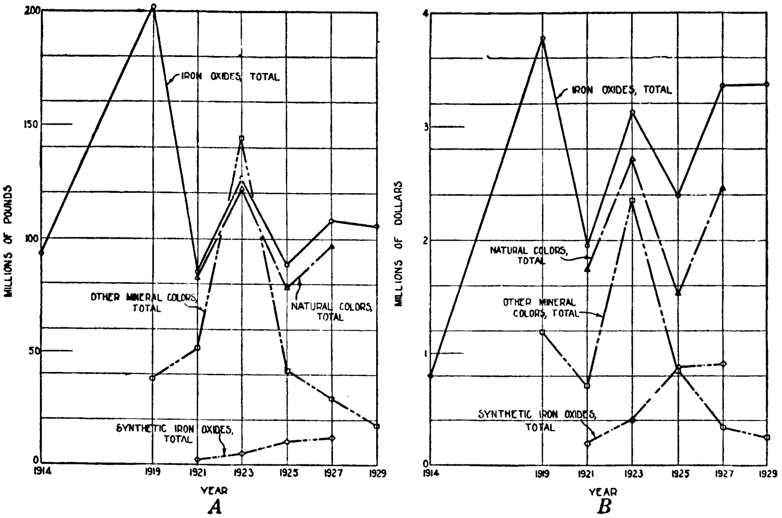

FIGURE 1.—Iron oxides and other mineral pigments in the United States, 1914–29: *A*, Production. *B*, Value. (Data compiled by the U.S. Bureau of Census.)

The production of iron ore sold for paint is given in table 3.

TABLE 1.—*Production of pigments in the United States between 1911 and 1914*

Pigment	Maximum annual production [1]			Price per short ton	
	Year	Quantity, short tons	Value	Maximum	Minimum
Umber and sienna	1911	1,005	$26,225	$27.30	$26.09
Mortar colors	1912	9,272	87,595	9.66	6.62
Slate and shale	1912	20,964	121,482	6.61	5.79
Ocher	1913	17,578	173,944	9.90	9.35
Metallic paint	1914	30,947	179,653	7.08	[2] 5.69

[1] Although these figures were the best obtainable, they were estimated to be at least 25 percent below the actual output.

[2] Includes crude iron ore sold for paint, which accounts in part for the low value per ton.

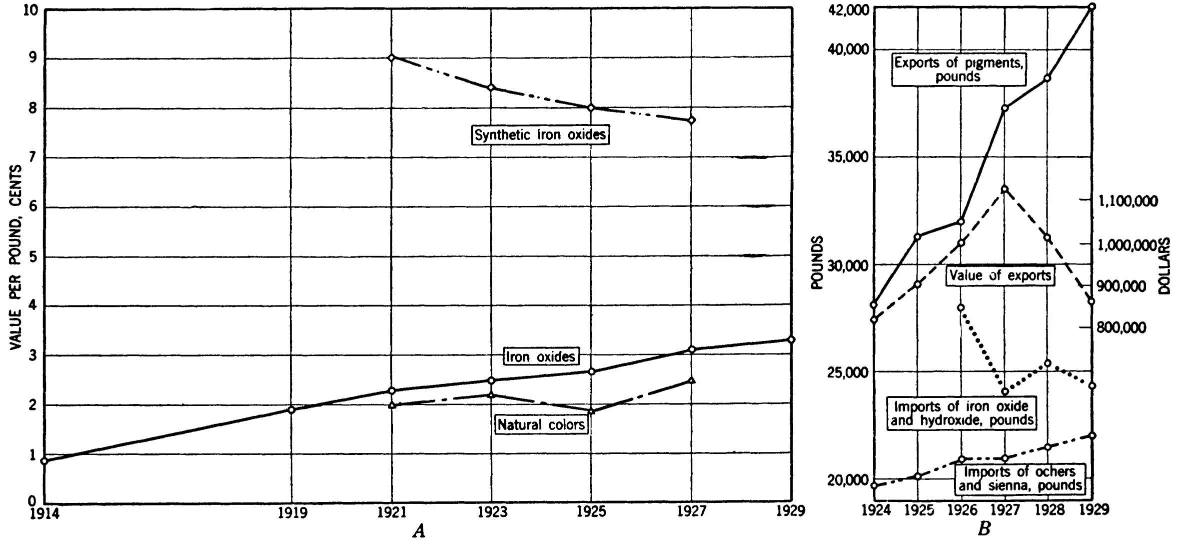

FIGURE 2.—*A*, Values per pound of various iron oxide pigments produced during the period 1914–29. *B*, Imports and exports of iron oxide and iron hydroxide pigments, 1924–29. (Data compiled from Foreign Commerce and Navigation of the United States for 1929, U.S. Bureau of Foreign and Domestic Commerce.)

TABLE 2.—*Iron oxides and other mineral pigments produced in the United States, by States, 1914–29*

[Compiled by the Bureau of Census, Department of Commerce]

	1929		1927		1925		1923	
	Short tons	Value	Short tons	Value	Short tons	Value	Short tons	Value
Iron oxides, total	52, 814	$3, 574, 800	54, 179	$3, 357, 895	44, 386	$2, 384, 148	63, 454	$3, 133, 953
Natural (ocher, sienna, umber, etc.), total	[1] 52, 814	[1] 3, 374, 800	48, 338	2, 452, 134	39, 023	1, 517, 997	61, 000	2, 718, 088
Pennsylvania	17, 456	1, 170, 345	(2)	(2)	(2)	(2)	11, 799	472, 979
New York	(3)	(3)	(2)	(2)	(2)	(2)	(3)	(3)
Other States	35, 358	2, 204, 455	(2)	(2)	(2)	(2)	49, 201	2, 245, 109
Synthetic precipitated, total	(4)	(4)	5, 841	905, 761	5, 363	866, 151	2, 454	415, 865
Other mineral colors, total	8, 632	254, 373	14, 600	343, 884	20, 554	858, 307	72, 445	2, 349, 082
Pennsylvania	4, 305	137, 790	(2)	(2)	17, 180	568, 458	46, 330	1, 895, 433
New York	(3)	(3)	(2)	(2)	724	160, 604	(3)	(3)
Other States	4, 327	116, 583	(2)	(2)	2, 650	129, 245	26, 115	453, 649

	1921		1919		1914	
	Short tons	Value	Short tons	Value	Short tons	Value
Iron oxides, total	42, 564	$1, 951, 887	101, 091	$3, 778, 942	46, 448	$797, 819
Natural (ocher, sienna, umber, etc.), total	41, 379	1, 737, 478	[1] 101, 091	[1] 3, 778, 942	[1] 46, 448	[1] 797, 819
Pennsylvania	13, 237	549, 061	62, 373	2, 433, 231	14, 396	199, 576
New York	7, 019	274, 889	9, 595	425, 966	(3)	(3)
Other States	21, 123	913, 528	29, 123	919, 745	32, 053	598, 243
Synthetic precipitated, total	1, 185	214, 409	(4)	(4)	(4)	(4)
Other mineral colors, total	25, 919	709, 939	19, 132	1, 176, 505	(2)	(2)
Pennsylvania	7, 815	298, 030	(2)	(2)	(2)	(2)
New York	(3)	(3)	(2)	(2)	(2)	(2)
Other States	18, 104	411, 909	(2)	(2)	(2)	(2)

[1] Includes data for synthetic iron oxide.
[2] No data.
[3] Included in figures for "Other States."
[4] Included in figures for "Natural" iron oxide.

IMPORTS AND EXPORTS

The data given in tables 4, 5, 6, 7, and 8 and figure 2, *B*,[9] indicate a drop from 27,987,000 to 24,441,000 pounds in quantity and of 10 percent in value in the importation of iron oxide and iron hydroxide pigments from 1926 to 1929. However, imports of ochers and siennas have increased steadily during the past 6 years, with an increase of 66 percent in value since 1924.

Likewise exports of mineral-earth pigments have increased 47 percent in quantity but only about 5 percent in value from 1924 to 1929. The values increased until 1927, but dropped from 1927 to 1929. (See fig. 2, *B*.)

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[9] U.S. Bureau of Foreign and Domestic Commerce, Foreign Commerce and Navigation of the United States for 1929: Vol. 1, 1930, pp. xxxviii, 190, 296, 384, 457, 552.

TABLE 3.—*Production of iron ore sold for paint,*[1] *1920–29*

Year	Short tons	Value	Year	Short tons	Value
1920	27, 382	$112, 364	1925	29, 704	$140, 986
1921	11, 624	56, 824	1926	23, 707	129, 541
1922	30, 668	166, 682	1927	25, 023	132, 007
1923	27, 823	140, 306	1928	17, 815	83, 190
1924	23, 106	103, 626	1929	15, 754	90, 352

[1] Katz, F. J., and Clark, M. B., Mineral Resources of the United States (Preliminary Summary): Bureau of Mines, 1929, p. A 64.

TABLE 4.—*Imports and exports of mineral-earth pigments*

IMPORTS

[Quantities in thousands of pounds and values in thousands of dollars]

Article	1924		1925		1926		1927		1928		1929	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Iron oxide and iron hydroxide pigments [1]	(2)	(2)	(2)	(2)	27, 987	667	24, 050	588	25, 491	607	24, 441	600
Ochers and siennas [1]	19, 657	250	20, 139	275	20, 846	390	20, 872	448	21, 499	433	22, 034	416
All others [1]	(2)	835	(2)	935	(2)	481	(2)	594	(2)	508	(2)	601

EXPORTS

Article	1924		1925		1926		1927		1928		1929	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Ocher, umber, sienna, oxides, whiting, etc	28, 207	824	31, 265	903	31, 955	1, 006	37, 292	1, 125	38, 733	1, 084	41, 960	863

[1] Dutiable.

[2] No data.

NOTE.—Mineral-earth pigments for 1929 include: Whiting, $183,587; and barytes, $319,055.

TABLE 5.—*Imports of mineral-earth pigments in 1929* [1]

Country	Iron oxide and iron hydroxide pigments [2]		Ochers and siennas [2]		Other mineral-earth pigments, value [2]
	Quantity	Value	Quantity	Value	
	Pounds		*Pounds*		
Arabia	(3)	(3)	44, 800	$1, 265	(3)
Belgium	86, 207	$1, 585	(3)	(3)	$128, 703
British India	(3)	(3)	555, 632	14, 396	(3)
Canada	2, 263, 412	43, 503	(3)	(3)	413
Czechoslovakia	(3)	(3)	(3)	(3)	337
Denmark	(3)	(3)	(3)	(3)	12, 218
Egypt	(3)	(3)	7, 837	169	3, 987
France	1, 725, 631	28, 222	16, 444, 385	265, 106	37, 668
Germany	1, 255, 617	72, 927	901, 209	13, 771	315, 146
Italy	(3)	(3)	2, 986, 330	83, 459	30, 277
Malta, Gozo, and Cyprus	(3)	(3)	(3)	(3)	43, 414
Netherlands	4, 584	241	(3)	(3)	13, 042
Spain	13, 723, 646	216, 326	789, 114	14, 339	(3)
Sweden	(3)	(3)	(3)	(3)	2, 360
United Kingdom	5, 381, 828	236, 353	304, 438	23, 856	13, 272
Total	24, 440, 925	599, 157	22, 033, 745	416, 361	600, 837

[1] U.S. Bureau of Foreign and Domestic Commerce, Foreign Commerce and Navigation of the United States for 1929: Vol. 1, 1930, p. 296.

[2] Dutiable.

[3] No imports

TABLE 6.—*Imported mineral-earth pigments with rates and amounts of duty collected, 1929* [1]

Article	Rate of duty	Quantity, pounds	Value	Duty	Equivalent ad valorem, percent
Iron oxide and iron hydroxide pigments.	20 percent	24, 343, 077	$593, 291	$118, 658. 20	----------
Ochers, crude, not ground	⅛ cent per pound	1, 364, 465	25, 381	1, 705. 58	6. 72
Siennas, crude, not ground	⅛ cent per pound	1, 676, 663	47, 378	2, 095. 83	4. 42
Ocher and sienna, washed or ground.	⅜ cent per pound	18, 979, 131	343, 111	71, 171. 74	20. 74
Brown, Vandyke, Cassel earth or Cassel brown.	25 percent	1, 363, 097	24, 581	6, 145. 25	----------
Umbers, crude, not ground	⅛ cent per pound	7, 083, 100	43, 977	8, 853. 88	20. 13
Umbers, washed or ground	⅜ cent per pound	1, 189, 110	28, 144	4, 459. 16	15. 84
Mineral-earth pigments [2]	25 percent	6, 610	1, 786	446. 50	----------

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[1] U.S. Bureau of Foreign and Domestic Commerce, Foreign Commerce and Navigation of the United States for 1929: Vol. 1, 1930, p. 552.

[2] Not specially provided for.

TABLE 7.—*Domestic exports of mineral-earth pigments, ocher, umber, sienna, and other forms of iron oxides for paints, 1929*

State or city	Quantity, pounds	Value	State or city	Quantity, pounds	Value
Total	41, 959, 784	$862, 570	Mobile	200, 164	$1, 014
Arizona	7, 978	570	Montana and Idaho	80, 000	1, 330
Buffalo	15, 215, 705	161, 625	New Orleans	923, 787	18, 273
Dakota	689, 469	19, 776	New York	4, 792, 465	212, 640
Duluth and Superior	132, 518	3, 882	Ohio	140, 827	961
El Paso	39, 480	2, 851	Philadelphia	1, 848, 885	16, 501
Florida	370	39	Puerto Rico	5, 575	190
Georgia	205, 210	4, 445	Rochester	328, 446	2, 531
Los Angeles	26, 360	1, 355	St. Lawrence	3, 334, 806	44, 934
Maine and New Hampshire	227, 653	4, 802	San Antonio	64, 628	1, 961
Maryland	160, 425	3, 833	San Francisco	1, 394, 746	42, 617
Massachusetts	2, 500	311	Vermont	1, 138, 556	14, 963
Michigan	3, 078, 480	61, 139	Virginia	7, 614, 686	231, 300
			Washington	306, 065	8, 727

TABLE 8.—*Domestic exports of mineral-earth pigments, ocher, umber, sienna, and other forms of iron oxides for paints, 1929*

Country	Quantity, pounds	Value	Country	Quantity, pounds	Value
Argentina	138, 123	$9, 120	Japan	1, 063, 437	$28, 752
Australia	931, 507	35, 696	Java and Madura	8, 238	587
Barbados	400	92	Latvia	93, 624	2, 146
Belgium	60, 508	2, 806	Liberia	200	12
Bermudas	719	28	Mexico	635, 940	19, 136
Bolivia	1, 800	130	Mozambique	20, 150	1, 106
Brazil	35, 163	2, 217	Netherlands	548, 004	12, 816
British Honduras	350	9	Netherland West Indies	1, 220	71
British India	4, 410	282	Newfoundland and Labrador	328, 750	3, 340
British Malaya	1, 380	154	New Zealand	68, 155	3, 483
Canada	24, 800, 591	332, 714	Nicaragua	7, 689	444
Chile	5, 520	345	Nigeria	2, 255	86
China	18, 084	1, 451	Other British West Indies	12, 903	471
Colombia	193, 696	6, 439	Panama	263, 156	4, 439
Costa Rica	12, 622	612	Peru	9, 434	261
Cuba	2, 187, 046	23, 057	Philippine Islands	78, 600	6, 262
Denmark	50, 746	1, 305	Rumania	200	31
Dominican Republic	70, 797	3, 021	Salvador	6, 149	278
Ecuador	17, 500	200	Sweden	2, 515	225
Estonia	46, 524	1, 053	Trinidad and Tobago	401, 726	4, 395
France	203, 498	4, 155	Union of South Africa	952, 236	50, 460
French Oceania	333	8	United Kingdom	7, 527, 173	255, 748
Germany	624, 699	28, 403	Uruguay	9, 789	677
Gold Coast	276	21	Venezuela	326, 450	6, 980
Guatemala	15, 772	621	Virgin Islands of United States	9, 670	281
Haiti	33, 700	1, 181			
Honduras	7, 246	588			
Hong Kong	730	79			
Italy	113, 421	4, 098	Total	41, 959, 784	862, 570
Jamaica	4, 960	198			

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The Acheson Graphite Corporation, Niagara Falls, N.Y.
W. P. Fuller & Co., San Francisco, Calif.
Smith Chemical Co., 28 Moore St., New York, N.Y.
C. K. Williams & Co., Easton, Pa.
Reichard-Coulston (Inc.), 95 Madison Ave., New York, N.Y.
The Synthetic Iron Color Co., Richmond, Calif.
The Georgia Peruvian Ochre Co., Cartersville, Ga.
The New Riverside Ochre Co., Cartersville, Ga.
The Cherokee Ochre Co., Cartersville, Ga.
The R. K. Miller Minerals Corporation, Cartersville, Ga.
Kreitner & Co., 726 Center Street, Cairo, Ill.

Stanley Doggett (Inc.), 99 John Street, New York, N.Y.
Clinton Metallic Paint Co., Clinton, N.Y.
Tennessee Products Co., 14 Cummins Station, Nashville, Tenn.
Manufacturers Mineral Co., 1107 West Idaho Street, Seattle, Wash.
American Pigment Corporation, Bedford, Va.
Pickands, Mather & Co., Ironwood, Mich.
The Colorado Fuel & Iron Co., Pueblo, Colo.

A list of manufacturers and dealers in mineral pigments of all kinds can be obtained in the Green Book, published by the Oil, Paint and Drug Reporter, 12 Gold Street, New York City.

PART I. IRON OXIDE, IRON MINERALS, AND ORES

IRON OXIDE

Iron oxide is the third most abundant oxide of the earth's lithosphere and, according to Clarke,[1] represents in the oxide form 6.82 percent of the total. The central core of the earth is thought to be composed mainly of iron or nickel iron with a density appropriate to the pressure and temperature in the central region.[2]

Metallic iron is one of the most important materials of construction. In certain forms it is necessary for living plants and as ferric oxide produces one of the oldest and still most important coloring ingredients for interior and exterior building decoration and for rouge, face powder, and other cosmetics. Its distribution is universal. Very few rocks on the earth's surface contain less than 5 percent of iron oxide. Those that contain only small amounts, such as the white clays, kaolins, and limestones, are more valuable because of their low iron oxide content; but, on the other hand, some of the most valuable rocks are those with an iron concentration high enough to pay for extraction of metallic iron.

If iron-bearing rock is to be used as a pigment, the iron oxide must be in such a condition that the color is a pleasing yellow, brown, or red without contaminating impurities that lower its esthetic value. Iron oxide is the base for most natural rock colors, and the yellows, reds, and browns are the end-product colors derived by weathering. The iron oxide colors are very resistant to change from age and weathering. Those used by the early Egyptians have been uncovered in their original bright, strong colors after centuries of burial or exposure to sunlight.

As the coloring power of the natural red, yellow, and brown mineral pigments is due largely to the content and condition of iron oxide, in many instances the occurrence of mineral pigments is closely allied to that of the iron ores. Pigment materials and iron ores often are mined in the same localities; in others iron ores are used for mineral pigments of the red and brown varieties; and, again, the two are separate.

In Georgia and Pennsylvania iron ore is removed as waste material in washing ocher, while finely divided, ocherous material is floated off as waste material in the concentration of limonite iron ore. Waste dumps from iron mines are being reclaimed in Pennsylvania for pigment materials.

Iron ores have a high concentration of iron oxide, but the color may have no commercial value. Ocherous material of good color may have an iron oxide concentration far below that required for iron ores but sufficient for pigments.

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[1] Clarke, F. W., Data of Geochemistry: U.S. Geol. Survey Bull. 770, 1924, p. 34.

[2] Williamson, E. D., and Adams, L. H., Density Distribution in the Earth: Jour. Wash. Acad. Sci., vol. 13, no. 19, Nov. 19, 1923, pp. 413–428.

IRON MINERALS

The principal minerals of iron are:

1. **Magnetite—magnetic iron ore (Fe_3O_4).**—Magnetite is a hard (5.5–6.5), strongly magnetic black mineral, often granular, with a metallic luster and a specific gravity of about 5. Its color makes it unfit for the bright pigments; carbonaceous materials are softer and more easily worked and are generally used for black colors.

2. **Hematite—specular iron ore, red hematite, fossil ore, Clinton ore (Fe_2O_3).**—Hematite is red to brownish red, steel gray, or even black. It may be fine grained, but the specular varieties are often coarse. The specific gravity is 4.8–5.3. Bright-red hematites are valuable for pigments but may be produced by low-temperature calcination from other forms of iron.

3. **Limonite—brown hematite, bog-iron ore, ocher, brown ore ($Fe_2O_3.H_2O$ or 2 $Fe_2O_3.3\ H_2O$).**—Limonite varies widely in structure and appearance. Some forms are soft, powdery, or claylike; others, massive, porous, vesicular, stalactitic, or solid. The specific gravity is 3.6–4.0. The color ranges from brown to yellow-brown, and the dense, compact masses may have black surfaces. Although mineralogists have distinguished at least seven hydrates of ferric oxide, Posnjak and Merwin[3] proved that no series of hydrated ferric oxides exists among the minerals. The only hydrate whose existence has been established satisfactorily is the monohydrate, which occurs in nature in two polymorphic forms—göthite and lepidocrocite—and in an indefinite, amorphous form, with considerable excess of absorbed water, known as limonite.

Table 9 lists the hydrated ferric oxide minerals as commonly named.[4]

TABLE 9.—*Hydrated ferric oxide minerals*

Name of mineral	Chemical formula	Iron oxide, percent	Water, percent
1. Hematite	$2Fe_2O_3$	100	0
2. Turgite	$2Fe_2O_3.H_2O$	94.7	5.3
3. Göthite and lepidocrocite	$2Fe_2O_3.2H_2O$	89.9	10.1
4. Hydrogöthite	$3Fe_2O_3.4H_2O$	87.0	13.0
5. Limonite	$2Fe_2O_3.3H_2O$	85.5	14.5
6. Xanthosiderite	$2Fe_2O_3.4H_2O$	81.6	18.4
7. Limnite[1]	$2Fe_2O_3.6H_2O$	74.7	25.3
8. Esmeraldaite	$2Fe_2O_3.8H_2O$	69.0	31.0

[1] Ford, W. E., Dana's System of Mineralogy: John Wiley & Sons, Inc., New York, 6th ed., 1915, 1420 pp.

4. **Siderite—spathic iron, chalybite, blackband, clay ironstone, kidney ore ($FeCO_3$).**—Siderite has a vitreous luster and is usually crystalline but may be compact and earthy. Its specific gravity is 3.83–3.88. The color ranges from light to dark brown. Siderite is unfit for pigments, although siderite deposits may have been the source of iron salts for ocher deposits.

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[3] Posnjak, Eugen, and Merwin, H. E., The Hydrated Ferric Oxides: Am. Jour. Sci., 4th ser., vol. 47, 1919, pp. 311–348.

[4] Ford, W. E., Dana's Textbook of Mineralogy: John Wiley & Sons, Inc., New York, 3d ed., 1922, 720 pp.

ORIGIN AND OCCURRENCE OF IRON-ORE DEPOSITS

Table 10 shows Eckel's[5] classification of iron-ore deposits.

TABLE 10.—*Summary of classification of iron-ore deposits, according to Eckel*

A. Sedimentary or bedded deposits:
1. Transported concentrates.
2. Spring deposits.
3. Bog and Lake ores.
4. Marine basin deposits:
   (*a*) Carbonate deposits.
   (*b*) Silicate deposits.
   (*c*) Oxide deposits.

B. Replacements and fillings:
1. Cavity and pore fillings.
2. Normal replacements.
3. Secondary concentrations.
4. Contact replacements.

C. Alteration deposits:
1. Laterite deposits.
2. Solution residuals.
3. Gossan deposits (spongy cappings of brown ore formed by the weathering and leaching of pyrite or other sulphide ores). (See fig. 3.)

D. Igneous deposits:
1. Magmatic segregations.

LIMONITE AND BROWN IRON ORES

The iron oxide ores are chiefly sedimentary, but replacement deposits are the principal sources of limonite and ochers. Detailed discussion of the origin and occurrence of different ocher deposits is given later under the State headings, especially Georgia, Michigan, New Jersey, New York, and Pennsylvania. One of the most important series of brown iron ores of historical and economic interest is that lying in the long Appalachian Valley of the eastern United States. (See fig. 4.)

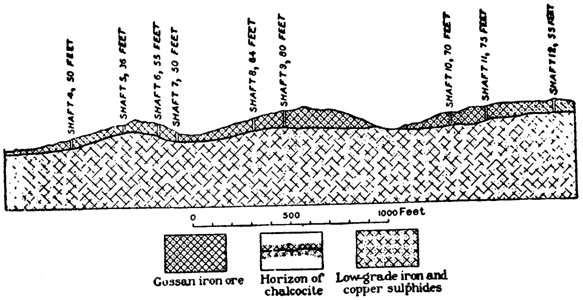

FIGURE 3.—Gossan deposits at Ducktown, Tenn., according to Emmons and Laney (Eckel).

BROWN IRON ORES OF THE APPALACHIAN VALLEY

According to Eckel,[6] the brown ores occur as scattered deposits overlying older rocks of different geologic ages. They have been deposited in most instances from iron-charged ground waters near the surface, particularly in limestone. The principal brown-ore deposits of the South occur in the Appalachian Valley or in its foothills. This limestone valley, almost continuous from Canada to Alabama, presents nearly ideal opportunities for the formation of the brown-ore deposits. As it is flanked on the east by iron-bearing crystalline rocks, which form the highlands of New York and New Jersey, the

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[5] Eckel, E. C., Iron Ores; Their Occurrence, Valuation, and Control: McGraw-Hill Book Co., New York, 1914, p. 39.

[6] Eckel, E. C., work cited, pp. 228–233.

South Mountain and Blue Ridge of Pennsylvania and Virginia, and similar ranges farther south, the progress of rock decay has for ages furnished a supply of iron-charged surface waters. The rocks of the valley itself, consisting chiefly of limestone with interbedded shales

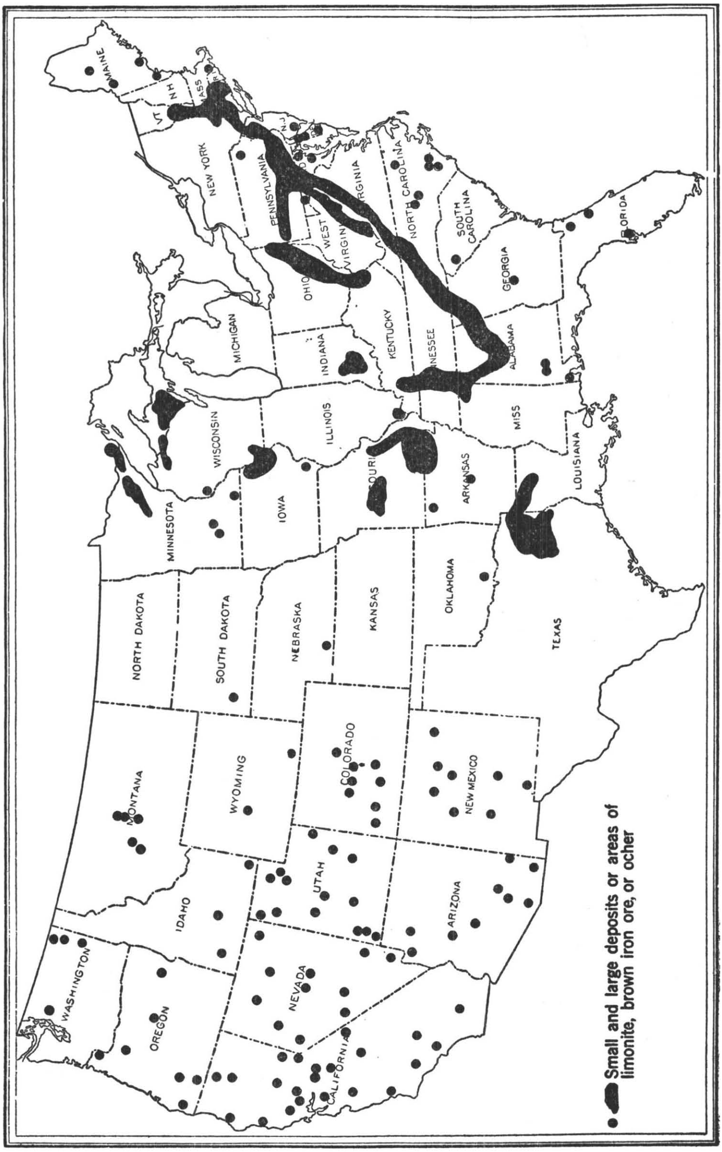

FIGURE 4.—Distribution of limonite, brown iron ore, and ocher in the United States.

and sandstones containing iron in small but persistent amounts, are more immediate sources of supply. Iron-charged surface waters have flowed from the hills into the valley, where the precipitated material has produced scattered brown-ore deposits from Vermont to central Alabama. (See State reports of New Jersey, New York, Vermont, Virginia, Pennsylvania, and Alabama.)

Throughout most of the range the heaviest deposits are along the eastern side of the valley; but the well-known Oriskany ores of Virginia, long worked at Longdale, Lowmoor, and other mines, are on its western side, as are also the Woodstock and Champion districts of Alabama. In Tennessee, northern Alabama, northeastern Georgia, and southwestern Virginia, however, most of the brown-ore mines that have become important shippers are close to the eastern side of the valley.

In virtually all places, except in the Virginia Oriskany district, the brown ores are associated with limestones, shales, and quartzites of Cambrian or lower Silurian age or with the clays and other residual material derived from the decay of these rocks. These deposits are likely to be richest at or near the surface and to disappear entirely when they strike solid rock. Their irregularities of form and richness are very pronounced, but usually careful study of local geologic features will enable both prospecting and work with reasonable economy and certainty. (See figs. 5, *A* and *B*, and 6, *A* and *B*.)

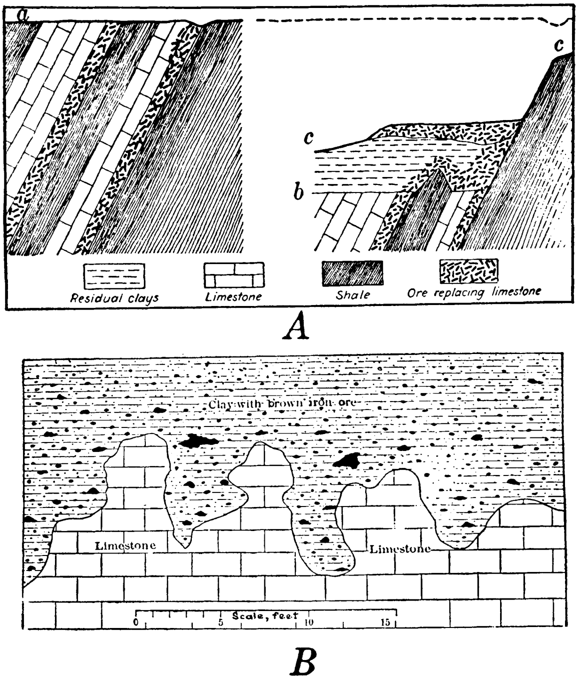

FIGURE 5.—*A*, Stages in origin of brown-ore deposit, according to Eckel: *a*, Rock surface, first stage, *b*, rock surface, second stage; *c*, ground surface, second stage. *B*, Vertical section showing structure of valley brown-ore deposits at Rich Hill mine near Reed Island, Va., according to Harder (Ries).

Although the theoretical metallic iron content of pure brown iron ore is 60 to 66 percent, depending on the iron minerals present, yet the richest deposits, worked by the most careful hand mining, rarely give ore grading above 55 percent, and the bulk of the ores will not yield more than 50 percent—some as low as 42 percent—of metallic iron.

OCCURRENCE OF HEMATITE

Hematite is by far the most important iron ore in the United States. (See fig. 7.) The two most notable commercial districts are the Lake Superior region and that near Birmingham, Ala. The geology and occurrence of the ores in these districts are described under the pigments of Michigan and Alabama, respectively. According to Ries:[7]

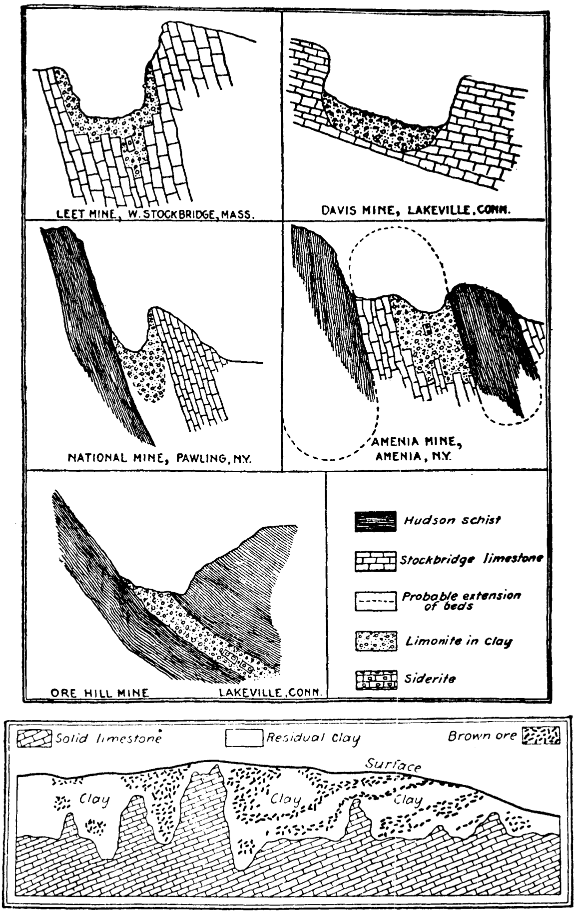

FIGURE 6.—Typical residual brown-ore deposits, according to Eckel.

Hematite may occur mixed with magnetite in magmatic segregations and contact metamorphic deposits, as beds in sedimentary rocks, as replacements in limestone, as irregular deposits formed by circulating surface waters, and as specular hematites in metamorphic rocks.

RED OR CLINTON HEMATITES [8]

The red or Clinton hematites are the chief ores of the southern iron and steel industry. Thousands of millions of tons of uniform com-

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[7] Ries, H., Economic Geology: John Wiley & Sons, Inc., New York, 4th ed., 1916, p. 524.

[8] Abstracted from Eckel, E. C., Iron Ores; Their Occurrence, Valuation, and Control: McGraw-Hill Book Co., New York, 1914, pp. 220-228.

position have been located and can be mined cheaply. The normal range of metallic iron is 33 to 40 percent. Lime carbonate is usually present, and the silica content is not as high as the low iron content would indicate. Ores of the same type and age are found in New York, Wisconsin, and Nova Scotia. (See fig. 8.) The oölitic ores of Newfoundland and Lorraine-Luxemburg are similar in type but of different geologic age. This type of ore is the main raw material for the Canadian, German, Belgian, and French steel industries.

Most of the red oölitic ores are associated with rocks of the Silurian age and occur as definite beds in the Clinton formation. The Clinton rocks outcrop along the eastern flank of the coal fields from Maryland to central Alabama. Although the ore beds are almost continuous for this great distance, they attain workable thickness and grade at only a few points in Virginia. The red ores are important in Tennessee, but attain their maximum thickness and best grade in Alabama, especially in the Birmingham district, where 3 to 5 distinct seams are found. The Big Seam of this district ranges in thickness from 15 to 30 feet, with 7 to 12 feet of workable ore. Analyses from Bulletin 400 [9] of the United States Geological Survey indicate a range of composition as follows: Fe, 33 to 36 percent; SiO_2, 11 to 33 percent; CaO, 5 to 19 percent.

FIGURE 7.—Occurrence of hematite and magnetite in the United States, according to Harder (Ries).

Chattanooga-Attalla region.—The region immediately north of the Birmingham district is virtually undeveloped, but from the vicinity of Attalla and Gadsden (Ala.) north to Chattanooga a number of properties have been or are being worked.

The ores in this district occur mainly as a broad, flat syncline or basin underlying Lookout Mountain. The mines have been opened on the two exposed outcrops of this basin, along the east and west flanks of Lookout Mountain, respectively. The total tonnage of the

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[9] Burchard, E. F., and Butts, C., Iron Ores, Fuels, and Fluxes of the Birmingham District, Ala.: U.S. Geol. Survey Bull. 400, 1910, 204 pp.

thin beds is enormous, and even the workable material to a depth of 1,000 feet is estimated to be well up in the hundreds of millions of tons.

OCCURRENCE OF MAGNETITE

Magnetite usually occurs as lenticular deposits in the metamorphic rocks of most mountainous regions. The most important series lies in the belt of crystalline rocks of the Appalachian highlands extending from New York to Alabama, although a number of deposits are found in the Western States. The principal districts are shown in figure 7. But, since magnetite is unimportant as a mineral pigment no further attention will be given it.

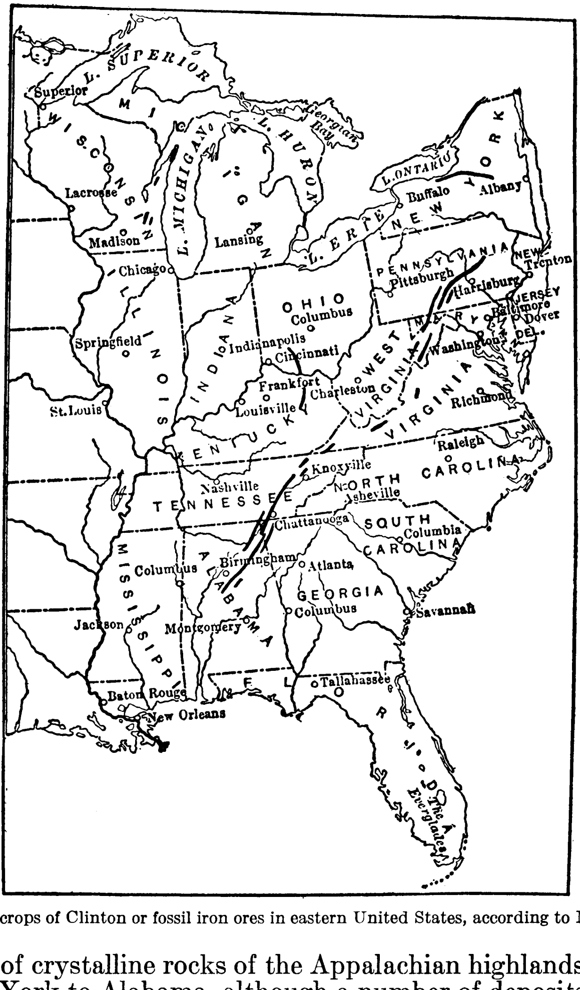

FIGURE 8.—Outcrops of Clinton or fossil iron ores in eastern United States, according to McCallie (Ries).

PART II. GENERAL INFORMATION ON MINERAL PIGMENTS[1]

Mineral pigments are the solid particles of required fineness that give color, opacity, or body to paint, stucco, plaster, mortar, cement, or similar materials and are substantially insoluble in the vehicle. They may be divided into three groups:[2]

1. The natural mineral pigments, including ocher, umber, sienna, ground slate and shale, metallic paint, and mortar colors. These are taken from the ground and prepared for the market by some simple purification or grinding treatment.
2. Pigments made directly from ores, including zinc oxide, leaded zinc oxide, sublimed blue or white lead, calcined umbers, and burnt siennas.
3. Chemically manufactured pigments, including white lead, litharge, red lead, orange mineral, lithopone, Venetian red, chrome yellow, Prussian blue, and other red and yellow ocherous colors made from scrap iron or iron waste.

Ladoo[3] gives a very complete classification of mineral pigments, and that portion pertaining to the materials studied in this paper is quoted in Bureau of Mines Bulletin 304.[4]

Mineral pigments are used industrially in general oil paints, ceramics, composition flooring, imitation leather, kalsomine, lacquer, linoleum, paper, rubber, and shade cloth.

COLOR

DEFINITION

1. The American Society for Testing Materials defines color as follows (D 16–24):

> **Color.**—A generic term referring to all of the colors of the spectrum, white and black, and all tints, shades, and hues which may be produced by their admixture.

2. Maerz and Paul[5] discuss color as follows:

> Color has no objective existence. It is solely a psychological phenomenon in which certain functions of light are affected by inherent plus momentary conditions of the retina of the eye for interpretation by the brain. The colors of objects may be completely altered by a variation of the light in which they are observed, and in the absence of light, all colors disappear—which is not the case with sound, taste, or feeling. And no one in the world can explain what color is to those who are colorblind.
>
> Colors are altered to an amazing degree, in hue, purity and value, both singly and in various combinations, by the simple presence alongside them of other colors. They are altered likewise by the reflected colors of their surroundings. They are altered by the character of the light in which they are observed, and according to the time of day. They are altered by the condition of rest or fatigue of the eye to any color, the presence of afterimage on the retina. And all these again operate in various combinations. Time and time again, the factors which alter colors have been explained in popular books on the subject; so that,

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[1] Wilson, Hewitt, Ochers and Mineral Pigments of the Pacific Northwest: Bull. 304, Bureau of Mines, 1929, pp. 3–10.

[2] Hill, J. M., Mineral Paints: U.S. Geol. Survey Mineral Resources of the United States, 1914, pt. II, p. 103.

[3] Ladoo, R. B., Nonmetallic Minerals; Occurrence, Preparation, and Utilization: McGraw-Hill Book Co., New York, 1925, pp. 364–391.

[4] Wilson, Hewitt, work cited, pp. 3–6.

[5] Maerz, A., and Paul, M. R., A Dictionary of Color: McGraw-Hill Book Co., New York, 1930, p. 143.

they may in truth be looked upon as matters of general information, certainly well known to those interested even in the slightest in color. They are facts that may be tested by anyone willing to give five minutes time to it. Yet there are people who claim that they can match or name colors, to exactness, by recollection alone.

ATTRIBUTES

Color is generally characterized by three attributes: (1) Hue, (2) value or brilliance, and (3) chroma or purity. Hue is the predominating spectral color in a color mixture or that property by which red, blue, and green are distinguished. (See table 11.) By value or brilliance a color is classed "as equivalent to some member of a series of grays ranging between black and white." By this property a dark red can be distinguished from a light red. Chroma or purity is "that attribute of all colors possessing a hue, which determines their degree of difference from a gray of the same brilliance."[6] This definition indicates the difference between a pure spectral red and a grayish red.

TABLE 11.—*Wave lengths of different hues,*[1] *millimicrons*

Hue	Representative wave length	Limits of wave length	Hue	Representative wave length	Limits of wave length
Visible spectrum:		400-800	Maximum visual intensity:	535	
Violet	410	400-422	Yellow	580	535-586
Blue	470	422-492	Orange	600	586-647
Green	520	492-535	Red	650	647-800

[1] Hodgman, C. D., and Lange, N. A., Handbook of Chemistry and Physics: Chemical Rubber Publishing Co., Cleveland, 14th ed., 1929, p. 964.

METHODS OF MEASUREMENT

Bruce[7] states:

> The color of a paint[8] is the result of a very complex relationship between the optical properties of the pigment particles, the color and refractive index of the vehicle, the ratio of pigment to vehicle, the conditions of observation and illumination, and often the surface covered. Upon the optical properties of the particles depends the pigment's power to diffuse, transmit, selectively absorb, and disperse incident light. These optical properties are determined not only by the chemical nature and refractive index, but in a large measure by the size, shape, and texture of the individual grains.

Three systems of color measurement were used in this study: (1) Comparisons were made with the common textile colors of the Standard Color Card of America; (2) comparisons were made with the standard colors of the scientifically arranged charts in the Munsell system; and (3) the wave lengths or hues of the more promising pigments were determined with the Hess-Ives tint photometer.

The Standard Color Card of America, eighth edition (revised 1928), issued by the Textile Color Card Association of the United States, Inc., 200 Madison Avenue, New York, was used to describe the shades and tints of this study in common color terms. This card consists of 192 samples of colored silk ribbon, 1⅛ inches by ½ inch in size. The upper half is smooth and the lower half corrugated. The colors are arranged in numerical order from 60001 to 60192 and are

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[6] Bruce, H. D., Tinting Strengths of Pigments: U.S. Bureau of Standards Res. Paper 7, 1928, p. 129.

[7] See footnote 6.

[8] Funk and Wagnalls Dictionary, 1924, defines paint as follows: "Paint, n. 1. A color or pigment, either dry or mixed with oil, water, etc."

given common, nontechnical names, such as "salmon pink", "peach", and "putty." Such expressions are excellent for trade purposes and for use in reports, but the reader must have a color card to get an exact idea of the hue discussed. These cards, however, are comparatively cheap and popular among the textile manufacturers and dealers. Many pigment colors of this study were not found in the color card and are therefore described as lying between this and that color number of the standard card. Colors cited in this bulletin, with names and numbers, are given in the following list.

COLORS CITED IN THIS REPORT

[Source: Standard Color Card of America]

60003	Cream.	60100	Deer.
60004	Polar bear.	60101	Beaver.
60005	Leghorn.	60112	Topaz.
60006	Maize.	60113	Gold-brown.
60013	Pink no. 1.	60114	Brown.
60014	Pink no. 2.	60115	Castor.
60016	Light blue no. 1.	60121	Nude.
60017	Light blue no. 2.	60122	Bisque.
60021	Tea rose.	60123	Monkey skin.
60022	Salmon pink.	60124	New cocoa.
60025	Flesh.	60125	Saxe blue.
60026	Pale pink.	60134	Terra cotta.
60033	Crane.	60135	Henna.
60036	Smoke.	60136	Mahogany.
60050	Silver.	60137	Heliotrope.
60052	Steel.	60139	Egg plant.
60060	Midnight.	60142	Oak wood.
60062	Honeydew.	60143	Tobacco.
60066	Reseda.	60144	Negro.
60071	Garnet.	60146	Marron glace.
60072	Light maroon.	60147	Leaf mold.
60077	Gobelin.	60157	Peach.
60080	Maple sugar.	60158	Crab apple.
60081	Mummy.	60159	Lacquer.
60082	Olive wood.	60164	Gold.
60083	Autumn.	60165	Bronze.
60084	Seal.	60169	Putty.
60085	Orchid.	60171	Blossom.
60088	Sunset.	60172	Old rose.
60089	Tan.	60175	Grecian rose.
60090	Pablo.	60176	Bois de rose.
60091	Terrapin.	60179	Chamois.
60097	Champagne.	60181	Ecru.
60098	Beige.	60186	Crocus.

The Munsell color system[9] uses the sphere for a geometrical arrangement of the colors in a systematic classification. Ten hues—red, purple-red, purple, purple-blue, blue, blue-green, green, green-yellow, yellow, and yellow-red—radiate from a common center of gray. With concentrated or full-strength colors this center of gray will have a low value or be close to black. Pure black has a value of 0. The light tints will have a light-gray center approaching pure white with a value of 10. The central point of gray always has a chroma of 0. As any hue increases in intensity the chroma number rises. However, the different hues vary in their maximum chroma, with red strongest. Such a system has an excellent foundation but is handicapped by the paucity of colors to cover all the natural variations presented in such

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[9] Munsell, A. H., A Color Notation: Munsell Color Co., Boston, 1919, 113 pp.; Priest, I. G., Gibson, K. S., and McNicholas, H. J., An Examination of the Munsell Color System: U.S. Bureau of Standards Technol. Paper 167, 1920, 33 pp.

studies as this. An endless number of combinations in hue alone can be made without relation to the other two variations of chroma and value. In this pigment study hues between red and yellow-red and between yellow-red and yellow were needed to make an accurate classification.[10]

For comparison with the Munsell colors the observations were made with the pigments direct—that is, not through the glass—and the surface was clean and dry. An observation of a strong color through the glass is similar to wetting the surface; that is, the chroma may be raised one or more points. The increase in chroma was not so noticeable with the tints. A classification of the pigments studied based on the Munsell system is given later.

Examples of the best ochers of this study were given a color analysis with a Hess-Ives tint photometer, and the wave lengths of 4 hues were determined by means of 4 color screens. The wave lengths as reported by the manufacturers were as follows: Red, 638 millimicrons; green, 535 millimicrons; blue-violet, 450 millimicrons; and yellow, 585 millimicrons. The transmission factors are: Red, 19 percent; green, 71 percent; blue-violet, 10 percent; and yellow, 11.4 percent.

The photometer consists of a box 10 by 17 by 14 inches equipped with a daylight lamp. The light from the lamp is reflected from the sample to one hemisphere of the field of vision, while the other half is illuminated by the reflection from the standard white magnesium carbonate block.

The color screens are placed in the line of vision in the eyepiece and filter out all but their respective wave lengths. A shuttered window in the line of sight leading to the white magnesium block can be given any percentage opening and the two halves of the hemisphere balanced in brightness. The percentage opening is then taken as the percentage of that wave length reflected from the sample under test. The results can be plotted in percentage as determined; or the sum of red, blue, and green readings can be recalculated to 100 percent. More details of this test are given in Bureau of Mines Bulletin 304;[11] other references on color analysis should also be consulted.[12]

TINTING STRENGTH

DEFINITIONS[13]

Tinting strength.—Tinting strength is "the power of coloring a given quantity of paint or pigment selected as a medium standard for estimating such power."

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[10] More hues are given in the publication by Maerz, A., and Paul, M. R., A Dictionary of Color: McGraw-Hill Book Co., New York, 1930, 207 pp.; Ridgway, Robert, Color Standards and Color Nomenclature: A. Hoen & Co., Baltimore, Md., 1912.

[11] Wilson, Hewitt, Ochers and Mineral Pigments of the Pacific Northwest: Bull. 304, Bureau of Mines, 1929, 74 pp.

[12] Meyer, W. W., The Adaptability of Various Methods to the Color Determination of White-Ware Bodies: Jour. Am. Ceramic Soc., vol. 13, no. 2, 1930, pp. 98–112.

Busby, H. S., Analysis and Comparisons of Systems of Color Measurement; A Proposed Arrangement for Measured Colors; and Some Notes on Interchangeability in Color Measurement: Proc. Am. Soc. for Test. Mat., vol. 22, pt. II, 1922, pp. 504–514.

Priest, I. G., The Spectral Distribution of Energy Required to Evoke the Gray Sensation: U.S. Bureau of Standards Sci. Paper 417, 1921, 35 pp. Nutting, P. G., A Method for Constructing the Natural Scale of Pure Color: U.S. Bureau of Standards Sci. Paper 118, 1909, 5 pp.; A New Precision Colorimeter: U.S. Bureau of Standards Sci. Paper 187, 1912, 5 pp. Coblentz, W. W., and Emerson, W. B., Relative Sensibility of the Average Eye to Light of Different Colors and Some Practical Applications to Radiation Problems: U.S. Bureau of Standards Sci. Paper 303, 1917, 77 pp. Lofton, R. E., A Measure of the Color Characteristics of White Papers: U.S. Bureau of Standards Technol. Paper 244, 1923, 10 pp.

[13] American Society for Testing Materials, Standard Definitions of Terms Relating to Paint Specifications: Standards, D 16-24, pt. II, 1927, p. 346.

Tint.—"Tint is color produced by the admixture of a coloring material, not white, with a white pigment or paint, the white predominating."

Shade.—"Shade is a term descriptive of that difference between colors which results from a difference in luminosity only, the other color constants being essentially equal. A darker shade of a color is one that has a lower luminosity."

Tone.—"Tone is the color which principally modifies a hue or a white or a black."

METHODS OF TESTING

The Government methods for testing pigments are given in United States Bureau of Standards Circulars 91 and 93 and Standard Specifications D 84-27, D 85-27, D 185-26, and D 50-27 of the American Society for Testing Materials. These are reprinted in part in the appendix of Bureau of Mines Bulletin 304.[14]

Method 1.—The usual method is to mix the pigment and zinc oxide in weighed amounts and grind them in bleached linseed oil as arbitrarily specified. This cycle is repeated for a standard pigment, and the two pastes are compared side by side on a clear glass slide both directly and through the glass. The method does not lend itself to quantitative evaluations. Dilutions of 1 part by weight of pigment to 9 parts of zinc oxide were used throughout this study, and comparisons were made with commercial pigments.

Method 2.—Quantitative results can be obtained with this method by varying the amount of pigment to zinc oxide until the color strength of the standard is matched. The ratio of the amount of the unknown pigment used to that of the standard is then taken as the numerical value for the tinting strength of the unknown.

Method 3.—Ostwald suggested that the tinting strength "can be measured by the ratio in which the chromatic and white pigment may be mixed before the chroma is just apparently gone."[15] This is another cut-and-try method.

Method 4.—Wilson[16] used the percentage gain in luminosity (measured with a tintometer), when a definite weight of zinc oxide was added, as an indication of the tinting strength.

CONSIDERATIONS INVOLVED IN MEASUREMENT OF TINCTORIAL POWER

Size of grain.—Zinc oxide is a sublimed product in a very fine state of subdivision. The numerical average particle size determined by Green[17] and by B. R. Silver, of the New Jersey Zinc Sales Co., ranges from 0.179 to 0.48 micron. (See fig. 9.)

As the size of grain of a given powder is decreased the surface exposed to incident light and the tinting strength are increased. When two powders, one of comparatively coarse particles and the other of very fine sizes, are mixed the fine material tends to coat the larger grains and hide their color. Bancroft[18] cites several examples of the apparent adsorption of one solid by another. One percent of Fe_2O_3 or rouge (passing a 200-mesh sieve) colored dolomite particles (coarser

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[14] See footnote 11.

[15] Bruce, H. D., Tinting Strength of Pigments: U.S. Bureau of Standards Res. Paper 7, 1928, p. 126.

[16] Wilson, H., Ochers and Mineral Pigments of the Pacific Northwest: Bull. 304, Bureau of Mines, 1929, p. 18.

[17] Green, H., A Photomicrographic Method for the Determination of Particle Size of Paint and Rubber Pigments: Jour. Franklin Inst., vol. 192, 1921, pp. 637-666.

[18] Bancroft, W. D., Applied Colloid Chemistry: McGraw-Hill Book Co., New York, 1926, p. 83.

than 100-mesh) a full red, but when the sizes were reversed the color of the dolomite remained practically white. The large size of grain probably accounts for the poor tinting strengths of some pigments of this study which contained high percentages of iron oxide. Many brands of prepared paints used for agricultural implements contain as high as 90 percent of natural barite.

White lead, a very common paint ingredient, is much more easily colored by pigments than is zinc oxide because of its coarser grain size, as table 12 shows. The numerical average particle size of three white-lead samples as determined by Silver ranges from 0.394 to 0.540 micron. (See fig. 9.) The hue is likewise changed toward yellow when white lead is used and away from the orange-brown of the zinc oxide mixture.

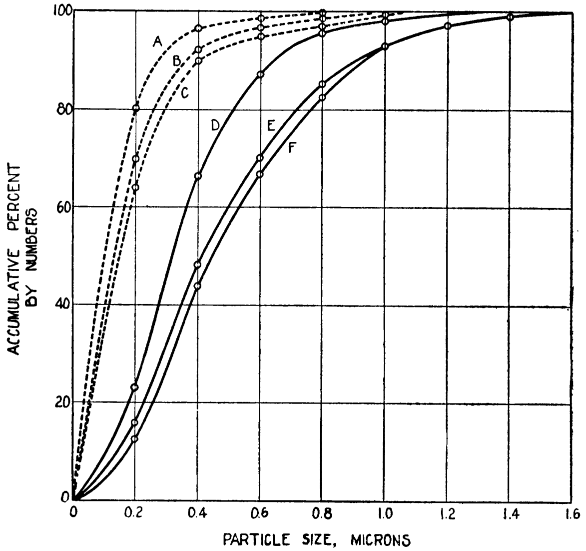

FIGURE 9.—Particle sizes of three samples of zinc oxide, A (Kadox), B (Florence White Seal), and C (XX Black), and three samples of white lead, D, E, and F. The numerical average particle sizes are: A, 0.179 micron; B, 0.238 micron; C, 0.279 micron; D, 0.394 micron; E, 0.520 micron; and F, 0.540 micron. (Courtesy of the New Jersey Zinc. Co.).

TABLE 12.—*Comparison of zinc oxide with white lead mixed with French ocher*

Pigment, percent	Luminosity, percent		Difference in luminosity, percent	Ratio of luminosities[1]
	Zinc oxide	White lead		
2.5	65	55	10	0.846
5.0	57	48	9	.841
10.0	49	39	10	.796
20.0	40	31	9	.775

[1] Corresponds to the ratio of "values."

Tinting strength with varying dilution.—Bruce[19] cites instances in which the relative value or brightness of two pigments on dilution with zinc oxide will be directly opposite at a high ratio of zinc oxide to that relation at a low ratio of zinc oxide.

Opacity of pigment.—The tinting strength will likewise vary with the opacity of the pigment particles and their power to diffuse light.

Change in hue.—When zinc oxide is mixed with a pigment the most noticeable change in the color is, of course, the increase in value or the tinting of the color. The zinc oxide used is not pure white. It contains some yellow, but the variation expected from this source would be constant in a given direction. The color analysis of zinc oxide and linseed oil alone gave the following percentages of reflection. A pure white body reflects 100 percent of each hue.

Color analysis of zinc oxide, percent

Red	84	Blue-violet	80
Green	82	Yellow	83

Bruce[20] states:

> When a chromatic pigment is diluted with a white one, light rays internally transmitted within a paint film or pigment mass will have a shorter mean path through selectively absorbing grains before reflection into the atmosphere, because of the interspersion of the highly diffusing and refracting white grains. Merwin[21] has pointed out that one effect of this will be the shifting of the dominant radiation in the direction of maximum spectral absorption. Merwin has shown also that because of the preferential scattering of light by fine particles the presence of very fine white pigment may cause a migration of the hue toward the violet end of the spectrum.

Prussian blue is so dark in full strength that it is virtually black; when slightly reduced its deeper values have a distinctly violet tone, but when further reduced they change into greenish tones.[22]

Small changes in hue will impair the accuracy of a comparison in tinting strength when made by the naked eye.

In this study it was found that hue changes with certain colors when they are diluted with zinc oxide. Some of the red and rose colors on dilution gain a purple-red hue. Red-purple is intensified markedly with the maroon colors; but, on the other side of red, the burnt siennas appear to change toward the yellow-red hues as zinc oxide is added. Thus the change with dilution does not necessarily follow straight vertical lines in the Munsell sphere of colors.

Changes in chroma and value.—Bruce[23] states that when a white pigment is tinted with any pigment other than black both chroma and value change. He adds:

> It is possible that these two attributes are mentally combined into one sensation which has been called the depth of tint. It does seem, however, that if there is any psychological tendency toward combination it is certainly not perfect, for of two tints of the same hue varying in both brilliance (value) and saturation (chroma) it is extremely difficult to select the deeper.

Mixtures of pure white and black, of course, will show only changes in value or brilliance.

Lowering of chroma numbers was noted with virtually all the pigments tested. For instance, the undiluted red oxides when

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[19] Bruce, H. D., Tinting Strength of Pigments: U.S. Bureau of Standards Res. Paper 7, 1928, p. 127.

[20] Bruce, H. D., work cited, p. 129.

[21] Merwin, H. E., Optical Properties and Theory of Color of Pigments and Paints: Proc. Am. Soc. for Test. Mat., vol. 17, pt. II, 1917, p. 496. See also Bull. 304, Bureau of Mines, 1929, p. 18.

[22] Maerz, A., and Paul, M. R., A Dictionary of Color: McGraw-Hill Book Co., New York, 1930, p. 138.

[23] See footnote 20.

compared with Munsell's colors had chromas as high as 7, but the diluted red oxide tints do not extend beyond 6 in chroma or intensity of red. Hence, an unknown pigment must be tested for tinting strength because estimates of the let-down hue, chroma, and value are likely to be inaccurate without trial.

FINENESS OF PIGMENT PARTICLES

The usual test for fineness is merely a determination of the amount of coarse grit that can be caught on a 200-, 300-, or 325-mesh sieve. Usually this grit content represents only a few percent of the total and does not indicate the average size of grain. It does indicate to some extent the thoroughness of preparation of the pigment and is more important with such pigments as the calcined siennas, umbers, and red shales ground from coarse sizes in the agglomerated or hardened condition.

Such properties as oil absorption, smoothness, plasticity, and spreading or covering power cannot be indicated by putting through the finest brass or cloth screens. The particles that affect these properties are much smaller than the screen openings.

METHODS OF TESTING GRIT

The grit content is usually determined by placing a weighed sample on the required sieve and washing it with water until all of the fines are removed. The residue is then removed from the sieve and dried for weighing. A small percentage of the dry residue will pass through the sieve even though these particles have been retained while wet. Kerosene is used in the Bureau of Standards fineness tests.[24] A simple qualitative test for grit is to place a small sample between the teeth, which are very sensitive to hard, gritty particles. The known grit specifications are given in table 13.

TABLE 13.—*Specified grit requirements of dry mineral pigments*

Authority	Pigment	Screen mesh	Maximum allowed, percent
United States Bureau of Standards Circular 90	Ocher	200	0.0
American Society for Testing Materials, D 84-27	Iron oxide, red and brown	325	3.0
American Society for Testing Materials, D 85-27	Ocher	325	1.0
A prominent paint manufacturer	General	325	1.0

The tinting-strength test, in which the pigment is mixed with zinc oxide, is another test of fineness. Coarser particles will not color the zinc oxide as well as a larger number of finer particles having the same total weight.

With products in whose preparation a grinding process is used, such as high-grade mixed and paste paints, a grit content is not as important as with pigments for linoleum, oilcloth, and low-grade paints, which are mixed, not ground. However, the absence of grit is an added sales advantage when competition is keen.

Table 14 gives the percentage of grit content retained on a 300-mesh sieve for a number of commercial mineral pigments. Other

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[24] U. S. Bureau of Standards, Recommended Specifications for Ocher, Dry and Paste: Circ. 91, 1920, p. 3.

samples were too small for tests of this nature. In some instances two values are given—the first for the percentage caught on a 300-mesh screen and the second, or total grit content, the sum of the plus 300-mesh product and the gritty settlings which have passed with the fines and wash water through the 300-mesh sieve. All the washings were collected in a suitable container and permitted to stand without agitation for 1 minute. All material in suspension was then decanted, and fresh water was added for additional washings until the residue was free of colored particles that remained in suspension for 1 minute when in freely dispersed condition. The residue was considered as grit. It was often necessary to add an alkali to disperse coagulated masses. One-hundred-gram samples were used.

TABLE 14.—*Fineness, oil absorption, and working properties of commercial pigments*

Company no.	Grade	Grit		Oil absorption		
		Plus 300	Total	Drops per gram	Part by weight	Working ability
A 1	Light French ocher			15	0.35	Some grit; spreads well.
A 2	Medium French ocher			16	.37	Do.
A 3	Dark French ocher			16	.37	Do.
A 4	Light domestic ocher			18	.42	Do.
A 5	Medium domestic ocher			15	.35	Very good.
A 6	Dark domestic ocher			16	.37	Do.
A 7	Domestic ocher	5.9	5.9	23	.53	
C 3	Yellow oxide			14	.32	Grainy.
C 4	Synthetic lemon			19	.44	O.K.; becomes fluid very suddenly.
C 5	Synthetic deep orange			20	.46	Do.
C 6	Synthetic orange			21	.49	Do.
C 7	Burnt sienna			28	.65	Soapy; hard to spread.
C 8	French ocher			16	.37	Some grit.
C 9	Domestic ocher			16	.37	Do.
C 10	Raw umber			22	.51	Some grit; soapy.
C 11	Raw sienna			30	.70	Some grit; hard to spread.
C 12	Burnt umber			25	.58	Do.
C 13	Red oxide			10	.23	Gritty; spreads easily.
C 14	Maroon			8	.19	A little grit.
C 15	Red			9	.20	No grit; good spread.
C 16	Red oxide			11	.26	Some grit; hard to spread.
C 17	do			8	.19	Gritty; good spread.
D 1	Golden ocher	1.3	1.9	8	.19	A little gritty; spreads well.
D 2	French ocher	.7	2.2	15	.35	Do.
D 3	American ocher	13.0		17	.39	
D 4	Italian burnt sienna	6.5	9.6	23	.53	A little soapy and gritty.
D 5	Double label	2.5	4.5	14	.32	Gritty; poor spread.
D 6	American raw sienna	3.6	5.0	19	.44	Gritty; good working.
D 7	Venetian red	3.4	5.3	12	.28	Do.
D 8	Italian raw sienna	6.3	10.0	21	.49	Gritty and soapy; poor working.
D 9	American raw umber	.2	.2	23	.53	Fine grained; smooth.
D 10	Vandyke brown	9.4	12.3	23	.53	Light weight; hard to spread; not gritty but not smooth.
D 11	Tuscan red	2.5	4.0	12	.28	A little grit; spreads well.
D 12	Red oxide	1.5		12	.28	A little grainy.
D 13	Turkish raw umber	12.7	18.3	23	.53	A little grit; hard to spread; soapy.
D 14	Spanish red oxide	2.5	7.9	8	.19	A little grit.
F 5	Yellow oxide	.7	.7	20	.46	Spreads well.
I 1	Raw sienna			16	.37	
I 2	Light ocher			16	.37	
I 3	Dark ocher			11	.26	
I 4	Mineral brown			9	.20	
I 5	Burnt umber			22	.51	

SPECIAL TESTS

To separate sizes finer than 300 mesh, elutriation, air-flotation, or settling tests are necessary; a microscope equipped with a micrometer scale is needed to estimate the size of particles after separation. Weigel [25] determined the size and character of three ochers, separating each by elutriation into five groups of different sizes and counting and measuring the particles of each group microscopically. He found

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[25] Weigel, W. M., Size and Character of Grains of Nonmetallic Mineral Fillers: Tech. Paper 296, Bureau of Mines, 1924, 44 pp.

that the ocher particles are rounded and are usually grouped as aggregates. The translucent, fine grains are usually free of impurities, while the larger sizes contain mica and quartz. The chemical analyses of the three samples are given in table 15.

TABLE 15.—*Chemical analysis of ochers studied by W. M. Weigel*

Constituents	Cartersville, Ga.	Iuka, Miss.	French ocher	Constituents	Cartersville, Ga.	Iuka, Miss.	French ocher
	Percent	*Percent*	*Percent*		*Percent*	*Percent*	*Percent*
SiO_2	38.04	38.00	40.65	MnO_2	1.01	Tr.	0.10
Al_2O_3	12.75	37.20	21.60	FeS_2			
Fe_2O_3	39.70	12.90	26.16	Alkalies			
CaO			.62	Ignition loss	6.40	13.16	9.73
MgO			Tr.				
TiO_2					97.90	101.26	98.86

Figure 10, *A*, and table 16 show the percentage parts by weight of the different sizes. The weight percentages are obtained by dividing the product of the number of each size and the cube of its diameter by the sum of these products, or $\frac{nd^3}{\Sigma\, nd^3}$.

These data indicate that at least 9.2 percent by weight of the Georgia ocher, 7.0 percent of the Mississippi ocher, and 12.1 percent of the French ocher would be caught on the 300-mesh screen. The chart indicates the inadequacy of screening methods to determine the sizes of the majority of the particles.

Figure 10, *B*, likewise taken from Weigel's data, indicates the percentage surface areas of the different particle sizes calculated by dividing the product of the number of each size and the square of its diameter by the sum of such product, or $\frac{nd^2}{\Sigma\, nd^2}$. Although the weight percentages show a maximum of 7 to 10 microns the surface areas show only a maximum with the finest sizes. A magnification of 950 was used for estimating particle sizes below 1 micron; undoubtedly with these claylike substances there is considerable material in the colloidal field or below 0.1 micron, but it is not shown in these data.

TABLE 16.—*Percentage weights of particle sizes, according to Weigel*

Average diameter, microns	Georgia ocher		Mississippi red earth		French ocher	
	Percent	Cumulative percent	Percent	Cumulative percent	Percent	Cumulative percent
80	4.6	4.6	7.0	7.0	3.3	3.3
60	2.1	6.7	.0	7.0	2.9	6.2
50	2.5	9.2	.0	7.0	5.9	12.1
40	4.4	13.6	2.8	9.8	10.2	22.3
30	8.3	21.9	7.1	16.9	11.8	34.1
20	10.2	32.1	7.6	24.5	10.9	45.0
15	16.9	49.0	11.0	35.5	13.7	58.7
10	12.1	61.1	13.5	49.0	12.0	70.7
7	10.7	71.8	19.6	68.6	9.1	79.8
5	9.9	81.7	13.1	81.7	8.8	88.6
3	10.0	91.7	9.7	91.4	4.5	93.1
1	8.6	100.3	8.5	99.9	6.5	99.6
	100.3		99.9		99.6	

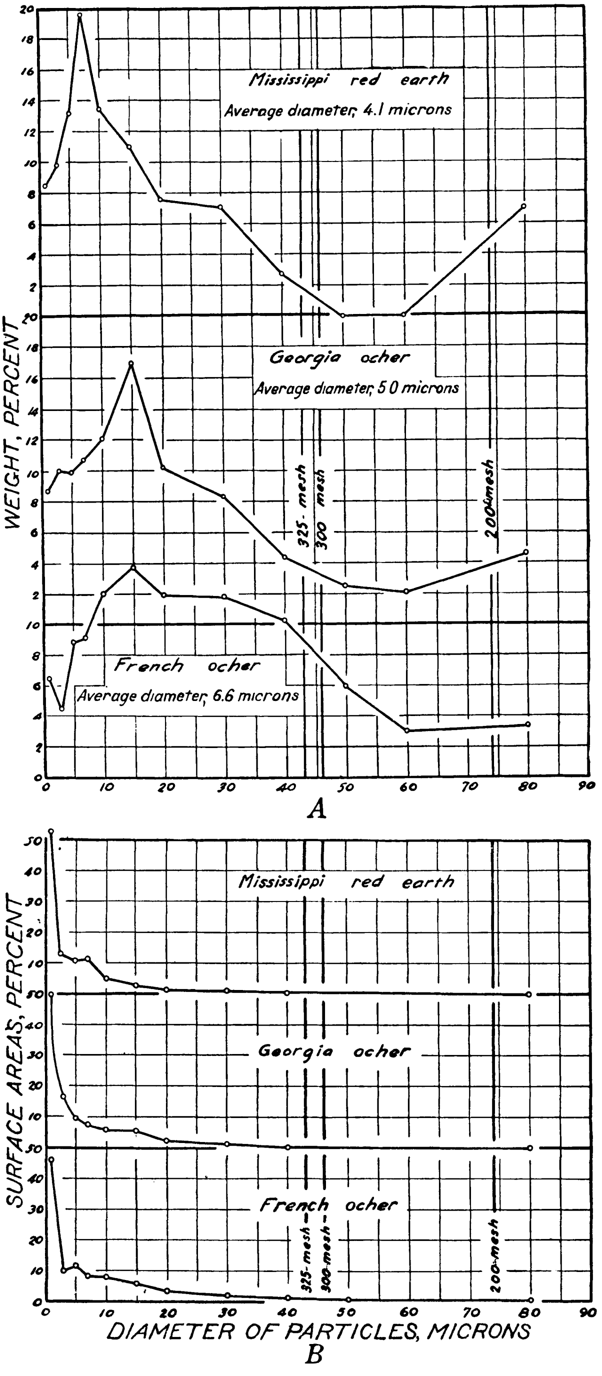

FIGURE 10.—Fineness of particles of three mineral pigments, according to Weigel: *A*, Weight versus diameter of particles. *B*, Surface area versus diameter of particles.

A number of other investigators [26] have developed apparatus and methods for determining the fineness of powders, but most of the recent systems have used air as the separating medium.

OIL ABSORPTION

Other physical properties of the pigment that affect the final cost of the prepared paint are the nature and extent of the particle surface, which must be covered with expensive linseed oil, and the absorption or porosity of the particle. The amount of linseed oil required to produce a given degree of fluidity depends largely on the size of the particles; this test is therefore an indirect method of finding the surface area or grain size. The coarse-grained pigments give low absorption of oil (unless porous) but have poor tinctorial power.

Method 1 ("rub-out" method).[27]—Place exactly 1 gram or any multiple thereof of the pigment upon a marble slab or glass plate and carefully weigh a dropping bottle containing some refined linseed oil. The bottle should be fitted with a ground-in pipette and rubber bulb. Note the weight of the bottle and oil. Gradually add, drop by drop, the refined linseed oil to the pigment; after the addition of each drop thoroughly incorporate the oil with the pigment by the use of a stiff spatula. The test is complete when exactly enough oil has been incorporated with the pigment to produce a very stiff, puttylike paste, which does not "break" or separate. Weigh the bottle and oil. The difference in weights equals the weight of oil used. Calculate the number of pounds of oil required to exactly "wet" 100 pounds of pigment.

Method 2 (used in this study).—Place 2 grams of the pigment on a glass plate and add refined linseed oil, drop by drop, from a burette until by working with a spatula the paste can just be smoothed into a thin layer on a microscope slide without cracking or rolling. Count the drops of oil and check the results. With most pigments this end point was fairly definite and could be checked easily. With others, particularly artificial pigments requiring large amounts of oil, considerable working was necessary to produce a smooth paste with the minimum amount of oil. The author believes that the oil need not be thoroughly incorporated with the pigment after the addition of each drop, as in method 1, for the first 8 to 10 drops of most low-absorption pigments or for the first 15 to 20 drops of the high-absorption pigments.

Different materials have selective adsorptions for the oil films and give characteristic working behaviors. It was thus impossible to bring all of the pigments to the same degree of consistency or fluidity, as they looked and felt different under the smoothing action of the spatula. The degree of consistency sought in these tests was a semiplastic one, far more viscous than that used for painting, but with enough fluidity to permit spreading the oil-pigment mass on the glass

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[26] Gardner, H. A., Fineness and Texture of Pigments: Paint Mfrs. Assoc. of the United States, Circ. 90, sci. sec., educational bureau, March 1920.

Pearson, J. C., and Sligh, W. H., An Air Analyzer for Determining the Fineness of Cement: U.S. Bureau of Standards Technol. Paper 48, 1915, 74 pp.

Wilson, Hewitt, Ceramics-Clay Technology: McGraw-Hill Book Co., New York, 1927, pp. 80–81. (Other references noted in this book.)

Work, L. T., Methods of Particle-Size Determination: Am. Soc. for Test. Mat., vol. 28, pt. II, 1928, pp. 771–812. (A list of references is given at the end of this article.)

Roller, P. S., Separation and Size Distribution of Microscopic Particles: Tech. Paper 490, Bureau of Mines, 1931, 46 pp.

[27] Gardner, H. A., Paints, Varnishes, Lacquers, and Colors: Institute of Paint and Varnish Research, Washington, D.C., 1930, pp. 83–84.

plates for the color tests. The laboratory of one of the large importers of mineral pigments kindly made oil-absorption tests of three samples; the author noted that the amount of oil required for the end point exceeded that given in this study by 21 to 63 percent. However, this laboratory produced a thick mass that was just below the running condition when the spatula was held in the air. The end point used in the present study is more like that of method 1. The oil absorption, in drops per gram and parts by weight of refined linseed oil to weight of dry pigment, for a number of commercial mineral pigments is given in tables 14 and 17.

The weight of linseed-oil drops falling from the burette varied when the rate was changed. A fast rate of 2.5 drops per second gave 0.0248 gram per drop, whereas a slow rate of 0.926 drop per second gave a weight of 0.022 gram per drop. The standard adopted for use in this study was a rate of 25 drops in 16 seconds or 1.562 drops per second, as it could be easily counted; the average weight was 0.0232 gram per drop.

American Society for Testing Materials Specification D 84–27 requires that linseed-oil pastes composed of linseed oil and red or brown mineral iron oxides contain 28 to 32 percent of linseed oil. United States Bureau of Standards Circular 91 requires that ocher pastes contain 29 to 31 percent of oil (total weight basis).

TABLE 17.—*Linseed oil required for some commercial pigments to produce a paste of spreading consistency*

Number of samples	Pigment	Linseed oil required, percent dry pigment		Number of samples	Pigment	Linseed oil required, percent dry pigment	
		Range	Average			Range	Average
5	French ochers	35–37	36.2	3	Raw umbers	51–53	52.3
6	American ochers	35–53	40.5	5	Yellow oxides	32–49	43.4
4	Raw siennas	44–70	54.3	9	Red oxides	19–28	23.3

CHEMICAL ANALYSIS

The usual chemical analysis of mineral pigments, giving the percentages by weight of silica, alumina, iron oxide, lime, magnesia, alkalies, and ignition loss, will indicate the total quantity of iron oxide, the accompanying coloring ingredients, and the type of base, such as clay or gypsum; but it does not give definite information about the original color, the mineral constituents of the diluting base material, or the important physical characteristics, such as fineness of grain, workability, and degree of iron oxide dispersion. The chemical analysis can be used in standardization tests for specific pigments to maintain certain minimum requirements for the chief coloring ingredients, and it will also reveal objectionable materials. An accurate and complete analysis, however, is expensive and difficult, whereas practical physical tests are easy and require little time.

Iron oxide requirements.—That the chemical composition determined by the usual ultimate analysis is considered of minor importance compared to the physical tests is shown by the general nature of the requirements in different specifications and the scarcity of specifications. Table 18 lists a few specifications and table 19 variations in the percentage of Fe_2O_3.

TABLE 18.—*Specifications for the chemical composition of iron oxide pigments*

Pigment	Authority	Minimum Fe_2O_3, percent	Maximum CaO, percent	Organic, coloring, lead chromate
Ocher	Circular 91, U.S. Bureau of Standards and A.S.T.M. D 85-27.	17	5.0	None.
Red, brown iron oxide, and iron hydroxide.	Circular 93, U.S. Bureau of Standards and A.S.T.M. D 84-27.	30		None.
Red and brown earths	A western dry-color and filler manufacturer	60		
Ocher	do	10–20		
Iron oxide	An eastern paint manufacturer	65	4.2	

TABLE 19.—*Chemical composition of commercial pigments*

Pigmen	Number of samples	Ferric oxide, percent		
		This study		Other data
		Variation	Average	
Georgia ocher	4	40.5–49.2	45.5	18.7–56.5; av., 63.43 (Watson).
Pennsylvania ocher	6	15.4–32.4	20.7	8–42.5.
French ocher	5	19–25.1	22.4	18–25.
Raw sienna	3	25.2–66.4	42.6	20–78; 27.2–62; av., 49 (Italian).
Burnt sienna	2	67.7–70	68.9	30.4–76.8; av., 58.7.
Metallic brown	4	48.8–62.2	55.6	
Red oxides	7	18.7–99.6	51.7	
Maroon	1		39.8	
Tuscany red	1		81.4	
Umber, general	4	Fe_2O_3, 36.2–56.9; MnO_2, 4.8–17.5.	Fe_2O_3, 48.1; MnO_2, 12.2.	Fe_2O_3, 25–47; MnO_2, 0–14.
Umber, Turkish	1		Fe_2O_3, 52.5; MnO_2, 15.3.	Fe_2O_3, 42.8–46.8; MnO_2, 11.5–13.7.
Burnt umber, Turkish				Fe_2O_3, 52–56.8; MnO_2, 11.8–13.
Vandyke brown	1		Fe_2O_3, 6.5; C, 22.5	Fe_2O_3, 1–23; C, 1–64.

Ferrous iron compounds.—Determinations for ferrous oxide were made on 49 miscellaneous samples of ochers and earths,[28] but it was reported for only 8. This ranged from 0.09 to 0.85 percent, with an average of 0.26 percent for the eight samples and 0.04 percent for the total number analyzed. No correlation could be made between the ferrous iron oxide content and the color. The dark color of Georgia ochers was not due to the ferrous oxide content. Dark-brown colors can be made with certain ferric oxides and hydrated forms, as shown later under synthetic iron oxide colors (p. 55).

IRON OXIDE CONTENT VERSUS TINTING STRENGTH

With pigments of the same hue and similar origin and geologic history there may be a relationship between tinting strength and content of ferric oxide. When natural pigments of different geological his-

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[28] Analyses were made by C. R. Corey, College of Mines, Univ. of Washington. The method used was that of Lord, N. W., and Demorest, D. J., Metallurgical Analysis: McGraw-Hill Book Co., New York, 5th ed., 1924, p. 42.

tories are compared, however, wide discrepancies are found. Bruce[29] states, "It naturally follows that the (tinting) strength of pigments should be evaluated by physical means, with no great reliance placed upon the results of chemical analysis." In this study discrepancies were found and noted in table 20.

TABLE 20.—*Discrepancies between tinting strength and ferric oxide content (analyses and tinting-strength tests checked)*

Laboratory no.	Type of pigment	Iron oxide, percent	Tinting strength	Laboratory no.	Type of pigment	Iron oxide, percent	Tinting strength
Alabama 2	Ocher	9.6	Strong.	Arizona 4	Ocher	19.0	Very weak.
Alabama 3	do	4.5	Medium.	Arizona 8	do	30.1	Do.
Alabama 5	do	3.6	Do.	Arizona 10	do	16.9	Do.
California 1	do	4.5	Do.	Arizona 12	do	27.8	Do.
Mississippi 4	do	3.5	Do.	Arkansas 1	do	19.4	Do.
Nevada 1	do	26.9	Weak.				
Utah 9	Burnt ocher	62.5	Do.				
Utah 28	do	26.7	Do.				

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[29] Bruce, H. D., Tinting Strength of Pigments: U.S. Bureau of Standards Res. Paper 7, 1928, p. 126.

PART III. NATURAL IRON OXIDE PIGMENTS: COMMERCIAL PIGMENTS AND NEW AMERICAN MATERIALS

GENERAL COLOR CLASSIFICATION OF IRON OXIDE PIGMENTS

The color classification given in table 21 is partly commercial and partly technical. Commercial terms are used where possible, but several new groups were added because no commercial duplicates were found. In many instances color overlapping was found. The classification is not accurate, and hues vary within each class.[1]

Figure 11, *A* and *B*, shows the relationship between the groups and classes. Munsell's color system was used in the construction of these charts, and pigments in each group were compared with the Munsell colors. However, as the members of most groups cover a variety of hues, chromas, and values the areas representing each group are only approximations.

TABLE 21.—*Color classification of iron oxide mineral pigments*

A. Ocher:
    Class 1. Orange-yellow hue; chief example, French ocher.
    Class 2. Orange-yellow hue, slightly grayed; chief example, Pennsylvania ocher.
B. Sienna:
    Class 1. Orange-yellow hue; chief example, Italian sienna.
        a. Pink modification of class 1.
    Class 2. Grayed, orange-yellow hue; chief example, Georgia ochers.
        a. Light grayed, orange-yellow hue.
        b. Dark grayed, orange-yellow hue.
C. Burnt ocher and sienna:
    Class 1. Red-brown or commercial.
    Class 2. Salmon hue.
D. Mineral brown, metallic brown:
    Class 1. Old rose and blossom.
    Class 2. Violet or commercial.
E. Mineral red: Indian, Venetian, or Spanish red.
F. Maroon: Red-purple.
G. Umber: Neutral black and gray.
H. Vandyke brown and graphite: Black and blue-gray.

OCHER

According to Maerz and Paul,[2] the word "ocher" comes from the ancient Greek *ochros* used by Homer with the word *chloros* to express the pallor of the face from fear in battle. Chloros implied a greenish tinge and later came to denote even a bright green, whereas ochros was used strictly for yellowish tones. After the time of Homer the term "ochros" was applied to the yellowish native clay, one of the oldest pigments known, if not the oldest. The word "ocher" is a

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[1] Another classification for the ocher and sienna groups is based on hue. In this arrangement the distinction between ocher and sienna hues is discarded and both are placed in an ocher-sienna class with subdivisions consisting of: (1) Orange-yellow (French), (2) slightly grayed, orange-yellow (Pennsylvania), ocher and Italian sienna, (3) pink orange-yellow, and (4) gray orange-yellow (Georgia pigments). Each of these groups will contain strong and weak members based on tinting strength.

[2] Maerz, A., and Paul, M. R., A Dictionary of Color: McGraw-Hill Book Co., New York, 1930, p. 169

generic term; in consequence, many defining adjectives have been prefixed to it to identify certain distinctive grades, usually according to variation in the color. From very early days the word was sometimes used alone, but it was practically always intended to refer to the pigment more exactly known as "yellow ocher". Today, however, the use of the word alone would leave a doubt as to which of several different-colored ochers was meant. The use of pigment names for color sensations usually leads to error and confusion.

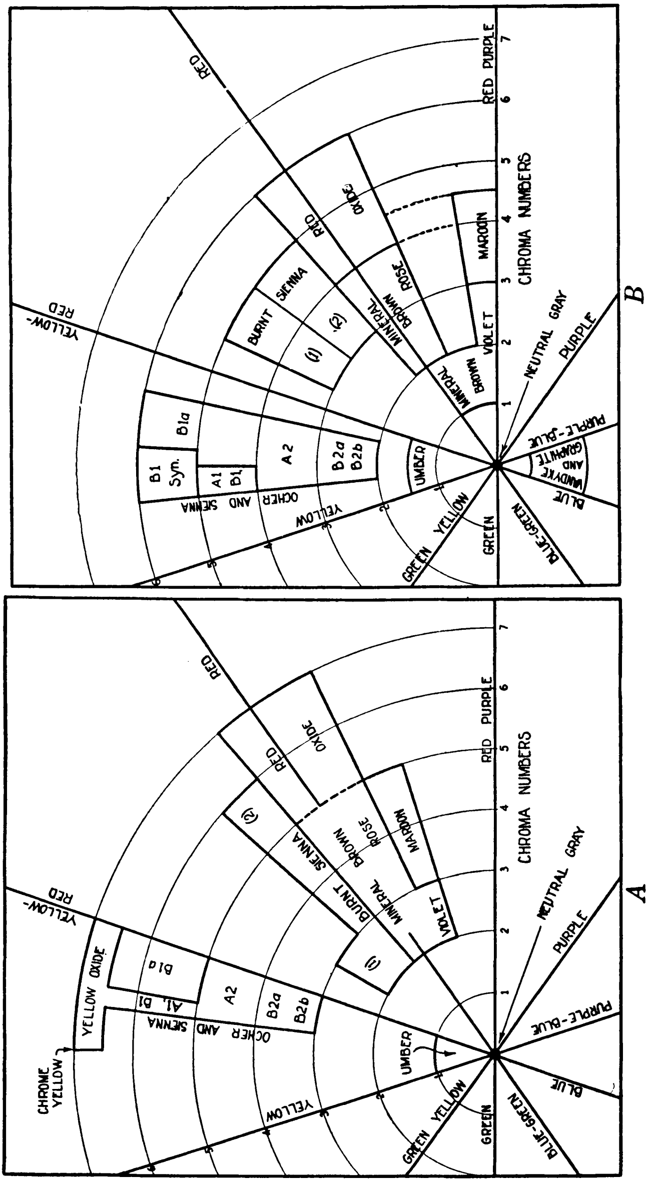

FIGURE 11.—Arrangement of iron oxide mineral pigments, according to the Munsell system: *A*, Full strength in linseed oil. *B*, 1 part by weight of pigment to 9 parts of zinc oxide in linseed oil. A1 and A2 refer to ochers and B1, B1*a*, B2*a*, and B2*b* refer to the sienna classification given in table 21.

No natural ochers found in this study have a true yellow hue but consist of mixtures of yellow, yellow-red (orange), and gray. The principal variation in hue apparently lies in the amount of gray mixed with the yellow and orange. Slight pink modifications were permitted in the ocher group, but as soon as this hue became strong the pigment was classified with the burnt ochers and siennas.

CLASS 1. ORANGE-YELLOW, FRENCH OCHER

The best grades of French ocher have been considered the highest type of natural yellow pigment. Although Pennsylvania ochers have a yellow-orange hue similar to the French, in nearly every instance they can be distinguished from the latter because of a slightly grayer tone and a lower yellow hue. Most Pennsylvania pigments do not have tinting strengths equal to the French. The so-called "Georgia" ochers are so much grayer or browner in hue than either the French or Pennsylvania ochers that is is difficult to recognize them as "yellow" ochers.

The French ochers have the advantage over other commercial yellow ochers in that their chroma is stronger than the American ochers and they contain more of the yellow-red hue. Yellow-red is a warmer and more attractive color than the true yellows, especially of the lower chromas, where a secondary hue of green appears. The advantage of the French over the Pennsylvania grade is far less than its advantage over the Georgia ochers. The Munsell notations (table 22) show that the class covers a rather narrow but distinctive range. The strongest artificial ochers exceed the French in chroma and tinting strength and can be made to duplicate the French closely in hue.

TABLE 22.—*Munsell notations of ocher, class 1, orange-yellow, French ocher*

	Concentrated	Diluted (1:9)
Hue	Yellow-red plus yellow	Yellow-red plus yellow.
Value	5-5+	7.
Chroma	(−)6-6	4-5.

The usual range in the principal ingredients of French ochers follows:

	Percent		*Percent*
Fe_2O_3	18-25	CaO	0.4-0.7
SiO_2	48-51	Ignition loss	7-11
Al_2O_3	18-21		

Table 23 gives typical analyses of French ochers from the catalog of one of the principal importers.

TABLE 23.—*Analyses of French ochers, according to an importer, percent*

Sample no.	1	2	3	4	5	6	7	8
Fe_2O_3	22.3	20.1	21.2	19.2	19.2	21.6	20.9	24.0
SiO_2	48.1	48.0	48.6	50.6	51.2	48.8	49.5	47.9
Al_2O_3	19.1	20.9	18.8	20.9	20.0	19.1	18.7	17.8
CaO	.4	------	.4	.5	.6	.5	.5	.7
Ignition loss	9.8	10.3	10.8	8.8	8.6	9.8	10.2	9.0
Total	99.7	99.3	99.8	100.0	99.6	99.8	99.8	99.4

NOTE.—No. 1 is described as "the highest quality, clear, very light color, good strength with rich, chromy tint and with no trace of red or green tones." No. 2 is not as light as no. 1. No. 3 is darker than no. 2. No. 4 is medium dark. No. 5 is a medium shade. No. 6 "is a dark shade, brilliant, very rich in tone; very strong and with a reddish tint. It is free from the flat, brown tones so often found in the deeper shades." No. 7 is extra dark. No. 8 "is a dark shade, slightly darker on the undertone with a reddish tinge to the overtone."

Some so-called "French-type blended ochers" contain 12 percent of ferric oxide, 27 percent of calcium sulphate, and 48 percent of silica and alumina; the ignition loss is 12 percent.

Table 24 lists the commercial French ochers used in this study and gives their ferric oxide contents.

When concentrated A 1, A 2, and A 3 showed the differences indicated by their grade descriptions; but these differences were small to the untrained eye, and the three samples were needed for side-by-side comparisons. There was less difference between medium and dark than between light and medium. The light grade was much yellower than the other two. When diluted (1:9) the light grade was much lighter and yellower, but the medium and dark were almost interchangeable.

TABLE 24.—*French ochers tested*

Company	No.	Description	Fe_2O_3, percent	Company	No.	Description	Fe_2O_3, percent
A	1	Light grade	19.0	C	1	Yellow	25.1
A	2	Medium grade	21.6	D	2	French	24.8
A	3	Dark grade	21.6				

When C 1 and D 2 were compared with A 1, A 2, and A 3 the following properties were noted. When concentrated C 1 was classed as medium grade, but when diluted (1:9) it was not as yellow as A 1 and was similar to A 2 and A 3 but gave a stronger tinting power. When concentrated D 2 was classed with the dark French grade, but when diluted gave a distinct pink tint when compared to the other four. These differences were noticeable when accurate comparisons were made but were minute when the French, Pennsylvania, and Georgia groups were compared.

This study revealed 5 American pigments that have properties similar to those of the French ochers—2 from Alabama, 1 from Illinois, 1 from Mississippi, and 1 from Washington. They are listed in table 25 and are described under their respective States. These pigments were selected principally on the basis of the orange-yellow-hue characteristic of French ocher; several have better yellow hues than the French grade. If an iron oxide content equal to that of the French ocher is a requisite the first three of these American ochers cannot be strictly classed with the French grade. Nevertheless, Illinois 29 is the only member of the group that does not equal the tinting-strength requirements of the French ochers. These materials should be investigated for possible future production of high-grade ocher pigments.

Figure 12, *A*, gives the tintometer color analysis of the American pigment group for dilutions of 2.5, 5, 10, and 20 percent of the pigment with 97.5, 95, 90, and 80 percent, respectively, of zinc oxide. (See fig. 12, *B*, for comparison with the French ocher.)

TABLE 25.—*New American ochers of class 1, orange-yellow hue*

State	No.	Fe_2O_3, percent	State	No.	Fe_2O_3, percent
Alabama	2	9.6	Mississippi	8	41.3
Do	4	9.6	Washington	D.P.	27.9
Illinois	29	[1] 8.2 [2] 10.9			

[1] Washed. [2] Ground.

CLASS 2. ORANGE-YELLOW, SLIGHTLY GRAYED, PENNSYLVANIA OCHER

The members of this class contain slightly more gray color than the French ochers. They vary considerably, but in a blind sorting test they were separated correctly from the French and Georgia classes. When viewed in the concentrated condition through the glass they showed the greatest difference from the French ochers; when viewed directly on the painted surface less difference was detected. The variable amounts of oil required for standard consistency and differences in the character of the surface appear to show differences in value rather than in chroma. Through the glass the grayness of the reduced chroma is exaggerated. Separating the French and Pennsylvania diluted tints was more difficult than separating the concentrated pigments. The Munsell-color numbers for this group are shown in table 26.

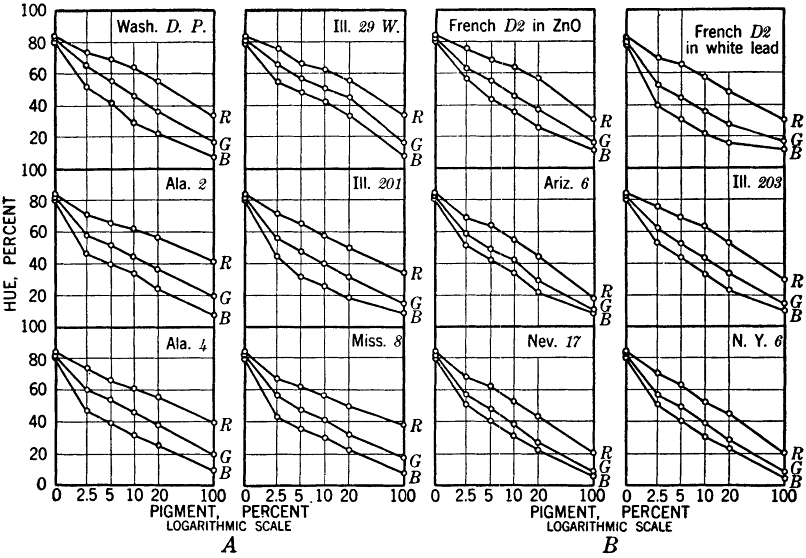

FIGURE 12.—*A*, Color analyses of American ochers similar to French ochers. *B*, Color analyses of some American ochers and siennas mixed with zinc oxide and linseed oil and a French ocher mixed with zinc oxide and with white lead. Wave lengths: Red, 638; green, 535; and blue-violet, 450 millimicrons.

Table 27 lists the commercial yellow ochers used in this study.

TABLE 26.—*Munsell notations of ocher, class 2, orange-yellow, slightly grayed, Pennsylvania ochers*

	Concentrated	Diluted (1:9)
Hue	Yellow-red plus yellow	Yellow-red plus yellow.
Value	4–5	7–8.
Chroma	3–6	2–4.

TABLE 27.—*Tested commercial ochers of class 2, orange-yellow, slightly grayed*

Company	No.	Grade	Fe_2O_3, percent	Company	No.	Grade	Fe_2O_3, percent
A	4	Light	16.0	C	2		32.4
A	5	Medium	15.4	D	3		16.6
A	6	Dark	16.7	I	2	Light	10.7
B	2		27.0				

When concentrated A 4 was much lighter than A 5 or A 6. Less difference was noted between the medium and dark grades, A 5 and A 6. Although A 5 was classed as medium, it had a lower chroma than A 6, which was classed as dark. A 6 varied toward red; it had a warmer hue. When diluted (1:9) the light grade was yellower and had the strongest tinting value of the three. A 5 and A 6 were similar, but the medium grade was grayer and the dark grade was pinker.

B 2 was similar to A 4 when concentrated but had a more orange hue. When diluted it showed greater tinting strength than A 4 and varied more toward pink. Although C 2 had a ferric oxide content of more than 30 percent the tinting strength was weaker than the average.

Although D 3 was classed as medium it had the weakest tinting strength of this group, varying toward cream.

I 2 had a concentrated hue near gold-brown (60113) and a diluted tint near chamois (60179). The tinting strength was near that of A 4.

The composition of domestic yellow ochers of class 2, most of which come from Pennsylvania, is reported by various manufacturers to range between the following limits:

	Percent		*Percent*
Fe_2O_3	8–22	Al_2O_3	15–28
Silica	46–62	Ignition loss	5–9

These figures indicate that the composition of class 2 ochers varies far more than that of the imported French ochers of class 1.

Table 28 lists the new American pigments classed with the ochers of class 2.

TABLE 28.—*New American ochers of class 2, orange-yellow, slightly grayed*

State	No.	Fe_2O_3, percent	State	No.	Fe_2O_3, percent
Medium tinting strength:[1]			Medium tinting strength [1]—con.		
Alabama	3	4.5	South Carolina	1	17.9
Do	5	3.6	Utah	19	23.2
Do	8	16.6	Vermont	1	7.6
Arizona	3	16.0	Virginia	[2] 4	8.8
California	1	4.5	Do	[3] 4	
Do	10	24.3	Weak tinting strength:		
Do	13	24.0	California	9	6.9
Idaho	2	21.2	Illinois	202	6.9
Illinois	83	17.6	Mississippi	1	3.6
Do	203	28.0	Do	7	4.7
Mississippi	4	3.5	Nevada	1	26.9
Do	5	7.4	Utah	27	8.2
Do	6	12.6	Vermont	2	4.8
Nevada	12	17.5	Virginia	5	9.7
Do	16	23.0			

[1] The percentage of iron oxide ranges from 3.5 to 29.9 for the ochers with similar medium tinting strengths

[2] Washed.

[3] Ground.

SIENNA

Sienna was first called "*terra di Siena*" or sienna earth because its special grade was first found near Siena, Italy. The term "sienna" was used in the textile field as early as 1874. Maerz and Paul[3] state:

> Later, in two forms, it was called raw sienna and burnt sienna. These terms have no color significance in themselves, and it is only by experience that one knows the range of colors they possess. In addition, whether full strength or reduced with white, the names still apply. Many of the pigments, in full strength, are very dark, so that it is only when reduced with white that their characteristic colors become apparent.

Ladoo[4] classifies sienna as a brown pigment:

> Sienna, Italian earth, terra di Siena, is a high-grade, natural, yellow-brown earth pigment consisting of a mixture of hydrous iron oxides and clays in varying proportions, with or without siliceous matter. It may contain a little manganese dioxide. It grades into ocher with decreasing iron oxide content and into umber with increasing manganese oxide content. It usually is higher in iron oxide than ocher (often 60 to 80 percent) and therefore stronger and richer in color. The color varies from pure brown to reddish brown.

No division line between sienna and ocher is made either in hue or percentage of iron oxide.

Santmyers[5] states, "Ocher grades into sienna, which differs from ocher chemically in that it generally contains more ferric iron than it does clay, and physically in that when finely ground it is more of a stain than a pigment." Again, "These ochers (burnt) are much richer in iron than the ordinary ocher,. which almost never contains more than 30 percent iron oxide."

No definite dividing line between siennas and ochers in iron oxide content has been found in literature. The 25-percent ferric oxide maximum of the French ochers was exceeded by only two commercial Pennsylvania ochers tested. Various investigators[6] have credited Pennsylvania ochers with 17.5 to 42.5 percent of iron oxide, although this present study found the higher amounts only in the darker pigments, which were classed as siennas. The so-called "Georgia ochers" were found to contain 18.7 to 56.5 percent of Fe_2O_3; Watson,[7] however, gives 63.43 percent as the average of eight Georgia ochers, and most of those in present commercial use contain more than 40 percent of iron oxide. These ochers are really siennas.

The catalog of a leading paint manufacturer showing both full-strength and let-down colors includes French yellow ocher and raw Italian sienna. Both have the same yellow-red hue; the only difference is in value and chroma. They appear to be different concentrations of the same pigment and indicate that the two terms apply to the same hue, the sienna meaning a darker or deeper shade.

No definite separation based upon common usage can be made between ochers and siennas. In this study they have been arbitrarily divided, principally according to hue and secondarily as to percentage of ferric oxide. On the hue basis consideration has been given both to the concentrated or full-strength pigment and to the diluted or let-down colors produced by mixing with zinc oxide and linseed oil.

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[3] Maerz, A., and Paul, M. R., A Dictionary of Color: McGraw-Hill Book Co., New York, 1930, p. 169.

[4] Ladoo, R. B., Nonmetallic Minerals: McGraw-Hill Book Co., New York, 1925, pp. 372, 381.

[5] Santmyers, R. M., Ocher and Ochery Earths: Inf. Circ. 6132, Bureau of Mines, 1929, p. 2.

[6] Ladoo, R. B., work cited, p. 378.

[7] Watson, T. L., Ocher Deposits of Georgia: Geol. Survey of Georgia Bull. 13, 1906.

In this study orange-yellow natural iron oxide mineral pigments whose hue and tinting strength are similar to those of the French or Pennsylvania commercial ochers and whose ferric oxide content is usually below 30 percent have been regarded as ochers. If the iron oxide content was high and the pigment had the weak tinting strength and hue of the ocher, it was classed with the ochers. If the hue was strongly grayed, the pigment was placed with the siennas even though the ferric oxide content was less than 30 percent. The materials received from Georgia, therefore, are placed in the sienna class. Some of the French ochers could be placed with the siennas if the analyses of Sirot and Jouet,[8] quoted by Ladoo, are correct. This classification shows 3 grades of French ocher: (1) Yellow, 7 samples of which gave iron contents of 19.52 to 22.70 percent; (2) red, 5 samples of which gave iron oxide ranging from 23.50 to 59.71 percent; and (3) brown, 2 samples of which gave ferric oxide contents ranging from 43.75 to 30.20 percent. Undoubtedly the red and brown grades would not be classed as French ocher in the present sense of the word.

Commercial siennas.—The commercial siennas of this study are listed in table 29. The so-called Georgia ochers have been added to this group.

TABLE 29.—*Commercial siennas tested*

Company	No.	Grade	Fe_2O_3, percent	Classification
C	11	Raw sienna	66.4	*2a*
D	6	American raw sienna	25.2	?
D	8	Italian raw sienna	36.2	1
I	1	American raw sienna	35.6	1
Pennsylvania	2	Ground sienna	68.1	*2b*

Of the commercial siennas, C 11 when concentrated was very dark greenish brown, near olive wood (60082) plus green. When diluted with 9 parts of zinc oxide the color changed to champagne (60097). It is similar to the light Georgia siennas.

D 6 when concentrated was reddish brown and compared favorably with standard brown (60114) when viewed directly and was close to gold-brown (60113) when viewed through the glass. When diluted, the hue changed to pink-gray, close to bisque (60122). The ferric oxide content is low, and it is distinctly different from the other siennas.

D 8 when concentrated was close to olive wood (60082) and when diluted was near sunset (60088). This Italian sienna is similar to French ochers C 8 and A 2, but the hue when concentrated is much darker than the concentrated ocher colors.

I 1 when concentrated was near gold-brown (60113) and when diluted was near pablo (60090). Its strong golden-brown let-down tint is allied to some of the strong synthetic ochers.

Pennsylvania 2 is classed by the manufacturer as a sienna after his purification treatment. After grinding in the ball mill the product is akin to the dark Georgia pigment.

The estimated maximum variation in composition of pigments that are marketed as raw siennas, including both foreign and domestic, is: Fe_2O_3, 20 to 78 percent; SiO_2, 3 to 50 percent; Al_2O_3, 0 to 25 percent;

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[8] Sirot, M., and Jouet, G., Ocher: Bull. Soc. d'encour., vol. 119, 1913, pp. 769–789. (Abstract in Jour. Soc. Chem. Ind., Aug. 15, 1913, p. 798.)

CaO, 0 to 14 percent; ignition loss, 7 to 23 percent. Table 30 shows the variation in composition of 12 of the best raw Italian siennas.

Different grades are described by the manufacturers as: "Dark shade with greenish tone"; "dark-red shade, pleasing medium light shade with chromy tint"; "reddish cast, very clean-cut light shade throwing a reddish-chrome tint"; "rich yellow shade"; "medium shade on a yellowish tone, throws a cream tint with white"; "light shade with creamy tint"; or "very dark-red shade of a rich brilliancy with reddish tint." The top colors may thus be clear yellow, reddish yellow, greenish yellow, dark yellow, and brownish yellow. The tints may be clear yellow, brownish yellow, reddish yellow, greenish yellow, or reddish brown.

TABLE 30.—*Analyses of raw Italian siennas, according to an importer*

	Maximum	Minimum	Average		Maximum	Minimum	Average
	Percent	*Percent*	*Percent*		*Percent*	*Percent*	*Percent*
Fe_2O_3	62.00	27.2	49.0	CaO	14.08	0.29	3.6
SiO_2	34.28	16.00	21.9	Ignition loss	22.60	10.70	15.6
Al_2O_3	19.10	1.74	8.7				

CLASS 1. ORANGE-YELLOW

The siennas of this class are among the most interesting because of their high tinting strength combined with a hue similar to that of the orange-yellow ochers and artificial yellow oxides. (Compare tables 22 and 31.) All have more than 30 percent of iron oxide. Seven new American siennas of this class found during this investigation are listed in table 32. They are recommended for further investigation as to quantity available, uniformity, costs of mining, purification, and marketing.

TABLE 31.—*Munsell notations of sienna, class 1, orange-yellow*

	Concentrated	Diluted (1:9)
Hue	Yellow-red and yellow	Yellow-red and yellow.
Value	4–5	6–7.
Chroma	5–6+	4–5.

TABLE 32.—*New American siennas of class 1, orange-yellow*

State	No.	Fe_2O_3, percent	State	No.	Fe_2O_3, percent
Illinois	82	59.2	Utah	11	50.0
Nevada	26	87.5	Do	16–A	41.4
Do	27	61.0	Washington	D.P.	48.6
Pennsylvania	4	68.2			

CLASS 1A. PINK MODIFICATION

All members of class 1*a* contain over 30 percent of ferric oxide, have greater tinting strengths than French ocher and Italian sienna, and show a pink secondary hue that makes them different from the orange-yellow group. (See table 33.) They differ from any commercial pigment noted in this study, but their color is so attractive and their tinting strength so great that they should have commercial value. When diluted with zinc oxide their original high chroma dropped a point, and they lost some of their pink secondary hue. On dilution the burnt-sienna and burnt-ocher tints approached them. Figure 12, *B*, gives the color-analysis charts of three of these pigments in comparison with French ocher.

Table 34 lists the pink orange-yellow siennas discovered in this study.

TABLE 33.—*Munsell notations of sienna, class 1a, pink modification*

	Concentrated	Diluted (1:9)
Hue	Yellow-red plus yellow	Yellow-red plus yellow.
Value	3-5	7.
Chroma	5-6.5	5-6.

TABLE 34.—*New American siennas of class 1a, pink modification*

State	No.	Fe_2O_3, percent	State	No.	Fe_2O_3, percent
Arizona	6	35.4	Philippine Islands	1	50.0
Do	11	33.7	Tennessee	1	76.7
Montana	1	51.6	Texas	2	40.9
New York	6	44.0			

CLASS 2. ORANGE-YELLOW, GRAYED

The so-called "Georgia ochers" are the chief commercial examples of this class.

CLASS 2A. LIGHT GRAYED

These pigments are readily sorted from the dark Georgia pigments (class 2*b*) and are distinctly darker gray than Pennsylvania or French ochers. They have greater chroma than the dark Georgia group but appear lighter, not from a change in hue but because they contain less dark gray. On the higher chroma side they merge with the class 1 siennas. The Munsell notations of this class are given in table 35. Their average iron oxide content is below that of the Georgia dark ochers; except for Georgia 1-A the iron oxide content lies below 40 percent. Various washing treatments did not brighten the Georgia pigments or produce hues like those of the French and Pennsylvania ochers. No fractional parts of the Georgia pigments examined contained the bright red or orange hues. Table 36 lists light gray siennas of class 2*a* which were tested in this study. Georgia 5 (washed), 6, and 7 and Illinois 111 could be classed as gray ochers because of their low ferric oxide content. Illinois 111 is a new pigment material with possible commercial value.

TABLE 35.—*Munsell notations of sienna, class 2a, orange-yellow, light grayed*

	Concentrated	Diluted (1:9)
Hue	Yellow-red plus yellow	Yellow-red and yellow.
Value	4	6.
Chroma	3.5-4	2.5-3.

Table 36.—*American siennas, class 2a, orange-yellow, light grayed*

Number	Fe_2O_3, *percent*	Number	Fe_2O_3, *percent*
Georgia 1A	46.4	Georgia 6	18.7
Georgia 1A[1]	[2] 40.5	Georgia 7	28.2
Georgia 5 [3]	21.3	Illinois 111	[3] 8.5 [4] 10.2
Georgia 5 [4]	37.4	Company I, no. 3	37.3

[1] Duplicate. [2] July 7, 1928. [3] Washed. [4] Ground.

CLASS 2B. DARK GRAYED

The so-called "dark Georgia ochers" are the chief examples of class 2*b*. These colors are readily separated in the concentrated or diluted condition from the light Georgia (class 2*a*) and other groups. They are characterized by their dark-gray color, which is even darker in this hue than most commercial siennas of this study. They are placed on the color charts (fig. 11, *A* and *B*) between the yellow and yellow-red hues, between chromas 3 and 4. The color values range from 3 to 4 when concentrated and from 5 to 6 when diluted. (See table 37.) Some Pennsylvania-grade ochers are similar in color to the Georgia groups, but they usually contain more yellow-red hue and have stronger chroma than the dark Georgia materials. The distinctive color is not confined to Georgia but may be found in the iron ores of other districts, such as Pennsylvania and Michigan. Undoubtedly it can be found in many places among the Appalachian iron ores. Pennsylvania 2, marketed as a sienna, is placed in this group, which it resembles more than any other, although it does not match the other members. With two exceptions, these dark pigments contain more than 45 percent of iron oxide.

Table 38 lists the dark-gray siennas of class 2*b* studied.

Table 37.—*Munsell notations of sienna, class 2b, orange-yellow, dark grayed*

	Concentrated	Diluted (1:9)
Hue	Yellow-red plus yellow	Yellow-red and yellow.
Value	3–4	5–6.
Chroma	3–3.5	2–2.5.

Table 38.—*American siennas, class 2b, orange-yellow, dark grayed*

Number	Fe_2O_3, *percent*	Number	Fe_2O_3, *percent*
Georgia 2A	49.2	Georgia 8	26.1
Georgia 3A	46.0	Georgia 9	56.5
Georgia 4 [1]	22.0	Michigan 1	83.7
Georgia 4 [2]	21.0	Pennsylvania 2	[3] 68.1

[1] Washed. [2] Ball-milled. [3] Ground.

BURNT OCHER AND SIENNA

Although yellow or yellow-brown has been the predominating hue of the preceding groups, red is the principal color tone of this and the following groups. The burnt siennas are made commercially by calcining or heating siennas. By this treatment most of the iron oxide is changed to the high-temperature red form of ferric oxide. Any ferrous oxide will oxidize and become red if oxidizing conditions are maintained in the heating chamber. The chroma of the red iron oxide is improved by removal of carbonaceous matter, which tends to gray or darken the red hue. Calcination at different temperatures produces different colors. An insufficient time of calcination or heating to temperatures below redness will merely char or darken the carbonaceous grays of certain clays and pigments. Firing in a smoky atmosphere or with reduced oxygen will also gray the color.

Just as the oxidation of woody organic material can proceed naturally at low temperatures in the open air, so can the change from the ferrous to the ferric form take place in arid, warm climates under natural conditions. Both the red and yellow hues can be formed under these conditions, although the exact difference in the conditions causing the formation of one or the other is not known at present. The red apparently represents end products obtained under low humidity and high temperatures. The yellow may represent an intermediate condition higher in humidity and lower in temperature. (See laboratory tests of artificial pigments.) The dark browns apparently represent deeply buried, saturated conditions, with little oxygen present. Therefore thick deposits of red could be formed only close to the surface but later could be buried by superimposed sediments. The yellow-browns could be formed at depth. The following list of new colors includes only pigments that have been made into the red hues naturally.

CLASS 1. RED-BROWN OR COMMERCIAL

The pigments of this class intermingle to some extent with the salmon class (class 2) of burnt sienna and with the metallic browns. Dilution tends to shift the hue toward yellow-red; that is, there is a loss in red, and the chroma rises toward class 2.

A study of commercial burnt ochers and siennas shows that some colors have retained their yellowish hues after calcination or burning but that others have changed to cherry red. The tints have changed to salmon colors with or without the bluish secondary colors. Some of the manufacturers' descriptions of the burnt Italian siennas are: "A light shade that is rich and bright"; "with rich bluish tone"; "a very dark shade, full of fire and animation with bluish tint"; "with terra cotta tint"; "with salmon tint"; "rich bright shade with yellowish tint"; "very transparent"; "an unusually brilliant shade, a wonderful undertone, very transparent and throws a rich terra cotta tint."

Table 39 shows the variation in composition of 10 commercial burnt siennas, as indicated in manufacturers' catalogs from foreign and domestic sources. The ignition loss of these "burnt" siennas ranged from 5 to 18.8 percent and indicates that contact with the high temperatures was not very severe. In general, the more nearly the temperature of burning approaches 1,050° C., or the longer the time of calcination, the greater will be development of the red hue.

TABLE 39.—*Composition of 10 burnt Italian siennas according to an importer*

	Maximum	Minimum	Average
	Percent	*Percent*	*Percent*
Fe_2O_3	76.8	30.4	58.7
SiO_2	26.2	13.0	19.8
Al_2O_3	20.0	4.2	10.2
CaO	14.4	.4	3.5
Ignition loss	18.8	5.0	9.2

Table 40 shows the source and ferric oxide content of the new American burnt ochers and siennas (class 1, red-brown or commercial) tested. In this study burnt ocher is considered the same as burnt sienna; but the tinting strength is weak, and the ferric oxide content is usually below 30 percent. Class 1 comprises pigments whose diluted hue is similar—browner or grayer but not redder than the commercial burnt siennas tested:

	Percent
D 4. Italian burnt sienna (Fe_2O_3)	70.0
C 7. Burnt sienna (Fe_2O_3)	67.7

The samples are arranged into four subgroups according to their tinting strengths. The strong members have higher tinting strengths than D 4; the medium class has strengths lying between those for D 4 and C 7; the weak members have strengths below that of C 7; and the very weak group has strengths below that of French ocher diluted with 9 parts of zinc oxide. The ocher, of course, has a different hue, but no commercial burnt ocher covers this weakness of tint.

Table 41 gives the variations shown by the Munsell notations in class 1 of the burnt ochers and siennas tested.

TABLE 40.—*New American burnt ochers and siennas, class 1, red-brown or commercial* [1]

State	No.	Fe_2O_3, percent	State	No.	Fe_2O_3, percent
Strong tinting strength:			Weak tinting strength:		
Nevada	22	70.3	Alabama	1	4.6
Do	25	63.2	California	6	4.3
Medium tinting strength:			Do	7	7.8
Arizona	7	35.1	Do	11	----------
Florida	1	19.0	Do	12	----------
Nevada	14	22.0	Mississippi	2	4.7
Utah	2	35.7	Do	3	2.5
			Utah	9	62.5
			Do	28	26.7

[1] 7 pigments were classed as very weak or too low in tinting strength for commercial consideration.

TABLE 41.—*Munsell notations of burnt ochers and siennas, class 1, red-brown or commercial*

	Concentrated	Diluted (1:9)
Hue	Red and red plus yellow-red	Red plus yellow-red and yellow-red plus red.
Value	2–3	5.
Chroma	2–3	3–5.

CLASS 2. SALMON

The burnt ochers and siennas of class 2, the salmon or red type, tested in this study lay between class 1 and the red oxides. Their concentrated colors had higher chroma than class 1 and showed a distinct mixture of yellow-red when compared with the red oxides. When the pigments were concentrated the chroma ranged from 3 to 6 but when diluted it ranged from 3 to 5. The change in hue on dilution was not appreciable. (See table 42.) This group merged directly into the red oxides, and several members of class 2 were classed in one or more concentrations with the red oxide group. Most of these pigments, however, have no counterpart among the commercial colors. Although these hues are produced in paints and wall coatings they are made by mixing standard reds and yellows. The commercial service of class 2 of the burnt ochers and siennas is therefore expected to be rather limited.

Table 43 lists new American burnt ochers and siennas of class 2.

TABLE 42.—*Munsell notations of burnt ocher and sienna, class 2, salmon hue*

	Concentrated	Diluted (1:9)
Hue	Red plus yellow-red	Red plus yellow-red.
Value	3	4–5.
Chroma	4–6	3–5.

TABLE 43.—*New American burnt ochers and siennas, class 2, salmon hue*[1]

State	No.	Fe_2O_3, percent	State	No.	Fe_2O_3, percent
Strong tinting strength:			Weak tinting strength:		
Arizona	2	92.2	Arkansas	2	19.7
New York	4	51.8	California	3	8.2
Texas	3	79.6	Nevada	15	2.3
Utah	14	69.6	New Mexico	1	10.0
Medium tinting strength:			Utah	3	26.0
Oregon	5	19.2	Do	17	6.6
Texas	4	25.7	Do	26	21.1
Utah	10	52.4	Do	31-B	5.5
Do	13	61.0			
Do	20	21.3			
Do	21	30.3			
Do	31-A	21.0			

[1] 3 pigments had very weak tinting strengths.

MINERAL BROWN, METALLIC BROWN

Mineral browns are made principally by calcining limonite and siderite ores. They are used extensively in the manufacture of low-cost railroad, floor, roof, barn, and structural iron paints. The ferric oxide content is 25 to 80 percent; the balance is largely silica and alumina. The tints may range from red to blue and purple hues. The commercial members of this group tested are shown in table 44.

TABLE 44.—*Commercial mineral browns tested*

Company	No.	Grade	Fe_2O_3, percent	Classification	Company	No.	Grade	Fe_2O_3, percent	Classification
D	5	Double Label	48.8	2	E	5	Mineral brown	52.9	2
E	2	Mineral brown	58.6	2	I	4	do	49.5	1
E	3	do	62.2	2					

CLASS 1. OLD ROSE AND BLOSSOM

Class 1 of the mineral browns when concentrated resembled the S.C.C.A. (Standard Color Card of America) old-rose hue and when diluted was similar to S.C.C.A. blossom. Both ranged toward gray. Commercial pigment I 4 belonged to this class. The concentrated color was near mahogany (60136) and the diluted color was bois de rose (60176) plus gray. This class (except I 4) showed more red or rose hue than the grayer or more violet commercial mineral browns and were not the red-browns of the burnt siennas; they were considered a mixture of the two. In hue they resembled the red oxides but contained more gray and were therefore placed on the charts (fig. 11, *A* and *B*) with lower chroma. The hue ranged both toward red-yellow and toward purple-red. Munsell notations for this class are shown in table 45. This series of pigments, like class 2 of the burnt siennas, represents a mixture of purer hues; although the colors are used to some extent commercially, they are usually made by compounding purer hues. The present commercial value of this group therefore may be limited.

New American mineral-brown pigments of class 1 found in this study are listed in table 46. The tinting-strength classification was based on a comparison with the commercial metallic browns, D 5, E 2, E 3, and E 5. (See table 44.) Those classed as strong had stronger tinting strengths than E 3 or D 5, those classed as weak had weaker strengths than E 2 and E 5, and those classed as very weak had weaker strengths than French ocher.

TABLE 45.—*Munsell notations of mineral browns, class 1, old rose and blossom*

	Concentrated	Diluted (1:9)
Hue	Red plus yellow-red or purple-red.	Red plus yellow-red or purple-red.
Value	3-3+	4+-6.
Chroma	3-5	2-4.

TABLE 46.—*New American mineral-brown pigments, class 1, old rose and blossom* [1]

State	No.	Fe_2O_3, percent	State	No.	Fe_2O_3, percent
Strong tinting strength:			Medium tinting strength:		
Alabama	7	79.5	Utah	4	16.7
California	17	83.8	Do	5	12.6
New York	3	42.6	Weak tinting strength:		
Utah	25	30.7	California	4	5.9
Vermont	3-B	--------	Utah	30	7.2
Wisconsin	2	94.4	Washington	4	26.4

[1] 6 samples had very weak tinting strengths.

CLASS 2. VIOLET OR COMMERCIAL

The commercial mineral browns (table 44) belong chiefly to this class. When concentrated the first four of the commercial pigments tested were near tobacco (60143) in hue, but showed varying amounts of red. A purplish tone was often noted by reflected light through the glass. E 3 and E 2 were darker than E 5 and D 5. When diluted with nine parts of zinc oxide, the hue was not like any in the standard color chart, but was a grayed orchid (60085), much darker than the true orchid hue. E 3 and D 5 had stronger tinting strengths than E 2 or E 5. The diluted hues were similar, except that E 5 had a pink tint different from the others.

Table 47 shows the new American pigments classed by this study as mineral browns of class 2.

TABLE 47.—*New American mineral-brown pigments, class 2, violet or commercial* [1]

State	No.	Fe_2O_3, percent	State	No.	Fe_2O_3, percent
Strong tinting strength:			Medium tinting strength:		
Texas	5	82.4	Arizona	9	32.3
Do	6	80.4	Nevada	2	11.5
Do	7	77.6	New York	1	21.1
Do	8	55.1	Weak tinting strength:		
Washington	6	79.4	California	14	21.8
Wisconsin	1	77.8	North Carolina	2	8.9

[1] 1 sample had very weak tinting strength.

The pigments listed in table 47 were closer in hue to the commercial mineral browns of table 44 than were the browns of class 1. Their tinting strengths were classed like those of class 1; pigments with strong tinting strengths excelled E 3 or D 5 (table 44), whereas those less than E 2 and E 5 were weak. In hue most of these pigments when concentrated lay on the red-purple side of red, with a few on the yellow-red side; when diluted the majority had changed to the purple-red hue, but retained the low chroma or grayed red and purple-red of this group. A dark-purplish hue was noted by reflected light through the glass from the concentrated pigments. Several of these materials with high tinting strengths had possible commercial values for the variety of gray colors, which are used for all types of structures and furnishings. The Munsell notations varied as shown in table 48.

TABLE 48.—*Munsell notations of mineral browns, class 2, violet or commercial*

	Concentrated	Diluted (1:9)
Hue	Red plus red-purple	Red to red-purple.
Value	2-3	4-6.
Chroma	2-3	1-3.

MINERAL RED

The red hue of natural red pigments is derived from hematite (Fe_2O_3). Such pigments may range from nearly 100 percent of Fe_2O_3 in the case of artificial reds to about 5 percent in the case of calcined clays and shales. The most common natural red pigments now on the market are Persian red and Spanish red.

Persian red, the original Indian red, contains 65 to 72 percent of Fe_2O_3 and is imported from Ormuz Island in the Persian Gulf. The full-strength color is rich crimson and on dilution develops a bluish tint.

Spanish reds, containing 82 to 87 percent of Fe_2O_3, are nearly pure-red hematites from Spain. Four samples listed by one importer varied in composition, as shown in table 49.

TABLE 49.—*Composition of Spanish reds*

	Percent		*Percent*
Fe_2O_3	84.00–84.40	CaO	1.21–2.70
SiO_2	1.74–5.00	Ignition loss	7.20–10.00
Al_2O_3	— -5.10		

Persian and Spanish reds are used for specification paints or where a cheap red oxide is needed. They are prepared by water-grinding, levigation, filter-pressing, drying, pulverizing, and air-flotation. Venetian reds were originally imported from Italy, but the term is now commonly applied to the cheaper grade of let-down, artificial red pigments. Domestic reds, containing 22 to 60 percent of ferric oxide, are produced for service as base pigments for red paints, to which other red pigments are added to increase the chroma. They likewise are used in mortar colors, composition products, sheathing paper, and the duller paint colors.

Venetian and Indian reds and red oxides are discussed under artificial pigments.

No natural pigment materials of this study duplicated the commercial red oxides on the market (table 50); most of these were roasted to oxidize the iron oxide to the red condition. Those shown in table 51, however, are close, but in most instances either they lose the red hue on dilution or their tinting strengths are too weak for commercial red oxides.

The hue of these pigments and many others in this study could be made to approach pure red by roasting under oxidizing conditions at temperatures of 500° to 1,000° C. Munsell color notations of this group are shown in table 52.

TABLE 50.—*Commercial red oxides tested*

Company	No.	Grade	Fe_2O_3, percent	Company	No.	Grade	Fe_2O_3, percent
C	13	Red oxide	99 6	D	7	Venetian red	22.4
C	15	Red	82.0	D	12	Red oxide	45.5
C	16	Red oxide	24.4	D	14	Spanish red	68.5
C	17	do	68.9	E	4	Venetian red	18.7

TABLE 51.—*New American red oxide pigments*

State	No.	Fe_2O_3, percent	Tinting strength	Already classed with—
Nevada	2	11.5	Medium	Mineral brown, class 2.
Oregon	5	19.2	do	Burnt sienna, class 2.
Utah	26	21.1	Weak	Do.

TABLE 52.—*Munsell notations of red oxides tested*

	Concentrated	Diluted
Hue	Red plus yellow-red Red plus red-purple	Red plus yellow-red. Red plus red-purple.
Value	3	4–5.
Chroma	5–7	4–6.

NOTE.—Munsell's R $\frac{4}{2\text{–}4}$ have the same purplish hue of these iron oxides.

Of the commercial red oxides tested, C 13 gave the darkest concentrated red color. It lay close to mahogany (60136), toward lacquer (60159). When diluted it was close to lacquer plus gray and was the strongest red pigment tested.

C 15 when concentrated was close to bois de rose (60176) and when diluted near Grecian rose (60175) plus gray.

C 16 was the highest in red hue of the group and lay close to lacquer, but when diluted gave a very weak grayed blossom (60171).

C 17 was a darker red when concentrated or lacquer toward garnet (60071) and when diluted was old rose (60172).

D 7 was near terra cotta (60134) concentrated and gave a weak grayed blossom when diluted.

D 12 was likewise near terra cotta but closer than D 7 and gave a gray Grecian rose when diluted. The tinting strength was greater than that of D 7.

D 14 was near bois de rose concentrated and grayed Grecian rose when diluted.

E 4 was near henna (60135), or the lowest of this group in red hue. When diluted it lay between blossom plus yellow toward peach (60157) and had the poorest red hue. If it has commercial value, a number of the new pigments of this study likewise have market possibilities.

MAROON

Although most of the violet class of the metallic browns are closely allied to the maroon colors only one pigment—Michigan 2—was classed as maroon in this study. It contained 88.7 percent of iron oxide and had a medium tinting strength. However, it does not have the true red-purple hue of the two commercial maroons (table 53) of this study, but lies between the maroons and red oxides. Munsell notations of this group are shown in table 54.

Colors at the end of the scale of iron oxide hues, such as these maroons or red-purples, should have commercial value because of their comparative purity of hue and possible service in producing varying hues and tints with other extremes.

TABLE 53.—*Commercial maroons tested*

Company	No.	Grade	Fe_2O_3, percent
C	14	Maroon oxide	81.4
D	11	Tuscany red	[1] 39.8

[1] 4.7 percent carbon.

TABLE 54.—*Munsell notations of the maroon pigments tested*

	Concentrated	Diluted
Hue	Red plus red-purple	Red-purple plus red.
Value	3	4.
Chroma	−5	3-4+.

Of the commercial maroons C 14 when concentrated was close to garnet (60071), a light shade of maroon, and when diluted was close to orchid (60085).

D 11 when concentrated gave a dark garnet and when diluted was near orchid. Both pigments are clear and true.

UMBER, NEUTRAL BLACK AND GRAY

The raw umbers lie on the yellow to yellow-red side of the hue circle opposite the carbon series of Vandyke browns and graphites on the blue side. The top or concentrated color ranges from slightly yellowish brown to rich greenish brown. The hues may be dull browns, bluish greens, or rich greens. The commercial umbers studied (table 55) represent the lowest values and chromas of this study. Munsell notations of the umbers are shown in table 56.

Of the commercial pigments C 10 when concentrated was near the standard color smoke (60036) when viewed direct, but had a lower value or was blacker when viewed through the glass. When diluted it was near silver (60050).

C 12 when concentrated was like C 10 but when diluted was near new cocoa (60124) plus gray. Burning or heating browned the color but slightly.

TABLE 55.—*Commercial umbers tested*

Company	No.	Grade	Fe_2O_3, percent	MnO_2, percent	Company	No.	Grade	Fe_2O_3, percent	MnO_2, percent
C	10	Raw umber	46.8	17.5	D	13	Turkish raw umber	52.5	15.3
C	12	Burnt umber	56.9	11.2	I	5	American burnt umber	18.0	22.6
D	9	American raw umber	36.2	4.8					

TABLE 56.—*Munsell notations of umber pigments*

	Concentrated	Diluted
Hue	Neutral gray-black or yellow-red.	Neutral gray, yellow, yellow-red.
Value	1-2	4-5.
Chroma	0-1	0-1.

TABLE 57.—*New American umbers*

State	No.	Ferric oxide, percent	Tinting strength	State	No.	Ferric oxide, percent	Tinting strength
New York	2	58.7	Strong.	Vermont	3-C	9.3	Medium.
Do	5	70.0	Medium.	Indiana	20	9.0	Weak.
Do	7	82.5	Do.	Do	21	31.8	Do.
Utah	16-B	20.8	Do.				

D 9 when concentrated had a hue of seal (60084), but was like putty (60169) plus greenish gray when diluted. D 13 when concentrated was like C 10, but diluted toward putty. I 5 when concentrated had a hue near negro (60144), but diluted to that between beaver (60101) and crane (60033).

The samples of this study classed as umbers are listed in table 57. Nine others were classed as very weak umbers of no commercial value. A number of umbers might be found in the manganese districts of Alabama, Arizona, Arkansas, Colorado, Georgia, Idaho, Massachusetts, Michigan, Minnesota, Montana, Nevada, New Mexico, Tennessee, Utah, Virginia, Wisconsin, and Washington. Manganese can be ground with sienna to produce raw or burnt umber colors,[9] but the market for these materials is small.

Both Turkish and domestic umbers are used in the United States. Variation in the composition, according to several producers, is given in table 58. Analyses of typical raw Turkish umbers as given by the importer are shown in table 59. Olive-green tones are typical of the true raw Turkish umber.

TABLE 58.—*Composition of raw umbers, according to producers*

	Percent		*Percent*
Fe_2O_3	25–47	CaO	2–4
SiO_2	16–35	MnO_2	0–14
Al_2O_3	3–13	Ignition loss	13–40

TABLE 59.—*Analyses of raw Turkish umbers, according to importers*

	Dark	Medium	Light		Dark	Medium	Light
	Percent	*Percent*	*Percent*		*Percent*	*Percent*	*Percent*
Fe_2O_3	42.8	44.0	46.8	CaO	4.20	4.00	2.35
SiO_2	15.56	17.30	18.00	MnO_2	11.60	13.71	11.45
Al_2O_3	13.45	3.92	7.19	Ignition loss	12.55	16.50	13.70

BURNT UMBERS

The burnt umbers are similar in composition and color to the raw umbers and even though burnt may give 5 to 15 percent loss on ignition, including carbon. The ferric oxide content may run as high as 57 percent; the silica, 20; and the manganese dioxide, 18. That they are not roasted very strongly under oxidizing conditions is shown by the retained greenish-brown top colors and tints present in some samples. Table 60 gives typical analyses, supplied by the importer, of burnt umbers from Turkey.

The dark grade in the table has a decidedly brown tone; the medium, a deep chocolate tone with a brown tint; and the light, a rich, reddish shade with red tint.

TABLE 60.—*Analyses of Turkish burnt umbers, according to an importer*

	Dark	Medium	Light		Dark	Medium	Light
	Percent	*Percent*	*Percent*		*Percent*	*Percent*	*Percent*
Fe_2O_3	56.8	52.00	56.54	CaO	2.9	4.15	3.78
SiO_2	14.2	17.15	16.23	MnO_2	13.0	11.75	11.15
Al_2O_3	6.0	6.20	4.02	Ignition loss	6.5	7.85	7.81

VANDYKE BROWN AND GRAPHITE, BLACK AND BLUE-GRAY

Probably the most common black pigment is Vandyke brown, named by the celebrated artist Van Dyck. Carbon and not iron oxide is the principal coloring ingredient of the Vandyke browns. The hue is generally close to neutral black when concentrated and near neutral gray when let down. These materials, however, may have greenish tones and bluish tints and cannot be legitimately classed

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[9] Wilson, Hewitt, Ochers and Mineral Pigments of the Pacific Northwest: Bull. 304, Bureau of Mines, 1929, p. 35.

with the iron oxide pigments, inasmuch as the black color is due to their carbon content.

According to the importer, the German Casseler Braun, which is said to be the pigment used by Van Dyck, has the following percentage composition: Fe_2O_3, 1.86; Al_2O_3, 1.42; CaO, 2.55; organic matter, 73.82; and hygroscopic water, 17.33. The variations in composition of Vandyke browns now on the market are shown in table 61.

The only commercial Vandyke brown tested was D 10 (table 62). When concentrated it has a hue more nearly that of true black than the umbers and a lower value through the glass than Munsell No. 1. The diluted hue is close to bluish steel (60052).

Sample 3 from Michigan was the only material tested of strong tinting power that could be classed with the Vandyke pigments. It had a carbon content of 18.4 percent and a ferric oxide content of 10.9 percent.

TABLE 61.—*Composition of Vandyke browns, according to an importer*

	Percent		*Percent*
Fe_2O_3	1–23	Organic matter	0–64
SiO_2	0–26	Total ignition loss	47–92
Al_2O_3	2– 4	Specific gravity	1.66–2.48

TABLE 62.—*Commercial Vandyke browns and graphites tested*

Company no.	Description	Fe_2O_3, percent	C, percent
D 10	Vandyke brown	6. 5	22. 5
G 1	Artificial graphite		93. 0
G 2	do		93. 0

TABLE 63.—*Munsell notations of Vandyke browns and graphites*

	Vandyke browns		Graphites	
	Concentrated	Diluted (1 : 9)	Concentrated	Diluted (1 : 9)
Hue	Neutral gray to black.	Purple-blue to blue	Neutral gray to black.	Purple-blue to blue.
Value	1–2	3–5	1–2	5.
Chroma	0–1	0. 5–1. 5	0–1	1.

Seven others were classed with this group but were too weak for commercial value. Munsell notations of the Vandyke browns are given in table 63.

Two artificial graphites were tested in this study (table 62). G 1 and G 2 had a concentrated hue near smoke, but when diluted were bluer and stronger than D 10—more like a grayed Saxe blue (60125). G 2 had a stronger tinting strength than G 1. Munsell notations of the graphites are given in table 63.

The two artificial graphites used in these tests were manufactured from retort coke and petroleum coke. The raw products were ground and processed in an electric furnace until their carbon content was graphitized. The material was then passed through swing-hammer pulverizers and tube mills and graded by air separation. Natural graphite is likewise used for pigment purposes.

Manufacturers' analyses of various gray and black pigments are listed in table 64.

OTHER BLACKS

Drop blacks contain 20 to 30 percent of carbon and 69 to 80 percent of calcium phosphate. They have bluish gray tints. One carbon black gave 59 percent of fixed carbon; 27 percent of volatile matter, including water; and 12 percent of ash. Black oxides with a magnetite base can be produced artificially.

TABLE 64.—*Composition of miscellaneous black and gray pigments and fillers*

Sample no	[1] 1	[2] 2	[2] 3	[3] 4	[4] 5	[5] 6
Fe_2O_3 percent	75.0	97.0	19.0	4.0	4.0	3.0
SiO_2 do		1.0	44.2	51.0	69.0	54.0
Al_2O_3 do			15.4	14.0	12.0	14.0
CaO do		.4	3.4	9.0	1.0	
MgO do					4.0	
Alkalies do					3.0	
FeS_2 do						8.0
Ignition loss do		2.2	11.3C, 3.2H_2O	17.0	6.0	16.0C, 1.0H_2O
Specific gravity				2.80	2.80	2.75

[1] Black oxides of iron; the balance of the composition is silicate of aluminum and calcium phosphate.

[2] Black oxides of iron with bluish and grayish tints.

[3] A mineral-black pigment.

[4] Slate flour, a natural bluish-gray slate used as a filler for dark paints, as iron and wood filler, and for special cements and composition products. The composition is similar to a red or buff-burning shale with free silica, although the quoted specific gravity appears high. Reddish-slate flours are also on the market.

[5] A black filler; it has a brownish tone and is used chiefly in iron fillers, in machinery paint, and for fillers in railway-equipment paints.

PART IV. ARTIFICIAL IRON OXIDE PIGMENTS

ARTIFICIAL RED PIGMENTS

The first artificial pigments were undoubtedly the reds produced by calcining or roasting ochers, siennas, or iron ores to red heat. This method followed the age-old ceramic process of firing iron-bearing clays and shales to produce red brick, tile, and pottery. Burnt ochers, burnt siennas, burnt umbers, red metallic paints, Canadian red, etc., are present-day examples of such calcination.

INDIAN RED AND RED OXIDE

The next step was to duplicate the crimson Persian or original Indian red by roasting the copperas (iron sulphate) crystals which were a byproduct of the pickling liquors in wire or galvanizing mills and in various other industries. Colcothar, rouge, and crocus are made by the same process but are used for different purposes. Iron sulphate is likewise produced for the pigment industry by dissolving scrap iron in sulphuric acid.

The Indian reds or red oxides range from the light shades with yellowish or salmon tints to dark shades with bluish tints or from the pure red hues to the maroon or red-purple. The ferric oxide content usually lies between 50 and 98 percent, silica, clay, and combined water making up the balance; the calcium sulphate content may run as high as 48 percent. In other words, the pure iron oxide has been diluted with fine silica, clay, or gypsum. The specific gravity of commercially pure red oxides is 4.80 to 5.10. Mineralogists give the specific gravity of hematite as 4.9 to 5.3 for the solid crystalline varieties and as low as 3.75 to 4.0 for the soft powdery ores.

TUSCAN RED

Tuscan red is a shade of Indian red made by combining ferric oxide with aniline colors, as red coal-tar dye (alizarin lake). These range in hue from dark scarlet to very deep maroons. The concentrated hues may be cherry red, maroon, or purple, whereas the tints range from pink to light blue or lavender.

VENETIAN RED

Venetian red is a term applied to the cheaper grades of chemically produced iron oxides, let down principally with calcium sulphate. The ferric oxide content ranges from 10 to 40 percent and the calcium sulphate from 35 to 85 percent. Limestone, calcium carbonate, or magnesium silicates may likewise be used for dilution. The specifications of the United States Government recognize only two ingredients in Venetian red—ferric oxide and calcium sulphate. They specify three grades containing 40 and 60, 30 and 70, and 20 and 80 percent of ferric oxide and calcium sulphate, respectively. Calcium sulphate is the product of chemical reaction when ferrous sulphate is neutralized with lime to produce iron hydroxide and calcium sulphate. The iron hydroxide is changed to the oxide by heating. Venetian reds range in hue from light colors with salmon or yellow tints to dark shades with blue tints.

ARTIFICIAL YELLOW PIGMENTS

GOLDEN OCHER

Golden ochers are yellow pigments of far greater chroma than the best iron oxide yellows. The golden color is produced by adding 5 to 15 percent of lead chromate to the ordinary yellow ocher. Two percentage analyses of golden ochers free of barite are given by one manufacturer: Fe_2O_3, 2.5 and 3.0; SiO_2, 15.1 and 13.0; Al_2O_3, 1.3; $CaSO_4$, 56.7 and 52.6; PbO, 7.6 and 9.0, respectively. The lead chromate content of the two pigments is approximately 11 and 13 percent, respectively. Both calcium sulphate and magnesium silicate are used to let down the golden ochers.

YELLOW OXIDE

Yellow oxides are manufactured pigments containing a high percentage of hydrated ferric oxide in the yellow condition. A typical percentage analysis as given by one manufacturer is: Fe_2O_3, 92; $CaSO_4$, 6; SiO_2, Al_2O_3, 1; MgO, trace; and free moisture, 1. The specific gravity was 3.83.

These pigments are made in several grades ranging in hue from lemon to orange and brown-yellow, depending on the methods of manufacture, described later. They are excellent pigments for composition products, paint, paper, and rubber. The concentrated colors can be diluted with clay and other siliceous fillers for buff colors and for tinting strengths similar to those of the natural ochers.

Table 65 lists the yellow oxides used in this study. These were compared with the natural ochers as follows: C 3 when concentrated was similar to the dark Pennsylvania grade; when diluted it had only medium tinting strength with the let-down color similar to the French ocher plus gray. C 4, C 5, and C 6 when concentrated were classed with the light Pennsylvania ochers with a variation toward yellow. The dilution test indicated very strong tinting strength, so much stronger than the French ochers that no comparison could be made. C 6 lay between C 4 and C 5 when diluted, as indicated by the grade names.

TABLE 65.—*Yellow oxides tested*

Company	No.	Grade	Fe_2O_3, percent	Company	No.	Grade	Fe_2O_3, percent
C	3	Yellow	34.8	F	1	Yellow	10.2
C	4	Lemon	63.3	F	2	do	15.0
C	5	Deep orange	81.1	F	3	do	20.8
C	6	Orange	79.2	F	4	do	20.9
D	1	Golden ocher	7.3	F	5	do	28.4
E	1	Yellow	46.4				

D 1, golden ocher, when concentrated was the strongest yellow of the study. It contained yellow-red and is not a true Munsell yellow; but when diluted the tinting strength was shown to be very weak—

weaker than the French, almost as if the iron oxide were the important ingredient and the additional chromium compound had no effect.

E 1 had more of the golden-ocher hue of the French than D 1 but was stronger than the French both concentrated and diluted.

F 1 to F 5 varied in dilution strength according to their iron oxide contents and were similar to the French in hue, with perhaps more of a tendency toward yellow than the yellow-red or orange of the French ochers. F 1 and F 2 had weaker tinting strengths than the French; F 3 and F 4 were equal to the French, and F 5 was stronger than the French but not as strong as C 4, C 5, and C 6. F 5 more nearly approached the orange color of the French than any of the other artificial yellows of this study.

Because of their tinting strength and hue, several artificial yellow oxides are similar to the tan group of ochers.

ARTIFICIAL BROWN PIGMENTS

Artificial brown pigments are used for the same purposes as the yellow oxides when the brown hue is desired. They are recommended for use by the manufacturers where greater tinting strength and "clarity of tone" are required than can be obtained with metallic browns. The ferric oxide content ranges from 36 to 86 percent; dehydrated calcium sulphate, up to 27 percent; loss on ignition, including carbon, from 4 to 22 percent; and clay or silica, the balance. Some contain a small percentage of manganese dioxide.

ARTIFICIAL BLACK PIGMENTS

Black oxides can also be produced. They contain 95 to 97 percent of ferroferric oxide (magnetite) and 3 to 5 percent of combined water, traces of alumina, and calcium sulphate with a specific gravity of 4.80. They are used for composition products and to some extent in the paint, varnish, and ink industries. Several patents describing the manufacture of black iron oxide pigments are given later.

REVIEW OF PATENTS ON MANUFACTURE OF ARTIFICIAL IRON OXIDE PIGMENTS

The following review of patents on the manufacture of artificial iron oxide pigments includes the production of the black, red, and yellow iron compounds. Patents 1327061 and 1368748 are reported to be those under which most of the yellow artificial pigments in this country are manufactured.

1. Steinau, Richard, and Steinau, Charles, Improvement in preparation of peroxide of iron: U.S. Patent 206635, July 30, 1878.

"Producing and collecting peroxide of iron by causing water contained in a suitable vessel to rise and fall through a layer of scraps to the alternate action of water and atmospheric air, and collecting the peroxide in the vessel containing the water."

Wrought-iron scrap, such as chips from the turning lathes which present an extended surface and permit free circulation of water and air, are placed in a sieve in the top of a vat filled with water. The vat is provided with a piston whose reciprocating action causes the water to immerse the scrap iron; as the water recedes the air follows to produce the oxidation. The rust accumulations are washed from the iron, collected, filter-pressed, and dried. No acids are used.

2. Treutler, Gustav A., Improvement in processes for the continuous preparation of nitrogen gas: U.S. Patent 207086, August 13, 1878.

"The continuous preparation of nitrogen gas for inhaling and other purposes, the same consisting in, first, the action of ferrous sulphate upon atmospheric air, whereby the latter loses a portion of its oxygen and the iron salt is converted into a ferric sulphate; and second, the deoxidation of said ferric sulphate and its reduction to ferrous sulphate by the action of metallic iron, substantially as and for the purpose specified." Air is forced through a mixture of iron filings covered with ferric sulphate.

3. Fireman, Peter, Manufacture of printing-ink pigments: U.S. Patent 802928, October 24, 1905.

"The method of making a precipitated magnetic black ferroferric oxide which consists in dissolving a ferrous salt, precipitating the salt by a substance having an alkaline reaction, oxidizing the precipitate by a current of air, and then filtering, washing, and drying it with the exclusion of air, substantially as described."

Waste ferrous liquors obtained by pickling sheet iron, etc., are precipitated by sodium carbonate, caustic soda, etc. As soon as the precipitant has been added the temperature is raised to 80° to 90° C., and air is injected at the bottom of the tank from numerous apertures. The precipitated ferrous carbonate or hydroxide is rapidly oxidized. The air is then shut off and the temperature brought to and maintained at the boiling point for a few minutes. The progress of oxidation is accompanied by changes in color. At first it is light green, but changes to different shades of dark green and blue to deep brown-black. If dried in the open air, even as low as 60° C., oxidation will continue with a change of color to reddish brown. Oxidation produced by blowing air through the precipitate should be continued only until the ratio of ferrous to ferric iron is within the limits of 1 to 0.8 to 1 to 2. Oxidation will continue during drying to produce the best ratios of ferrous to ferric iron in the finished product within the limits of 1 to 2 to 1 to 3. The best black color can be maintained by drying in a closed vessel, from which the air has been excluded, or in vacuo.

4. ———, Production of printing-ink pigments: U.S. Patent 857044, June 18, 1907.

"The method of producing dry precipitated black ferroferric oxide, which consists in dissolving a ferrous salt, precipitating the salt by a substance having an alkaline reaction, oxidizing the precipitate by a current of air to such a degree as to produce a ferroferric oxide wherein the ratio of the ferrous to the ferric iron is greater than that represented by the formula $FeO.Fe_2O_3$, and drying the same with the exclusion of air." The drying operation is conducted in vacuo in a specially designed, steam-heated drier.

5. Carrick, James Taylor, Preparation of iron compounds: U.S. Patent 997237, July 4, 1911.

"The process of treating a ferrous solution for the production of a blue-black pigment, which consists in adding to the acid or neutral ferrous solution an ammonium compound in large excess and afterward subjecting the mixture to prolonged oxidation, said process being carried out entirely in the cold and under normal pressure.

"To a substantially neutral or slightly acid ferrous solution—such as the waste pickle liquor obtained in galvanizing after its treatment with scrap iron—there is added a prescribed fraction of the quantity of amomnia necessary to precipitate the whole of the iron in solution; the mixture is then diluted and oxidized by blowing air into it until it becomes yellow." It is later boiled with more ammonia to darken it.

6. Penniman, Russell S., and Zoph, Norman, M., assignors to West Coast Kalsomine Co., Process of manufacturing iron compounds: U.S. Patent 1327061, January 6, 1920.

"The method of manufacturing iron compounds, which consists in immersing metallic iron in a heated solution of ferrous sulphate, and continuously supplying an oxidizing agent whereby the ferrous sulphate is converted to ferric sulphate and the hydrate of iron is precipitated, permitting the metallic iron and ferric sulphate to react to regenerate the ferrous sulphate for further oxidation and repetition of the cycle, and recovering the hydrate."

Metallic iron, preferably in the form of strips or thin sheets, is placed in a wooden or other acid-proof permeable container in the top of a large acid-proof tank containing a solution of ferrous sulphate or any other water soluble salt of iron. Air is blown into the solution at the bottom, and heat is applied by steam pipes to raise the temperature to 60° C., at which temperature the most economical oxidizing action is produced. The ferric hydrate, which precipitates in the solution, is or can be changed into the desired pigment. It does not correspond exactly to the formula for ferric hydrate, $Fe(OH)_3$, but contains some basic salt and is partly dehydrated. Its color is yellow or yellowish brown and it can be calcined or burned into a red oxide of iron.

The process is cyclic, continuous, and self-sustaining; the only materials necessary to maintain the reaction are metallic iron and the oxidizing agent.

The pigment formed remains in the solution until the proper tone and quality have been obtained. The operation is stopped and the pigment filtered out, dried, and ground or calcined. The solution is then returned to the tank.

7. PENNIMAN, RUSSELL S., JR., AND ZOPH, NORMAN M., assignors to National Ferrite Co., Process of manufacturing iron compounds and product: U.S. Patent 1368748, February 15, 1921.

"The process of manufacturing iron compounds, which comprises introducing an oxidizing agent into a heated solution of a soluble iron salt having metallic iron immersed therein and colloidal ferric hydrate mixed therewith."

This is a continuation of Patent 1327061, the product from which is likely to form comparatively coarse particles possibly of crystalline structure and poor density and color. The improved process disseminates a colloidal hydrate of iron throughout the clear ferrous or ferric solution. "The colloidal precipitate of ferric hydrate may be prepared by the oxidation of colloidal ferrous hydrate precipitated from a soluble ferrous salt with lime or some other suitable alkaline agent, or by the direct precipitation of colloidal ferric hydrate from a soluble ferric salt, or in any other suitable manner. With this colloidal ferric hydrate is mixed, conveniently in the same tank in which the hydrate is prepared, a solution of ferrous or ferric sulphate. Metallic iron is then immersed in the bath, the temperature of which is preferably maintained at about 60° C., and an oxidizing agent such as air is introduced, whereupon the cycle of operation proceeds" as described. "The introduction of the nuclear colloidal ferric hydrate during the initial stages of the process has the effect of retarding or preventing the crystalline formation of the precipitated ferric hydrate, or at least of determining the precipitation of the material in a physical form of superior pigment value."

"The proportion of ferric hydrate (introduced and disseminated through the solution of the iron salt) to iron salt solution may vary through a broad range, but very satisfactory, practical results are obtained when the proportions are in the ratio of 1 pound of ferric hydrate to from 5 to 20 gallons of iron salt solution."

8. BALL, FRANK, assignor to West Coast Kalsomine Co., Process of manufacturing iron compounds: U.S. Patent 1385769, July 26, 1921.

"The process of producing iron compounds, which consists in supporting pieces of metallic iron in an elongated vessel and passing through the vessel and the body of iron therein a stream of an oxidizing medium comprising an aqueous fluid, adapted to act as a vehicle for an oxidizing agent, and the oxidizing agent" (air).

This patent is intended to improve the process described under Patents 1327061 and 1368748 by providing a mechanical means for suspending the metallic iron in the solution, to provide a means of circulating the iron solution past the metallic iron, and to speed up the reaction. A vertical acid-proof cylindrical tile acts as the container, and compressed air is introduced at the bottom of the tile to induce circulation of the liquid.

9. FIREMAN, PETER, assignor to Magnetic Pigment Co., Pigment and method of producing same: U.S. Patent 1392925, October 11, 1921.

"A method of preparing yellow pigment which comprises, adding to a solution of ferrous chloride, calcium hydroxide in quantity to precipitate 75 percent to 85 percent of the iron, oxidizing the precipitated ferrous hydroxide at a temperature not substantially exceeding 100° F., until the ratio of ferrous to ferric iron is substantially 1:0.5 and completing oxidation at a temperature approaching 212° F."

Other ferrous salts such as the sulphate can be used as the source of iron, and other soluble hydroxides and carbonates such as sodium carbonate can be used as precipitants. The fresh precipitate of ferrous hydroxide is first light blue then greenish blue, then acquires a yellowish tinge, and finally is a clear yellow.

10. ———, assignor to Magnetic Pigment Co., Pigment and method of producing same: U.S. Patent 1392926, October 11, 1921.

"A method of preparing brown pigments which comprises, adding to a solution of an iron salt, a quantity of an alkali metal carbonate sufficient to produce an alkaline reaction, and energetically oxidizing the precipitated ferrous hydroxide at a temperature exceeding 110° F. during the early stages of oxidation and regulating the reaction to prevent formation of black oxide."

After the precipitation of ferrous hydroxide the temperature is reduced to below 110° F. during the first 2 hours of operation and then slowly raised to reach the boiling temperature after 3 to 4 more hours. Oxidation is continued at this temperature until completion of the brown color.

11. ———, assignor to Magnetic Pigment Co., Pigment and method of producing same: U.S. Patent 1392927, October 11, 1921.

"A method of preparing brown pigments in tan shades which comprises adding calcium hydroxide to a solution of ferrous chloride and oxidizing the precipitated ferrous hydroxide at temperatures substantially between 105° and 130° F."

12. ———, assignor to Magnetic Pigment Co., Pigment and method of producing same: U.S. Patent 1424635, August 1, 1922.

"A method of preparing brown pigment which comprises adding to a solution of ferrous chloride sufficient sodium carbonate to produce an alkaline reaction, partially oxidizing the precipitated ferrous hydroxide at a temperature of substantially 110° F., and completing oxidation at gradually increasing temperatures approaching 212° F."

13. French, Thomas, Apparatus for making iron oxides: U.S. Patent 1438372, December 12, 1922.

A furnace for calcining iron salts such as the sulphate to produce the iron oxide.

14. Snellenberger, Richard O., assignor to Iron Oxide Products, Manufacture of iron oxide: U.S. Patent 1543968, June 23, 1925.

"That improvement in the manufacture of iron oxide, which consists in exposing to air comminuted iron treated with an oxidation-accelerating chemical reagent (sulphate of iron) and moistening said material when it reaches a temperature of approximately 160° F. to reduce its temperature, until the oxidation has been substantially completed."

15. Stewart, Henry C., assignor to the Westmoreland Chemical & Color Co., Method of manufacturing iron oxide: U.S. Patent 1642975, September 20, 1927.

A rotary furnace for calcining copperas to form iron oxide.

16. Fireman, Peter, assignor to Magnetic Co., Method and apparatus for preparing pigments: U.S. Patent 1490372, April 15, 1924.

"The method of producing iron oxide pigments, which comprises electrolyzing sodium chloride in the presence of an iron anode, thereby producing brine solutions containing ferrous chloride and sodium hydroxide, separately withdrawing the ferrous chloride and sodium hydroxide solutions from the zone of electrolysis, recombining the solutions to precipitate ferrous hydroxide, oxidizing the ferrous hydroxide under predetermined conditions to produce a pigment, separating the pigment from the sodium chloride, and returning the sodium chloride for further electrolysis.

"The most suitable iron salt (for pigments) is the chloride of iron, because lime, the cheapest precipitating agent, can be used for precipitating ferrous hydroxide therefrom. Lime cannot be used with iron sulphate without contaminating the resulting pigment with an equivalent quantity of insoluble calcium sulphate. Furthermore, with the use of iron chloride a greater variety of colors is available.

"However, from the point of view of purity, lime has the disadvantage of unavoidably carrying some siliceous gangue which passes ultimately into the pigment."

17. Saunders, Harold F., assignor to the Chemical Specialties Co., Process of producing ferric pigments: U.S. Patent 1496605, June 3, 1924.

"A process of the character described which consists of providing an electrolytic bath comprising an acid solution of an ionizable salt, providing a ferrous anode in said bath, and a conducting cathode, and establishing electrolysis, maintaining low current density whereby hydroxide of iron is produced in said bath, and treating said hydroxide of iron by calcination to produce a red ferric pigment."

18. ———, assignor to the Chemical Specialties Co., Process of producing ferric pigments: U.S. Patent 1496606, June 3, 1924.

"A process for producing ferric pigments of red-brown color, which consists of providing an electrolytic bath composed of sodium nitrate in solution, providing a ferrous anode and a conducting cathode therein, and establishing electroylsis while maintaining said bath at a temperature of between 80° and 90° C., segregating oxides of iron and maintaining the same at a temperature of 1,800° F. for 1 hour, and thereafter maintaining said oxides of iron at a temperature of 1,000 ° F. for a period of 3 hours."

Additional recorded data on the preparation of artificial pigments are given in various published articles.[1]

PRODUCTION OF ARTIFICIAL YELLOW-BROWN HYDRATED FERRIC OXIDE

Cheap sources of sulphates and chlorides of iron ore are available in this country. Ferrous sulphate ($FeSO_4{\cdot}7H_2O$), green vitriol, or copperas is a byproduct in tin-plate and pickling factories. Two general methods are used to produce yellow-brown pigments from these salts. By the first method the heated solution of iron salt is treated with an alkali, such as calcium hydroxide, ammonium hydroxide, sodium hydroxide, or sodium carbonate, to produce the ferrous or ferric hydroxides. Ferric chloride is preferred in United States Patents 1392925, 1392926, 1392927, and 1424635, and ferrous sulphate is used in Patents 802928, 857044, and 997237. The hydroxides are oxidized by blowing air into the solution for given periods of time, while the temperatures are held within certain limits for different-color developments.

By the second method a solution of ferrous sulphate is warmed and treated directly with air to precipitate the hydrous oxide of iron [2] in the presence of metallic iron according to the following probable equation:

$$4FeSO_4+O_2+6H_2O\rightarrow 2(Fe_2O_3.H_2O)+4H_2SO_4.$$

Ferrous sulphate is re-formed by the metallic iron and sulphuric acid,

$$Fe+H_2SO_4\rightarrow FeSO_4\pm H_2,$$

and is ready for further reaction. This process is described in more detail in United States Patents 1327061 and 1385769. It has been modified in United States Patent 1368748 by the addition of a colloidal suspension of ferric oxide hydrate to the ferrous sulphate sulution to prevent coarse or crystalline formation of the hydrated ferric oxide of poor color.

Patent 1368748 may be modified further by the use of other suspensions than ferric hydroxide. Some of the newest synthetic iron oxide pigments on the market are produced by diluting concentrated hydrated ferric oxide with siliceous bases such as white clay. A very intimate mixture of the oxide and diluent can be made by introducing the diluent as a suspension in the original ferrous sulphate solution. The hydrated ferric oxide is adsorbed on the surfaces of the dispersed clay particles in the same manner that it probably is adsorbed in the natural formation of ocher. Expense and time are likewise saved in

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[1] Ayres, G. H., and Sorum, C. H., Influence of Hydrolysis Temperature on Some Properties of Colloidal Ferric Oxide: Jour. Phys. Chem., vol. 34, April 1930, pp. 875–884; 2629–2635.

Chemical Age (London), Residual Material in the Pigment Industry: Vol. 23, Sept. 13, 1930, p. 227.

Dorr, V., Conversion of Batch into Continuous Processes: Ind. and Eng. Chem., vol. 21, May 1929, p. 466.

Fireman, Peter, Versatility of Ferrous Hydroxide: Ind. and Eng. Chem., vol. 17, June 1925, pp. 603–604.

Posnjak, E., and Merwin, H. E., Article Dealing with the System $Fe_2O_3-SO_3—H_2O$ from 50° to 200°: Jour. Am. Chem. Soc., vol. 44, 1922, p. 1965.

Reavell, J. A., The Neill Process for the Manufacture of Red Oxide: Chem. Age, vol. 19, Nov. 10, 1928, pp. 431–432; Gas Jour., Nov. 28, 1928, pp. 183–184.

Sorum, C. H., Study of Coagulation of Colloidal Ferric Oxide: Jour. Am. Chem. Soc., vol. 51, April 1929, pp. 1154–1162.

Weiser, H. B., The Hydrous Oxides: McGraw-Hill Book Co., New York, 1926, 246 pp.

[2] This precipitate may contain some "basic sulphate": $4FeSO_4+O_2+2H_2O\rightarrow 4Fe(OH)SO_4$.

subsequent mixing of the two and in preparation of the colloidal ferric hydroxide.

A third method, which apparently has not been patented, could be suggested: The direct hydrolysis of ferric chloride and treatment by air without the use of alkaline precipitating agents.

Patents 1490372 and 1496605 use electrolytic methods in production of the original ferrous salts. For example, ferrous chloride is produced from a sodium chloride solution containing an iron electrode.

LABORATORY EXPERIMENTS IN PRODUCTION OF SYNTHETIC YELLOW IRON OXIDES [3]

Both ferrous sulphate and ferric chloride were used with and without precipitating agents.

FERROUS SULPHATE WITH PRECIPITATING AGENTS

The method and results of the precipitation of pigments from ferrous sulphate using various reagents are given in table 66. The oxidizing agent—air or oxygen—was bubbled through the solution after the precipitating agents had been added, and the bath was brought to the proper temperature. The reducing agent consisted of a 5-foot coil of iron wire suspended in the top of the 2-liter reaction bottle. Unless noted the concentration of ferrous sulphate was 25 grams per liter.

TABLE 66.—*Production of synthetic pigments using ferrous sulphate with precipitating agents*

	1	2	3	4	5	6	7	8
Iron salt	1,000 cm³ $FeSO_4$	500 cm³ $FeSO_4$	1,500 cm³ $FeSO_4$, pH 3.8.	1,250 cm³ $FeSO_4$.	1,250 cm³ $FeSO_4$	1,000 cm³ $FeSO_4$	1,000 cm³ $FeSO_4$ [a]	1,000 cm³ $FeSO_4$ [a]
Precipitating agent	1 cm³ 15 N NH_4OH.	NH_4OH to precipitate all Fe.	10 cm³ saturated $Ca(OH)_2$.	75 cm³ saturated $Ca(OH)_2$.	200 cm³ saturated $Ca(OH)_2$.	400 cm³ saturated $Ca(OH)_2$.	NH_4OH.[b]	NH_4OH.[b]
Colloid addition	None	None	None	None.	None	None	None	None.
Oxidizing agent	Air	Air	Air	Air.	Air	Air	Air	Air.
Reducing agent	Fe	Fe	Fe	Fe.	Fe	None	None	Fe.
Temperature of bath, ° C	60	80	70	35–52.	35–52	40	28	28.
Time of oxidation, hours	3	2	6	2.25.	2.25	2	1	1.
Ease of filtration	Difficult	Difficult	O.K	Difficult.	Difficult	Difficult	Difficult	Difficult.
Precipitate washed	Yes	No	Yes	Yes.	Yes	Yes	Yes	Yes.
Temperature of drying, ° C	56	56	56	56.	56	60	56	56.
Color	Strong tan ocher	Black	Strong tan ocher plus red.	Strong tan ocher.	Strong tan ocher	Dark red-brown	Red-brown	Red-brown.

[a] 30 grams per liter.

[b] Added until solution became light blue. Precipitation nearly complete.

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[3] Experiments by E. W. Jackson, student in the department of chemical engineering, University of Washington.

The results indicate that, if all the iron is precipitated by ammonium hydroxide, dark red-brown and black are more likely to be produced than yellow, both with and without the iron reducing agent. The change from the precipitated green and red-brown salts to the yellow hydrous oxide is apparently very difficult when ferrous sulphate has been the original solution.

Good yellow-ocher colors were produced after partial precipitation of the iron by calcium hydroxide when a reducing agent was used, but in this instance precipitation by the hydroxide was very small and hydrolysis of the ferrous sulphate was the major reaction. The calcium sulphate formed likewise served as a white suspension and diluting agent upon which the particles of hydrous ferric oxide collected.

FERROUS SULPHATE WITHOUT PRECIPITATING AGENTS

The results of the experiments on precipitation of pigments without addition of reagents are given in table 67. Ferrous sulphate was changed to hydrous ferric oxide by the use of air alone in the first three experiments of this table. The reaction was very slow at 30° C.; good yellow colors were produced at 80° and 90°. The higher the bath temperature the greater the tendency to produce red hues at the expense of yellow.

In experiments 5 to 8 precipitated ferric hydroxide was added to the bath before the air treatment and the products were darker. The amounts of hydroxide may have been too great. Although the temperature of drying the washed precipitates was varied between 28° and 90° no apparent change in color was noted.

By increasing the bath acidity with sulphuric acid an attractive orange-tinted product was produced, but the reaction was blocked by the collection of sulphate on the iron wire.

The pH of the ferrous sulphate solutions used was about 4. This acidity is due to hydrolysis as shown:

$$\begin{array}{c} FeSO_4 \rightleftarrows Fe^{++} + SO_4^{--} \\ 2H_2O \rightleftarrows 2OH^{-} + H_2^{+}. \\ \uparrow\downarrow \\ Fe(OH)_2 \quad H_2SO_4 \end{array}$$

TABLE 67.—*Production of synthetic pigments using ferrous sulphate without precipitating agents*

	1	2	3	4
Iron salt	1,500 cm^3 $FeSO_4$	1,500 cm^3 $FeSO_4$, pH 3.8.	500 cm^3 $FeSO_4$, pH 3.8.	1,000 cm^3 $FeSO_4$+ H_2SO_4.
Colloid addition	None	None	None	None.
Oxidizing agent	Air	Air	Air	Air.
Reducing agent	Fe	Fe	Fe	Fe.
Temperature of bath, ° C	30	80	90	70.
Time of oxidation, hours	6	1.5	0.5	2.
Ease of filtration		O.K	O.K	O.K.
Precipitate washed		Yes	Yes	Yes.
Temperature of drying, ° C		56	56	56.
Color	No results	Strong tan ocher	Strong peach-tan	Strong peach-tan ocher.[1]

[1] Small yield; sulphate film on Fe stopped reaction.

TABLE 67.—*Production of synthetic pigments using ferrous sulphate without precipitating agents*—Continued

	5	6	7	8
Iron salt	1,000 cm³ $FeSO_4$	1,000 cm³ $FeSO_4$	1,000 cm³ $FeSO_4$	1,000 cm³ $FeSO_4$.
Colloid addition	14 grams $Fe(OH)_3$	14 grams $Fe(OH)_3$	14 grams $Fe(OH)_3$	14 grams $Fe(OH)_3$.
Oxidizing agent	Air	Air	Air	Air.
Reducing agent	Fe	Fe	Fe	Fe.
Temperature of bath, ° C	55	55	55	55.
Time of oxidation, hours	6	6	8	6.
Precipitate washed	Yes	Yes	Yes [2]	Yes.
Temperature of drying, ° C	28	56	60	90.
Color	Strong tan ocher	Strong tan ocher	Strong tan ocher	Strong tan ocher.

[2] Drying with $FeSO_4$ solution produced a gray-brown color.

FERROUS SULPHATE WITH KAOLIN SUSPENSION

Good yellow-ocher colors were produced without precipitating agents but with metallic iron in the bath at temperatures of 40° to 65° C. when kaolin (white clay) was used as a colloidal suspension in the bath. The kaolin probably acts only as a diluent for hydrous ferric oxide particles, but it may assist in preventing the formation of dark red-brown hues. This would be an easy and simple method for producing diluted ocherlike products, as the mixing is very intimate and requires no extra machinery or additional processing. Kaolin or other inert suspensions could likewise be intimately incorporated with the hydrous ferric oxide concentrate after the reaction has been completed but while the oxide is still a suspension in water. This method is better than grinding the two together dry. No doubt other inert and finely divided materials, such as calcium sulphate and barium sulphate, could be used for this purpose. (See table 68.)

TABLE 68.—*Production of synthetic pigments, using ferrous sulphate with kaolin suspension*

[Precipitating agent, none; reducing agent, Fe; filtration difficult on paper; precipitate washed]

	1	2	3	4
Iron salt	1,000 cm³ $FeSO_4$ [1]	2,000 cm³ $FeSO_4$ [1]	1,500 cm³ $FeSO_4$,[2] pH 4.2.	1,000 cm³ $FeSO_4$,[2] pH 4.2.
Colloid addition	4 grams kaolin	12 grams kaolin	21 grams kaolin	$Fe(OH)_3$ and kaolin.
Oxidizing agent	O_2	Air	Air	O_2.
Temperature of bath, ° C	40	65	60	40.
Time of oxidation, hours	2	1.5	3	2.
Temperature of drying, ° C	25 and 60	56	60	56.
Color	Strong tan ocher [3]	Medium-yellow ocher.[3]	Weak ocher [4]	Weak peach-tan.

[1] 50 grams per liter.
[2] 30 grams per liter.
[3] Low yield.
[4] Large yield.

FERRIC CHLORIDE EXPERIMENTS

The data from experiments using ferric chloride are recorded in table 69. Better yellow colors were produced with ferric chloride when kaolin was used as a colloidal suspension than when the chloride was hydrolyzed alone. A strong yellow-brown color was likewise produced by precipitating the entire iron content with lime water and then oxidizing with air.

Peter Fireman (Patent 1392925) found that by passing air through a solution of ferrous chloride to which a quantity of slaked lime had been added (3,600 gallons of $FeCl_2$ to 2,000 pounds of slaked lime) any desired color could be obtained by varying the process. To produce black he heated the mixture at once to the boiling point. Yellow was produced by operating first at low temperatures and then increasing the temperature slowly to the boiling point. The color ranged from dark blue at the start through green and after a long period of oxidation to brown, which on boiling became yellow. Similar results were obtained by Fireman with soda ash, but an excess of the alkali was considered necessary.

TABLE 69.—*Precipitation of hydrous ferric oxides from ferric chloride*

[Reducing agent, none; filtration difficult]

	1	2	3	4
Iron salt	750 cm^3 $FeCl_3.6H_2O$.	20 grams $FeCl_3.6H_2O$.	6 grams $FeCl_3.6H_2O$.	1,500 cm^3 $FeCl_3.6H_2O$.
Precipitating agent	None	None	None	$Ca(OH)_2$.[1]
Colloid addition	None	21 grams kaolin	30 grams kaolin	None.
Oxidizing agent	None	None	None	Air.
Temperature of bath, ° C.	70–75	90–100	90–100	30–100.
Time of oxidation, hours.	1	1	1	7.
Precipitate washed	A little	Yes	Yes	A little.
Temperature of drying, ° C.	60	60	60	56.
Color	Brown [2]	Ocher [3]	Weak ocher red	Strong tan ocher.

[1] Saturated at 30° C.; enough added to precipitate all Fe.
[2] Large yield; finely divided; no ocher color.
[3] When diluted it is similar to French.

CONCLUSIONS

These preliminary experiments indicate that—

1. The higher temperatures of the reaction bath give a faster reaction and more of the red hue with ferrous sulphate.
2. Excess sulphuric acid formed from the reaction or added tends to produce red hues; hence, the metallic reducing agent is needed not only to restore the ferrous sulphate but to control the color.
3. Metallic iron apparently is not needed for color control in the ferric chloride process.
4. Strong, rapidly acting hydroxides produce red-brown and black oxide with ferrous sulphate.
5. Hydrous ferric oxide is stable at ordinary temperatures. The yellow-brown color is lost near 130° C., and therefore drying temperatures up to 100° C. do not affect the color of the monohydrate. Other hydrous combinations may be affected.

PART V. STATE RESOURCES OF MINERAL PIGMENTS[1]

ALABAMA

Possible pigment materials of Alabama are the Clinton or red hematite ores, the limonite or brown ores, and the yellow ochers described later by Jelks Barksdale. In northern Alabama and in western Kentucky and Tennessee limonite occurs in residual and sedimentary clays overlying the Mississippian limestone.[2] (See figs. 4, 7, and 8.) The Alabama limonites are analyzed in table 70.

TABLE 70.—*Chemical composition of Alabama limonite ores, percent*

Constituents	Average, Alabama[1]	Average, Champion area, Birmingham district[2]	Constituents	Average, Alabama[1]	Average, Champion area, Birmingham district[2]
Fe_2O_3	69.5	67.5	S	0.09	
Mn		.72	Al_2O_3	3.61	2.44
SiO_2	11.22	12.50	CaO	.84	
P	.38	.26	H_2O	13.00	7.10

[1] Ries, H., Economic Geology: John Wiley & Sons, Inc., New York, 4th ed., 1916, p. 557.

[2] Burchard, E. F., and Butts, Charles, Iron Ore, Fuels, and Fluxes of the Birmingham District, Ala.: U.S. Geol. Survey Bull. 400, 1910, p. 169.

CLINTON OR RED HEMATITE ORES OF ALABAMA

Ries [3] states:

> The Clinton ore bodies are found in Red Mountain on the east side of the valley in which the city of Birmingham lies. There the Clinton formation, which is 200 to 500 feet thick and dips southeastward from 20° to 50°, is composed of beds of shale and sandstone and includes four well-marked iron-ore horizons, generally in the middle third of the formation. Of these four beds, the Big and Irondale are the most important. The thickness of the former is estimated at from 16 to 30 feet, but the good ore is rarely more than 10 to 12 feet thick, and at most places only 7 to 10 feet are mined. In the middle of the district, the bed is separated into two benches by a parting along the bedding plane, or by a shale bed. Either bench, though producing in one part of the district, may grade into shaly low-grade ore in another part.

Analyses by Harder [4] show a variation in composition as follows: Fe, 37.00 to 54.70 (Fe_2O_3, 52.8 to 78.2 percent); SiO_2, 7.14 to 13.70 percent; Al_2O_3, 3.81 to 5.66 percent; CaO, 19.20 to 0.50 percent; Mn, 0.23 to 0.19 percent; S, 0.08 to 0.07 percent; P, 0.49 to 0.10 percent.

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[1] The descriptions of 34 samples tested in this study were eliminated from this report because of inferior pigment qualities and of 37 others because their source could not be ascertained from persons submitting the samples.

[2] Burchard, E. F., Iron and Manganese Ores: U.S. Geol. Survey Bull. 315, 1907, p. 154; Hayes, C. W., and Ulrich, E. O., Columbia, Tenn.: U.S. Geol. Survey Geol. Atlas, Folio 95, 1903.

[3] Ries, H., work cited, p. 543.

[4] Harder, E. C., Iron Ore, Pig Iron, and Steel: U.S. Geol. Survey Mineral Resources of the United States, 1908, pt. I, 1909, p. 83.

The occurrence of iron ores in Alabama has been summarized by Schrader, Stone, and Sanford [5] as follows:

> **Hematite (Clinton, dyestone, fossil, oölitic, red iron ore).**—Most important iron ore of State; 1 to 5 beds. Greatest mining district, Jefferson County between Bessemer and Birmingham; also mined in Blount County at Village Springs; Cherokee County, Gaylesville and Round Mountain; DeKalb County, Fort Payne and Valley Head; Etowah County, Attalla and Gadsden; St. Clair County, Springville. Formerly mined in Shelby County at Columbiana, and in Tuscaloosa County south and east of Dudley; occurs also in Bibb, Clay, Coosa, Jackson, Marshall, Talladega, and Tallapoosa Counties, and in other places. * * *.
>
> **Limonite.**—Mined in Bibb and Tuscaloosa Counties near Woodstock; Blount County, near Champion; Calhoun County, near Anniston, Jacksonville, Piedmont; Cherokee County, Baker Hill, Bluffton, Langdon City; Franklin County, Russellville; Jefferson County, Birmingham district. Principal ore used in Colbert, Lamar, and Marion Counties. Occurs also in Clay, Cleburne, Coosa, and other counties, as gossan of pyritiferous ore; also in concretionary masses.

OCCURRENCE OF OCHER

By Jelks Barksdale [6]

Ocher of more or less purity is distributed extensively throughout Alabama; deposits of this mineral occur in a number of places both in the Coastal Plain region of the southern part of the State and in the Paleozoic region of the northern part. It is thus evident that ocher has been found either in or closely associated with geologic formations ranging in age from late Tertiary to early Paleozoic. Figure 13 shows the location of all known deposits.

Rail or river transportation is readily accessible to most of these deposits; as a system of improved highways reaches virtually every section of the State formerly inaccessible deposits can now be reached by motor trucks. Some of the most important deposits—as those at Vine Hill, Autauga County; Coosada, Elmore County; Jackson, Clarke County; Shelby, Shelby County; and Attalla, Etowah County—are either on or near railroads. The deposits near Jackson are practically at tidewater, as well.

In the Coastal Plain region ocher occurs as beds or lenses in unconsolidated strata and seems to be of the same age as the enclosing rocks. All these deposits are yellow and most of them exhibit very bright shades. The beds are 2 to 5 feet thick and the overburden in most places is not excessive for strip-pit mining. The overlying materials consist primarily of sands and clays, which can be removed rather cheaply. Frequently a bed of consolidated ferruginous sandstone or conglomerate from a few inches to 1 foot thick immediately overlies the ocher; this would assist materially in supporting the overburden in underground mining and would make a very satisfactory roof material.

Ocher has been mined from deposits near Vine Hill, Autauga County, and near Coosada, Elmore County; a small amount is now being mined from a deposit near Jackson, Clarke County. The ocher is mined by the strip-pit method, sun-dried, and ground to the proper size for market. The material is not washed, but is hand-picked to remove all large impurities.

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[5] Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful Minerals of the United States: U.S. Geol. Survey Bull. 624, 1917, pp. 12 and 13.

[6] Staff geologist, Geological Survey of Alabama.

Other deposits occur near Perdue Hill, Monroe County; at Baker Hill, Barbour County; along the Gulf, Mobile & Northern Railroad 22 miles northwest of Mobile, Mobile County; and about 4 miles southwest of Jones Mill, Monroe County.

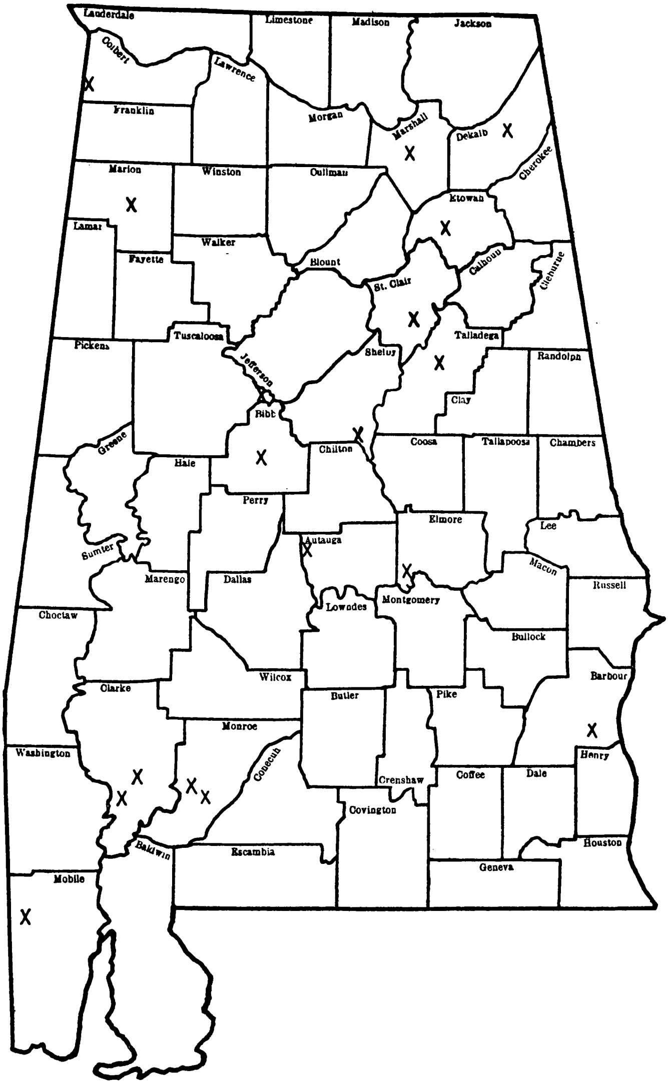

FIGURE 13.—Outline map of Alabama, showing location of known ocher outcrops.

Northern Alabama deposits seem to be of secondary origin and belong to a much later geologic age than the associated formations. They usually occur on but not in limestone formations and are associated with clays and frequently brown iron ore.

Both red and yellow varieties are known in this part of the State. The most important deposits of red ocher are at Shelby, Shelby County; Attalla, Etowah County; and Pierce's Mill, Marion County.

Occurrences of less importance have been reported in an old marble quarry on the north bank of the Cahaba River in sec. 32, T. 24 S., R. 10 E., Bibb County; just above the limonite in an old pit in sec. 23, T. 18 S., R. 5 E., Talladega County; and about 4 miles northwest of Fort Payne, DeKalb County.

An important deposit of yellow ocher has been found near Allsboro, Colbert County. Minor deposits of this mineral are known near Pell City, St. Clair County; Guntersville, Marshall County; Pierce's Mill, Marion County; and in the brown iron-ore workings at Central Giles, Tuscaloosa County. Yellow ocher and ocherous clays have been reported in the Tuscaloosa formation in Fayette and Tuscaloosa Counties, but these deposits do not appear to have commercial possibilities.

Red ocher has been mined from a deposit near Attalla, Etowah County, but no production of yellow ocher has been reported from northern Alabama.

The entire production of the State has been from strip-pit mines.

Additional information may be obtained from the publications of the Alabama Geological Survey.[7]

TESTS OF ALABAMA PIGMENTS BY THE UNITED STATES BUREAU OF MINES [8]

ALABAMA NO. 1

Alabama sample no. 1 was a red pigment from the property of the Shelby Iron Works at Shelby, Shelby County. It came from old brown-ore pits and contains many small pebbles of hematite. The pigment immediately overlies the cherty Ordovician limestones of Beekmantown age and is closely associated with variegated sands and clays that carry limonite. The overlying material has been removed from the iron-ore content so that the pigment now occurs at the surface. It ranges from 15 to 50 feet in thickness and extends discontinuously over an area of about 1 square mile. The deposit has not been worked on a commercial scale. A narrow-gage ore railroad extends into the immediate vicinity of the deposit from the Louisville & Nashville Railway one fourth mile away.

Laboratory tests.—The sample was dried, crushed, and ground to pass a 10-mesh screen before sampling. It was a very plastic and colloidal material which dispersed in water with difficulty even with severe blunging or agitation, being similar in its plastic qualities to the ball clays of the pottery industry. If it could be washed in the original, damp condition it might disperse more readily. The washing test left 13.6 percent of light-gray sand with some dark-red and black particles. The lighter-colored residue will dilute the red color if all are ground together. Hence, the sample should be prepared by washing. Twenty-three drops per gram or 0.53 part by weight of XX refined linseed oil produced a paste that could be spread on the glass slide. The paste was difficult to spread even with this amount of oil because of the excessive plasticity and stickiness.

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[7] Smith, E. A., and McCalley, H., Index to Mineral Resources of Alabama: Geol. Survey of Alabama Bull. 9, 1904, p. 62.
Jones, W. B., Index to Mineral Resources of Alabama: Geol. Survey of Alabama Bull. 28, 1926, p. 211.
Smith, E. A., Johnston, L. C., and Langdon, D. W., Jr., Geology of the Coastal Plain of Alabama: Geol. Survey of Alabama Special Rept. 6, 1894.
McCalley, H., Valley Regions of Alabama. Part I. The Tennessee Valley Regions: Geol. Survey of Alabama Special Rept. 8, 1896.
McCalley, H., Valley Regions of Alabama. Part II. The Coosa Valley Regions: Geol. Survey of Alabama Special Rept. 9, 1897.
Adams, G. I., Butts, Charles, Stephenson, L. W., and Cooke, C. W., Geology of Alabama: Geol. Survey of Alabama Special Rept. 14, 1926, 312 pp.
Payne, H. M., Undeveloped Mineral Resources of the South: Am. Min. Cong., 1928.

[8] All of the following data on geologic and geographic occurrence were obtained through the kindness of the Geological Survey of Alabama.

The sample was grouped with class 1, red-brown, burnt siennas. Its original color in linseed oil alone was a medium neutral brown, and when diluted to 10 percent with zinc oxide the color changed to weak brownish cream. The sample contained only 4.6 percent of ferric oxide. The color strength was weak for burnt siennas, although it is comparable to that of some ochers. The commercial use of this pigment is therefore very doubtful.

ALABAMA NO. 2

Alabama no. 2, yellow ocher, came from a deposit owned by J. W. Floyd, about 1 mile southeast of Bakerhill, Barbour County. It occurs in the Naheola formation of the Midway group of the Eocene in the following section:

	Feet
Clay to top of bluff	15
Ferruginous sandstone	2
Yellow ocher	5
White, yellow, and gray sand	20

The overburden is heavy, and only a small amount of the material has been mined. The ocher outcrops near the water level in a deeply cut stream valley at two places about one fourth mile apart. The areal extent has not been determined. Transportation facilities are poor; the outcrop is about one half mile from an improved highway, 9 miles from the Central of Georgia Railroad, and 10 miles from the Chattahoochee River.

Laboratory tests.—After the ocher was dried and ground a 100-gram sample was selected and washed. Most of the material dispersed in water readily, although the residue (45.6 percent), consisting of white and brown sand, was freed of the last traces of yellow ocher with difficulty. If this sample were prepared by grinding, the color would be greatly diluted and weakened. The washed ocher dried to a medium-hard mass with high shrinkage. Twenty-four drops per gram or 0.56 part by weight of linseed oil produced a paste that would spread on the glass slide; the paste was difficult to spread even with this amount of oil because of excessive plasticity and stiffness of the mixture.

The full-strength color in oil was topaz (60112) which changed to sunset (60088) when diluted with zinc oxide. The ferric oxide content was 9.6 percent. The pigment was assigned to the light French grade, class 1, yellow, ochers in full strength, although when let down it was more like the dark French grade. This pigment should have commercial possibilities, even though the iron oxide content is apparently low and the oil requirements are high.

ALABAMA NO. 3

Yellow ocher was found on the property of George S. Bennett about 4½ miles east of Glendon, Clarke County. The ocher outcrops near the summit of a broad flat-topped hill as a seam 8 to 10 feet thick. The lower 2 feet grade into the yellow clay at the bottom. A ledge of ferruginous sandstone 6 inches thick lies over the ocher; above this ledge 3 to 15 feet of sand and clay complete the overburden. The ocher is underlain by yellow and mottled clays. Outcrops appear at several places around the hill; the areal extent seems to be about 40 acres. The ocher and associated clays lie over the Vicksburg limestones but do not belong in this formation. The deposit is about 4½ miles from the Southern Railway, and the dirt roads in the vicinity are poor. During the summer of 1928 this pigment was mined and hauled in motor trucks to a mill at Jackson about 8 miles away, where it was prepared for market by hand-picking, drying, and grinding.

Laboratory tests.—The sample was easily washed; the washing test left 28.3 percent of clean gray sand, which if not removed would dilute and weaken the color. The purified ocher dried to a hard, brittle mass with high drying shrinkage.

Eighteen drops per gram or 0.42 part by weight of linseed oil produced a stiff paste, which was spread on the glass slide with difficulty.

The full-strength hue in oil was between topaz (60112) and gold (60164). When diluted with zinc oxide the color changed to chamois (60179). The ferric oxide content was only 4.5 percent. This material was classed as light Pennsylvania, class 2, yellow, ochers and showed medium tinting strength when let down with zinc oxide, varying toward yellow.

ALABAMA NO. 4

Alabama no. 4, yellow ocher, came from the Central Giles mine near Vance, Tuscaloosa County. The mine is owned by the Central Iron & Coal Co., Holt, Ala. This material occupies pockets in brown-ore pits and is found at several places in the area. As only brown ore was shipped it is impossible to tell how much ocher has been thrown out or sent through the washers. The sample was taken from the west side of the main workings near the incline from a body about 25 feet in diameter, as shown on the face of the pit. The deposit is large enough to have commercial importance.

Laboratory tests.—The sample was easily washed; the washing test left 67.5 percent of gray sand and mica, which if ground with the fines would dilute and weaken the color. The purified ocher dried to a medium-hard mass with moderate shrinkage. Twenty-five drops per gram or 0.58 part by weight of linseed oil made a stiff topaz (60112) paste. When diluted with nine parts of zinc oxide the color changed to sunset. The iron oxide content was 9.6 percent. This material was placed with class 1, light yellow-ochers and was close to the light French. It was classed as "strong" in the dilution test.

ALABAMA NO. 5

A yellow ocher was found on the property of the Vine Hill Land Co. 1½ miles east of Vine Hill, Autauga County. The deposit is about 2 miles from a railroad, but the dirt roads in this district are poor. The bed is overlain with about 6 inches of ferruginous sandstone; above the sandstone lie 1 to 15 feet of varicolored sands and clays. No ocher has been mined from this deposit, but a small amount has been obtained in the immediate vicinity. The areal extent of the bed is not known.

Laboratory tests.—The 25-pound sample was dried and ground for purification. The material was easily washed; the washing test left 49.7 percent of clean light-gray sand and mica. The fines when dried gave low shrinkage but a medium-hard dry mass, which required 20 drops per gram or 0.46 part by weight of linseed oil to produce a stiff paste, whose spreading properties were poor because of excessive plasticity. The full-strength color in oil was topaz (60112) toward sunset (60088). When diluted with zinc oxide the hue changed to chamois (60179). The ferric oxide content was only 3.6 percent. This material was classed with Pennsylvania or class 2, light-yellow, ochers, although it showed medium strength and a cream tint when let down with zinc oxide.

ALABAMA NO. 7

Alabama no. 7 and the data regarding it were submitted by Eugene I. Weil, Gadsden, Ala. The iron ore is in secs. 24 and 25, T. 12 S., R. 3 E., and sec. 20, T. 12 S., R. 4 E., St. Clair County. The thickness of these seams is 5 to 8 feet of solid ore with no parting. Weil reports that 10,000,000 tons are available, which can be mined by stripping for about $1 per ton, f.o.b. cars. These veins dip only 8° to 23°, and the light overburden makes stripping easy.

Laboratory tests.—The 5-pound sample of hard, red oölitic ore was too hard for any washing treatment. After being ground in water the dried fines required 15 drops per gram or 0.35 part by weight of linseed oil to make a smooth henna (60135) paste. When diluted with nine parts by weight of zinc oxide the color changed to between Grecian rose (60175) and bois de rose (60176). The ferric oxide content was 79.5 percent. This material was placed with class 1, old rose, mineral browns. The tinting strength was as strong as that of the commercial metallic browns, and the tints were attractive. The material should have commercial value if market conditions are satisfactory.

ALABAMA NO. 8

Sample no. 8 was submitted by the owner, Will H. Cooper, P.O. box 597, Mobile, Ala. It came from SE¼ sec. 21, T. 7 N., R. 3 E., in Clarke County. The material occurs as a seam from a thin layer to 6 feet thick; the areal extent is more than 160 acres. The sand and gravel overburden, ranging from 10 to 20 feet, could probably be sluiced from the ocher. The property is within 1 mile of the Southern Railway between Mobile and Birmingham and about 10 miles from the ocher plant at Jackson.

Laboratory tests.—A portion of this highly plastic, claylike material was washed free of sand. The color of the full-strength paste with linseed oil lay between topaz (60112) and gold-brown (60113). When diluted with nine parts of zinc oxide the color approached sunset (60088). The ferric oxide content was 16.6 percent. This material was classed with Pennsylvania or class 2, yellow, ochers. The tinting strength was medium. The color and working properties indicated commercial value.

ARIZONA

According to G. M. Butler, dean of the University of Arizona College of Mines and Engineering, there is no record of the mining or shipment of any mineral pigments from Arizona,[9] although ochers and similar pigments have been used by the Indians from time immemorial.

Schrader, Stone, and Sanford [10] have summarized the occurrence of the iron ores of Arizona as follows:

> **Hematite.**—Occurs in gossan of copper deposits at many localities in Santa Cruz County, at Pluto, Isabella, and other claims, and in Yuma County, at the Palmer and Wharton claim. Occurs as contact mineral in Cochise County in magnetite on croppings of Black Diamond copper mine, Dragoon; in Greenlee County, in the Clifton-Morenci district; and at Manganese Blue mine. Gila County, mined with copper ores in Globe district. * * *.
>
> **Limonite (brown hematite, brown iron ore).**—Cochise County, Copper Queen mine at Bisbee. Gila and Pinal Counties, mined for contained copper in Old Dominion mine, Globe district. Greenlee County, abundant in Clifton-Morenci district, valuable as flux. Mohave County, common in Black Mountains and Cerbat Range, Chloride district. Pima County, coating quartz veins at McCleary prospects near Helvetia, at Old Baldy prospect. Yavapai County, in ores of Bradshaw Mountains. * * *.
>
> **Mineral paint.**—Yuma County, 30 miles northeast from Quartzsite and at Bouse's well.

TESTS OF ARIZONA PIGMENTS BY THE UNITED STATES BUREAU OF MINES

During this study a number of samples were received from private parties and through the United States Bureau of Mines Intermountain Experiment Station at Salt Lake City.

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[9] Upham, W. E., Specular Hematite Deposits, Planet, Ariz.: Min. and Sci. Press, Apr. 15, 1911, pp. 521–523.

[10] Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful Minerals of the United States: U.S. Geol. Survey Bull. 624, 1917, pp. 25–27.

ARIZONA NO. 2

A sample of hematite was received from Carl Trischka, geologist, Phelps-Dodge Corporation, Bisbee, Ariz. A description of the deposit was contributed by D. Moreau Barringer, Jr., box 445, Warren, Ariz. The deposit is 18 miles south of Seligman, Ariz., the nearest railroad shipping point. A good unimproved road leads to the prospect, which is at an elevation of approximately 5,000 feet. Water and wood are plentiful, and operations can be continued for 9 months of the year in this climate.

The ore is reported to be hematite; its chief impurity is calcite. The analysis furnished by D. M. Barringer is: Fe, 61 percent; CaO, 4.5 percent; SiO_2, 2 percent; sulphur and phosphorus, little or none. One third to one half of the ore as mined will be of equal grade to the sample tested, and the different grades can be separated easily on a picking belt.

The ore forms irregular lenses in limestone near the contact of limestone and diorite. Because the ore is soft and the limestone hard the outcrops do not indicate the size of the ore bodies beneath. Only the largest of these lenses, as indicated by surface exposure, has been developed to any extent. A shaft 130 feet deep continues in ore and the average width of the lens to this depth is more than 50 feet. Its length along the outcrop is probably 500 to 1,000 feet. Other outcrops are smaller than this one and probably represent smaller deposits. A rough calculation indicates 175,000 tons of "probable ore," of which at least 30 percent is of paint grade. An estimate by D. M. Barringer of the cost, f.o.b. cars, is $15 per ton, including double mining costs due to sorting plus $4 to $5 for haulage to the railroad.

Laboratory tests.—The sample as received was a bright-red, almost knife-hard rock, with a conchoidal fracture, containing carbonates as indicated by effervescence when treated with hydrochloric acid. It was ground in water in a pebble mill to the usual fineness; a deep-red powder of soft texture and medium shrinkage on drying resulted. Eleven drops per gram or 0.26 part by weight of linseed oil made a soft henna (60135) paste. When diluted with nine parts of zinc oxide it changed to light bois de rose (60176). The ferric oxide content was 92.2 percent. This material was grouped with class 2, salmon, burnt siennas. The light red-brown, full-strength color diluted to very strong, bright red-brown, close to the red oxide colors. If economic and marketing conditions are satisfactory, this material should have commerical value.

ARIZONA NO. 3

A sample of gray and yellow-brown clay sent by Henry Blackford, secretary of the Chase Mines, Inc., Prescott, Ariz., was taken from a 4-foot vein, 300 yards from an excellent highway, between Prescott and Phoenix and 7 miles from Prescott.

Laboratory tests.—The 1-pound sample of 2-inch lumps had an irregular, mottled poor color. A sample ground in water in the pebble mill gave, when dried, a hard, high-shrinking, light-brown mass. Twenty-two drops or 0.51 part by weight of linseed oil made a mealy mummy (60081) paste. When diluted with zinc oxide this changed to champagne (60097). The ferric oxide content was 16.0 percent. This material was classed with dark Pennsylvania or class 2, yellow, ochers but varied toward brown sienna. The dilution test indicated medium strength toward cream.

ARIZONA NO. 4

Arizona no. 4 came from the same deposit as no. 3. The material is reported to come from a 14-inch vein.

Laboratory tests.—The sample has a darker brown color than no. 3, but is likewise mottled and varies both in hardness and color. After being ground and dried it produced a hard, high-shrinking powdery mass. Twenty-four drops or 0.56 part by weight of linseed oil produced a soft paste with a color between olive wood (60082) and autumn (60083). When diluted with nine parts of zinc oxide the color changed to light champagne (60097). The ferric oxide content was 19.0 percent. This material was one of the weakest yellow or cream ochers, too weak to classify with the commercial pigments, although the iron oxide content indicated stronger tinting strength.

ARIZONA NO. 6

A sample was submitted by J. I. Anderson, 614 Dougherty Street, Prescott, Ariz., owner of a claim 300 feet from the Phoenix highway and 6 miles south of the Prescott courthouse in Yavapai County. Prescott is the nearest shipping point on the Santa Fe Railway. The ocherlike material occurs as a vein about 4 feet thick with about 2 feet of silt overburden. The country rock is reported to be decomposed granite and shale. The ocher is estimated to cover an area of 50 to 150 by 1,000 feet. Only the location work has been done on this claim. Underground methods will probably have to be employed in mining this material, and the cost estimated by Anderson will probably be more than $20 per ton at first.

Laboratory tests.—The small 3-ounce sample of already powdered material required 25 drops per gram or 0.58 part by weight of linseed oil to produce a light-brown (60114) to gold-brown (60113) paste. When diluted with nine parts of zinc oxide the color changed to dark sunset (60088). The ferric oxide content was 35.4 percent. This pigment was classed with class 1*a*, strong pink, siennas, stronger than and of a different hue from commercial ochers now on the market. The full-strength dark red-brown diluted with nine parts of zinc oxide changed to strong pink-tan. The effect of further dilution is shown in figure 12, *B*. This material is similar in strength to the artificial yellow pigments; if the quantity and uniformity of material, mining, preparation, and marketing conditions are atisfactory, it should have commercial value.

ARIZONA NO. 7

Arizona no. 7 came from the same claim as Arizona no. 6.

Laboratory tests.—The 3-ounce sample of powdered red-brown pigment required 24 drops per gram or 0.56 part by weight of linseed oil to produce a leaf-mold (60147) paste. When diluted with nine parts of zinc oxide the color changed to monkey skin (60123). The ferric oxide content was 35.1 percent. This material was classed with class 1, red-brown, burnt siennas. The full-strength color was dark neutral brown, which diluted to a brown toward violet-gray. The tinting strength was medium. The oil requirements are high, but if the color is acceptable it may have market value.

ARIZONA NO. 8

Arizona no. 8 was submitted by J. I. Anderson from the same claim as Arizona no. 6; it was designated as no. 1 sample, second shipment.

Laboratory tests.—This 2-ounce sample required 23 drops per gram or 0.53 part by weight of linseed oil to produce an oak-wood (60142) paste. When diluted with nine parts of zinc oxide the color changed to weak champagne (60097). The ferric oxide content was 30.1 percent. This material was classed with the weakest yellow ochers, although the iron oxide content was high. The test does not indicate commercial value for this material.

ARIZONA NO. 9

Arizona no. 9 was a small sample of Arizona no. 8, which had been heated on a stove by J. I. Anderson to produce a red color.

Laboratory tests.—Twenty drops per gram or 0.46 part by weight of linseed oil produced a paste of a color between leaf mold (60147) and mahogany (60136). When diluted with nine parts of zinc oxide the color changed to between monkey skin (60123) and Grecian rose (60175). The ferric oxide content was 32.3 percent. This material was grouped with class 2, violet, mineral browns. The dilution test indicated medium tinting strength. The let-down color ranged from the standard toward rose. These tests indicated commercial value for this pigment if other conditions are satisfactory.

ARIZONA NO. 10

Arizona no. 10 is another J. I. Anderson sample (labeled sample no. 2) from the same locality as the preceding.

Laboratory tests.—This small sample required 20 drops per gram or 0.46 part by weight of linseed oil to produce an oak-wood (60142) paste. When diluted with nine parts of zinc oxide the color changed to polar bear (60004). The ferric oxide content was 16.9 percent. This material was classed with the weakest cream ochers, changing from dark red-brown to weakest pink-cream on dilution. It was too weak for comparison with the commercial grades, although the analysis indicated fair strength.

ARIZONA NO. 11

A 20-gram sample marked "iron oxide" was also submitted by J. I. Anderson from the same location as Arizona no. 6.

Laboratory tests.—This material required 22 drops per gram or 0.51 part by weight of linseed oil to produce an oak-wood (60142) paste. When diluted with nine parts of zinc oxide the color changed to sunset (60088). The ferric oxide content was 33.7 percent. This material was grouped with class 1*a*, pink, siennas, and was more like artificial commercial ochers than natural yellow ochers now on the market. The neutral red-brown, full-strength color diluted to strong gray-cream and indicated commercial possibility if economic conditions are satisfactory.

ARIZONA NO. 12

A 50-gram sample of powdered brown ocher from the same location as Arizona no. 6 was included in the shipment from J. I. Anderson.

Laboratory tests.—Twenty-three drops per gram or 0.53 part by weight of linseed oil produced an oak-wood (60142) paste. When diluted with zinc oxide the color changed to light champagne (60097). The ferric oxide content was 27.8 percent. This material was classed with the weakest yellow ochers, diluting from dark red-brown to gray-cream. Because of low tinting strength this material is not of commercial grade, although the iron oxide content is high.

ARKANSAS

Apparently no mineral pigments have been mined in Arkansas, but brown Tertiary limonite ores of small economic value do occur in southwestern Arkansas adjoining the Texas fields and in the Ozark region of Missouri and Arkansas in residual clays over Cambrian limestone.[11]

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[11] Burchard, E. F., Iron-bearing Deposits in Bossier, Caddo, and Webster Parishes, La.: U.S. Geol. Survey Bull. 620-g, 1915, pp. 129-150.

Schrader, Stone, and Sanford[12] have summarized the occurrence of iron ores in Arkansas as follows:

Limonite.—Small quantity in nearly every county; has been mined near Berryville, Carroll County, and in Lawrence and Sharp Counties. * * *.

Ocher.—Clay County, irregular beds of yellow ocher in Tertiary, near Piggott; has been mined. * * *.

Reddle (red chalk).—Abundant in many localities; probably useful in paint manufacture; not mined.

Two samples of ocherous material were received from George C. Branner, State geologist of Arkansas.

TESTS OF ARKANSAS PIGMENTS BY THE UNITED STATES BUREAU OF MINES

ARKANSAS NO. 1

Arkansas no. 1 was taken from the Wilcox formation of Tertiary age lying in the Gulf Coastal Plain of southern Arkansas. The deposit is in the SE.-NE. sec. 18, T. 5 S., R. 16 W., Saline County, Ark., near Durian spur on the Rock Island Railroad. The fee owner of the land is W. S. Brown. The owner of the mineral rights is the Wisconsin-Arkansas Lumber Co., Malvern, Ark., and the agent, A. B. Cook. A hole was dug in the top of a low hill into the deposit; about 6 feet of surface gravel and clay were penetrated before the ocherous seam of approximately 4½ feet was exposed. The areal extent can be inferred only from the well holes in the neighborhood, which would indicate at least 2 to 3 acres. No development work other than the test pit not more than 200 yards from the railroad has been done on this deposit.

Laboratory tests.—The 4-pound sample consisted of a mixture of yellow ocherous and gray claylike material of good plastic properties. No carbonates were indicated by hydrochloric acid. The sample was washed, and 4.2 percent of residue was removed. This sandy material, however, had as good a color as the fine clay and could undoubtedly be ground with the ocher. The dried, pulverized fines required 17 drops per gram or 0.39 part by weight of linseed oil to produce a mealy paste of a color between pablo (60090) and terrapin (60091). When diluted with nine parts of zinc oxide the color changed to polar bear (60004). The ferric oxide content was 19.4 percent.

After submitting a portion of the purified sample T. P. Foster, 1601 Woodrow Street, Little Rock, Ark., stated that Geo. S. Mepham & Co., East St. Louis, Ill., was ready to purchase this material in the washed condition. However, the test of this sample indicated a tinting strength too weak for classification in the commercial grades. If stronger, it would have been placed with the light-grade, class 2, ochers.

ARKANSAS NO. 2

Sample no. 2 was taken from the Wilcox formation of Tertiary age lying in the Gulf Coastal Plain of southern Arkansas. The deposit is in the SW.-SE. sec. 17, T. 2 S., R. 14 W., Saline County, Ark. The fee owner of the land is J. H. Murray, R. 2, box 43, Alexander, Ark. An ocherous sandy clay containing some free limonite occurs in a bed about 5 feet thick overlain by 2½ to 6 feet of overburden. The deposit may cover several acres. Murray has sold a few tons of this material to T. P. Foster, Little Rock, Ark., and was delivering it during January 1930. The deposit lies about 2 miles from Lena, Saline County, on the Rock Island Railroad.

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[12] Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful Minerals of the United States: U.S. Geol. Survey Bull. 624, 1917, pp. 38, 40.

Laboratory tests.—The 3-pound sample consisted of 4- to 6-inch lumps of reddish-brown conglomerate in which pebbles were cemented together with iron oxide in a somewhat vesicular structure. The mass was for the most part knife hard, although there were some soft spots. No carbonates were indicated by hydrochloric acid. After being ground in water the pulverized fines required 14 drops per gram or 0.32 part by weight of linseed oil to produce a henna (60135) paste. When diluted with nine parts by weight of zinc oxide the color changed to peach (60157). The ferric oxide content was 19.7 percent. This material was grouped with class 2, salmon, burnt ochers. The light, bright-colored, brown-red, full-strength hue diluted to weak brown, varying toward cream-pink from the standard. Its commercial value would be restricted to local use.

CALIFORNIA

CALIFORNIA MINERAL-PAINT MATERIALS

By HENRY H. SYMONS and C. McK. LAIZURE

Mineral paint has been produced steadily in California since 1890, when the first recorded production was made. (See table 71.) This material came from Alameda, Amador, Butte, Calaveras, Colusa, Los Angeles, Napa, Nevada, Placer, Riverside, Shasta, Sonoma, Stanislaus, and Ventura Counties, with a total of 22,430 tons, valued at $216,289. Other deposits in El Dorado, Imperial, Kern, Kings, Lake, Mendocino, San Diego, Siskiyou, Trinity, and Yuba Counties may have commercial value, but as yet no commercial shipments have been made from these counties.

TABLE 71.—*Total recorded production of mineral paint in California, 1890–1928*

Year	Tons	Value	Year	Tons	Value	Year	Tons	Value
1890	40	$480	1904	270	$1,985	1918	728	$4,738
1891	22	880	1905	754	4,025	1919	1,780	17,055
1892	25	750	1906	250	1,720	1920	779	8,477
1893	590	26,795	1907	250	1,720	1921	446	4,748
1894	610	14,140	1908	335	2,250	1922	1,620	13,277
1895	750	8,425	1909	305	2,325	1923	1,049	11,773
1896	395	5,540	1910	200	2,040	1924	532	5,234
1897	578	8,165	1911	186	1,184	1925	669	6,969
1898	653	9,698	1912	300	1,800	1926	569	5,846
1899	1,704	20,294	1913	303	1,780	1927 1928	919	9,592
1900	529	3,993	1914	132	847			
1901	325	875	1915	311	1,756			
1902	589	1,533	1916	643	3,960	Total	22,430	216,289
1903	2,370	3,720	1917	520	2,700			

California mineral paints have been used as the color pigments in mortar, stucco, and cement mixes; in calcimine; as pigments in oil paint; as various fillers; in linoleum; in cosmetics, etc. Their colors and composition vary greatly. Yellow, the most common, is colored by limonite; red is colored with hematite; the browns might be colored with either or both hematite or limonite. All are mixed with clay. Several plants in the State treat their ochers and blend them to give uniform colors and quality at all times. The materials as they come from the mine vary in color, but when they are properly handled uniform quality and color can be maintained.

These deposits occur as soft, fine-grained, red shales; as gossan after sulphide ore bodies; as yellow or brown clays colored by water carrying iron in solution and depositing it on the clay; or as iron oxide or hydroxide deposited from spring waters high in iron.

In addition to the natural deposits, tailings from chlorination plants, pyrite sinter from acid works, and magnetite concentrated from black sands have been used in the manufacture of synthetic ochers.

DEPOSITS BY COUNTIES

Alameda County.—A deposit of red chert has been found on the John Berendiere ranch 12 miles southwest of Livermore on Arroyo Mocho road in sec. 14, T. 4 S., R. 3 E., and only about 100 feet from the manganese deposit of the same owner. A sample of this rock was submitted to the Paraffine Paint Co. factory at Oakland. It was tested (May 1919) and found to have properties of sufficient value to warrant further investigation. A rock of similar color and properties, used in the manufacture of linoleum, has been obtained from Pennsylvania for years by this company.

On the surface the deposit appears of considerable extent, as outcrops were noted at several place on the hillside.

The rock is dark, highly stratified, and quite uniform in quality and color, and looks greasy and schistose on some cleavage faces.

Amador County.—At many places overlying the sands and clay of the Ione formation red and yellow iron oxide occurs. Most of this material is red oxide mixed with clay or sand. Very few places were noted where the material was of high enough quality or occurred in sufficient quantity to have commercial interest. It is in the form of concretions on the surface or is mixed with the soil.

Some piles of chlorination tailings from treatment of gold-bearing sulphides at mines along the mother lode years ago possibly would be suitable for paint.

Butte County.—An ocher deposit owned by the Chico Ocher & Mineral Paint Co. occurs on 360 acres of land in secs. 5 and 6, T. 23 N., R. 4 E., near the Doon road and 1 mile from the Southern Pacific Railroad.

There was some production before 1900. The deposit was worked through an adit 200 feet long and a small open pit.

Calaveras County.—On the Holmes ranch at Sampo Seco a body of decomposed slate stained by iron oxide has produced a durable paint.

Late Ocher mine one half mile west of Valley Springs produced several carloads of ocher 30 to 35 years ago but has been idle lately. The ocher ranges in color from yellow to dark red.

D. F. Rhoden, Valley Springs, reported to the division of mines of California an ocher deposit 3 miles from that place. Samples of brown and yellow ocher were submitted, but the deposit has not been visited so the extent and character are not known.

There are several deposits of iron ore in the county; some might be suitable for paint. Most of the ore is limonite.

Colusa County.—Ruby King mineral-paint mine is in secs. 29 and 31, T. 17 N., R. 6 W., 4 miles south of west of Lodoga and 27 miles by road from Arbuckle, the nearest railroad point. The 40 acres of patented ground on which the mill and principal workings were located have been sold to the State for unpaid taxes and nearly all movable equipment has been removed. The unpatented mining claims have reverted to the public domain. No work has been done for several years. The remaining paint material in sight appears quite siliceous. It occurs irregularly in lumps and small masses.

Eldorado County.—Samples of both red and yellow ocher from different parts of the county have been brought to the attention of the State division of mines. The deposits have not been visited, as several are remote from the railroad.

Imperial County.—A number of thermal springs occur on the north end of Mullet Island at the southeast end of Salton Sea. These springs deposit iron oxide about their vents in the form of yellow and red ocher. The owner is Capt. Charles Davis, Niland.

Kings County.—An occurrence of mineral paint is associated with a gypsum deposit in sec. 13, T. 24 S., R. 17 E., northwest of Dudley.

Lake County.—The deposit of Bartels Bros. is in sec. 3, T. 15 N., R. 7 W., 2 miles north of Hough Springs. It forms a low spur off one of the higher mountain ridges; the outcrop is said to be 100 feet wide and 1,500 feet long. Two colors lie side by side—one between burnt umber and burnt sienna and the other slightly dark, yellow ocher. This pulverulent material requires little or no grinding, only screening and bolting, to prepare it for use as paint. Pits dug in the deposit to a depth of 10 feet show the same character of material as at the surface. Samples have been shipped for test, and small amounts have been used for paint around Hough Springs, which is on the main stage road 26 miles west from the railroad at Williams.

Material from a deposit of hematite in Jerusalem Valley near Dollar Springs in sec. 8, T. 11 N., R. 5 W., northeast of Middletown, has been used locally for paint.

Los Angeles County.—Red and yellow ocher was noted along the oxidized croppings on the veins in Renton Canyon on Santa Catalina Island. Above no. 4 tunnel on the Renton vein near the automobile road to no. 3 tunnel a 6- to 18-inch vein of red ocher is exposed. This material is being tested for use in paint.

On the coast 2 or 3 miles north of Redonda are some bluffs of very fine, pure clays of yellow, brown, and ocher tints suitable for mineral paints, for which they have been tested by practical painters.

Mendocino County.—Red rock thought to be suitable for paint making is found on the property of Mrs. Effie M. Heughes, Calpella, on patented land in sec. 27, T. 17 N., R. 12 W., formerly part of the Yorcho ranch. The total area is 360 acres. Manganese is also reported on the property, but no development work has been done. A good road runs to the property, which is 14 miles northwest of Ukiah.

Napa County.—The Carl Browne paint mine on Benali Mountain 2 miles south of Calistoga is now owned by W. R. Teale. Some of this white material has been shipped to Richmond, where it was used in making porcelain; several years ago some was shipped to Oakland for the manufacture of bisque doll heads. None, however, was mined during 1930. This material is exposed in other places in the immediate neighborhood. Red iron oxide and kaolin also occur on Teale's property.

No work was done during 1930 at the property of the California Paint Mineral & Mining Co., owned by Mrs. Ellen M. Knoles. Yellow ocher, however, has been shipped in the past.

Nevada County.—Before 1900 shipments of paint material of reddish-brown oxide of iron, formed from the residue of pyrite ores mined for their copper values, were made from Nevada County.

Neva May, Genevieve, and White Cloud mining claims, owned by J. N. McMahon, R. A. Paine, and A. P. Adams, all of Nevada City, Calif., are in sec. 18, T. 17 N., R. 11 E., M.D.M., near Washington and about 18 miles east of Nevada City. The vein of red and yellow ocher is about 20 feet wide. Samples submitted to the State division of mines were of good quality and shades.

Placer County.—Low-grade iron oxide in the form of red and yellow ocher has been shipped from the Bancroft ranch and other properties near the Hotaling iron mine in the Clipper Gap district. No prospecting has been done for the past 2 years. This oxide was used for paint.

Some low-grade yellow ocher or iron-stained shale has been shipped from the Everhart Bros. property 2 miles from Gold Run. Although the exact use to which it was put is not known, it is believed to have been used for filler, mortar color, or a similar purpose. The deposit has not been producing for the last 3 or 4 years.

Dark reddish-brown ocher, evidently decomposed iron oxide sand, was shipped in 1924 from near Sugar Pine mill about 25 miles by road from Colfax via Forest Hill. It was reported to have been used in paint.

Riverside County.—In sec. 14, T. 4 S., R. 7 W., about 500 yards southeast of the Paint mine is a ledge of yellow ocher (reported to be 8 feet wide) in a deposit of fire clay, owned by George W. Lord, Corona. The ocher is light-colored and fine-grained but contains minute inclusions.

The paint mine of the Corona Pressed Brick & Terra Cotta Co., formerly owned by George W. Lord, is in secs. 10, 11, 14, and 15, T. 4 S., R. 7 W., S.B.M.

The National Paint & Color Co. at one time manufactured about 20 various colors—ocher, red, vermilion, gray, etc. The works is equipped with all required machinery, a 15-hp. engine, and a 35-hp. boiler using oil as a fuel. The company owns extensive clay deposits near Corona, among which is a tract of about 20 acres containing about 5 feet of ocher, stated to be of choice quality.

San Diego County.—A bedded deposit of mineral paint is 8 miles northeast of Encinitas in secs. 3 and 10, T. 13 S., R. 3 W., S.B.M. The deposit is traceable for some 4,000 feet, its strike being nearly east and its dip 45° N. It ranges from 70 to 100 feet in width and is underlain by diorite; this forms the foot wall whereas basalt forms the hanging wall. Near the foot wall its color is reddish and yellowish; toward the hanging wall it grows lighter, passing from pale yellow and gray to white. About 12 feet of the width are said to have commercial value.

San Joaquin County.—Earthy red hematite as shale occurs in sec. 2, T. 4 S., R. 4 E., at the Ladd manganese mine.

Shasta County.—Iron ore occurs in Shasta County at several places along the contact of the McCloud (Carboniferous) limestone and quartz-augite-diorite of the late Jurassic or early Cretaceous age.[13] The principal outcrops are 1½ miles north of Heroult, where considerable ore has been mined; on the northeast side of Hirz Mountain; and on the north and west sides of Gray Rock.

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[13] Diller, J. S., Redding, Calif.: U.S. Geol. Survey Geol. Atlas, Folio 138, 1906.

The deposits show limonite on the surface, but magnetite of the contact type lies below. In places pyrrhotite and chalcopyrite occur with the magnetite; these lead to the belief that the deposits might prove to be gossan of the copper-ore bodies.

In sec. 36, T. 34 N., R. 4 W., on the south side of the Pit River one half mile south of Heroult, are 14 claims owned by T. H. Peterson, Heroult. They cover a large body of iron gossan 500 feet wide by 1 mile long north and south. A number of short adits have been run and are reported to show some pyrite and copper. The surface ore has considerable value for mineral paint, but none has been marketed as yet although the owner is reported to have had various offers.

Sonoma County.—There are indications of iron ore along the second ridge back from the shore line, beginning about 6 miles east of Fort Ross and continuing northwest into Mendocino County. The most important properties are:

Hooper ranch—J. W. Hooper, owner; 5 miles north of Nobles.

Lanchester ranch—W. M. Richardson, Plantation House, owner; east of Fish Mill. Both yellow ocher and hematite occur; some of it is suitable for paint.

Fort Ross—a large body 6 miles east of Fort Ross.

Red and yellow ocher (hematite and limonite) mineral-paint pigments were produced here for several years, but none have been mined for a decade or more.

The deposit of the Healdsburg Paint Co., known and operated in the past under various names, is on Porter Creek 10 miles by road southwest of Healdsburg in T. 8 N., R. 10 W. The material is low-grade high-silica hematite.

The Meeker ocher deposit is an ocherous clay in sec. 21, T. 7 N., R. 10 W., 1½ miles north of Camp Meeker. This material has been shipped in the past but not in the last 10 or 15 years.

An undeveloped deposit of ocherous clay occurs just west of the hotel at Occidental, and a small deposit of soft red hematite at Mark West Springs has been utilized locally for paint.

Siskiyou County.—In secs. 19 and 20, T. 46 N., R. 10 W., on the north side of the Klamath River, a bed of breccia dips toward the river at about 45°. The cementing material is red-ocher clay, used formerly by the Indians as paint.

Stanislaus County.—Mineral-paint material, mainly yellow ocher, has been mined on a small scale near Knights Ferry for many years. Outcrops are exposed in many places on both sides of the river, but only three properties are ready to begin production.

The 34-acre tract of the California Ocher Mining Co., 665 Third Street, San Francisco, is part of the old Voyle holdings; C. H. Kaul is manager. This company has owned it for the past 35 years and produced a large quantity of ocher during that time, although operations have been intermittent, depending on demand. The deposit is in sec. 17, T. 1 S., R. 12 E., and is a soft yellow-ocher stratum 4 to 6 feet thick in the form of a very flat anticline. It is opened by a number of drifts. Mining is usually done by local parties under contract.

The Weidman ranch deposit, owned by Prowse & Williams of Knights Ferry, is on the south side of the river directly opposite Knights Ferry. The ocher stratum on this property is 4 to 6 feet thick. About 2 acres have been worked out. It has been idle for the past 6 years; meanwhile high water has filled the drifts and caved in most of the workings so that it will be necessary to run a new drift when the property is reopened.

The Voyle mine, owned by V. J. Winkler, Knights Ferry, Calif., is in sec. 29, T. 1 S., R. 12 E., M.D.M., on the north side of the Stanislaus River at Knights Ferry, 13 miles by paved highway east of Oakdale, the nearest railroad point. There are 60 acres in one tract, on which most of the mining has been done, and 18 in another, which is undeveloped. The present owner has been operating the property for the last 12 years. The deposit is a stratum of yellow ocher 5 to 8 feet thick, lying practically horizontal, with clay below. It is opened by drifts; pillars are left to support the roof. The material varies in hardness, being quite soft in places, but the workings are dry and it stands well. Auger drills are used in mining. Operations are intermittent, depending on demand.

Trinity County.—Red ocher occurs in sec. 15, T. 35 N., R. 8 W., on the east side of East Fork of Stuarts Fork, and in sec. 9, T. 35 N., R. 8 W.

Ventura County.—Soft red-shale beds about 60 feet thick are exposed on the north slopes of South Mountain and extend several hundred feet. The material is uniform brick red and pulverizes readily upon crushing, leaving little or no grit.

There was a small production from this deposit in 1923. The property has been in litigation.

Yuba County.—Development work was done several years ago on the Dempsey ranch in sec. 3, T. 15 N., R. 6. E. The weathered, rain-beaten red ocher still on the dump gives some indication of fair quality.

Yellow ocher is exposed in small outcrops in sec. 29, T. 20 N., R. 8 E., 1 mile west of Strawberry Valley.

MINERAL-PIGMENT COMPANIES

Two plants on San Francisco Bay use California materials to manufacture mineral pigments by blending clays and various iron oxides for the desired colors.

The plant of the C. K. Williams & Co. of California, Emeryville, Calif., was built in 1928. Verne Frazee is the general manager. The company manufactures color pigments and fillers by a patented chemical process. The material is run through tube mills, buhrstones, and pulverizers, is chemically processed, and is roasted in rotary kilns. The various colors range in iron content from 5 to 95 percent of Fe_2O_3. These products are in 15 different shades of reds, yellows, browns, greens, and black and are marketed for stucco, cement, and mortar colors, specification pigments, and fillers.

The Synthetic Iron Color Co. is at Richmond, Contra Costa County, Calif. N. M. Zoph is the manager. This plant was built in 1924 and has operated continuously. The capacity of the plant is 3 tons daily. The material is run through grinding and pulverizing mills to wooden tanks, which are air and steam agitated, and to driers. The product is in a variety of colors, which are used for color paints, calcimine, and stucco pigments.

IRON ORES OF CALIFORNIA

The occurrence of iron ores in California has been summarized by Schrader, Stone, and Sanford [14] as follows:

Brown iron ore (limonite, brown hematite).—Is present in every county. Alameda County, mixed with hematite is common as a gossan capping of the pyrite deposit at Beona Heights. Amador County, in concretions and earthy masses at Pine Grove, with hematite and magnetite at Volcano. Butte County, large blocks at Burns Creek; thick masses at the Monarch mine; cubes at Red Hill and Magalia. Calaveras County, common in mines southeast of Campo Seco, near Valley Springs, Esmeralda, and Murphy; massive and yellow ocher at the Eureka mines, near Valley Springs; the Detert deposit near Valley Springs was formerly worked. Inyo County, pseudomorphs after long prisms of stibnite from the Cerro Gordo mine. Mariposa County, fine large cubes have come from the Chowchilla Valley. Placer County has been mined with magnetite; at Hotaling, iron-ore deposits 6 miles north of Auburn; occurs at Gold Run. Plumas County, massive in Lights Canyon and at Nelson Point. Riverside County, Eagle Mountain and near Dale. San Bernardino County, prospects in Cave Canyon area north of Scott station. San Luis Obispo County, occurs in secs. 1 and 6, T. 31 S., Rs. 10 and 11 E.; brown banded masses have come from the Perfumo ranch. This deposit lies in the Los Osos Mountains interbedded with shales and sandstones of the Franciscan formation, and in Jurassic shale and limestone in Perfumo Canyon about 5 miles south of west from San Luis Obispo. Shasta County, with magnetite in numerous prospects, common as cappings of the pyrite deposits of the county; at Gossan, Iron Mountain, near Keswick; mined as iron flux for Bully Hill smelter; pseudomorphs after hedenbergite at Ydalpan; highly iridescent specimens have come from Copper City; excellent bronze stalactites occur at the Lost Confidence mine, Iron Mountain. Sonoma County, yellow ocher at the Occidental mine. Siskiyou County, occurs in sec. 10, T. 46 N., R. 10 W. Tulare County, common in Mineral King district. Yolo County, in the sands at Capay. * * *.

Hematite (red iron ore).—Large deposits await development. Alameda County, massive red earthy, mixed with limonite, forms the capping of the pyrite body at Leona Heights. Alpine County, common at Monitor. Amador County, large deposit in Ione formation, 2 miles west of Ione, also in Calaveras formation. Butte County, common in the gravels at Magalia, Butte Creek, Oroville, and Stirling City. Calaveras County, at Douglas Flat, Murphy, Wallace, and Quail Hill. Del Norte County, at Kelsey tunnel, 14 miles southeast of Crescent City. Eldorado County, Pioneer mine; heavy masses at Shingle Springs, in the gravel at Diamond Springs, Green Valley, Virner and other places. Humboldt County, large vein 3 miles south of Centerville. Inyo County, massive specular, at the Defiance mine, occurs also in Owens Valley. Kern County, at Kane Springs and Ricardo. Lake County, massive, near Red Glenrock, in Cobb Valley. Madero County, Minarets; one of the largest deposits of magnetite-hematite occurs here; much of this ore is martite. Marin County, massive specimens at Maillard ranch, about 2 miles southwest of San Geronimo. Mono County, common in the Blind Springs district. Napa County, massive red near St. Helena, massive, at White Sulphur Springs and Placerville. Nevada County, with gold at Meadow Lake; minor deposits at Indian Springs and at Newton. Orange County at Fullerton. Placer County, with magnetite at the Hotaling deposit about 6 miles north of Auburn, small amounts at Clippergap, Red Hill, and near Weimar. Plumas County, with magnetite near Crescent Mills, at Mumfords Hill, Lights Canyon, Genesee Valley, and Nelson Point. Riverside County, Eagle Mountain, derived from the extensive deposit of magnetite. San Bernardino County, near Kane Springs, Cima, Silver Lake, and Leastalk; at Dale, on Iron Mountain in the Kingston Range, Newberry on Providence Mountain, and in prospects in Cave Canyon area, north of Scott Station, and elsewhere in the county are deposits of massive hematite after magnetite or martite. Shasta County, abundant; the Ready or Pit River deposit has been utilized at the electric smelting furnace at Heroult; the cappings of the pyrite beds of this county are thick deposits of earthy hematite and limonite. Sierra County, found in small quantity. Siskiyou County, in the gravels of Shasta River. Sonoma County, large deposit at Noble's ranch, near Fort Ross, and near west fork of Gualala River. Stanislaus County, foliated near La

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[14] Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful Minerals of the United States: U.S. Geol. Survey Bull. 624, 1917, pp. 45–46, 60.

Grange. Tehama County, at Beegum. Trinity County, in the sands at Trinity Center. Yuba County, in the sands of the Brownsville district. (See fig. 14.)

Various publications contain other references to California iron ores.[15]

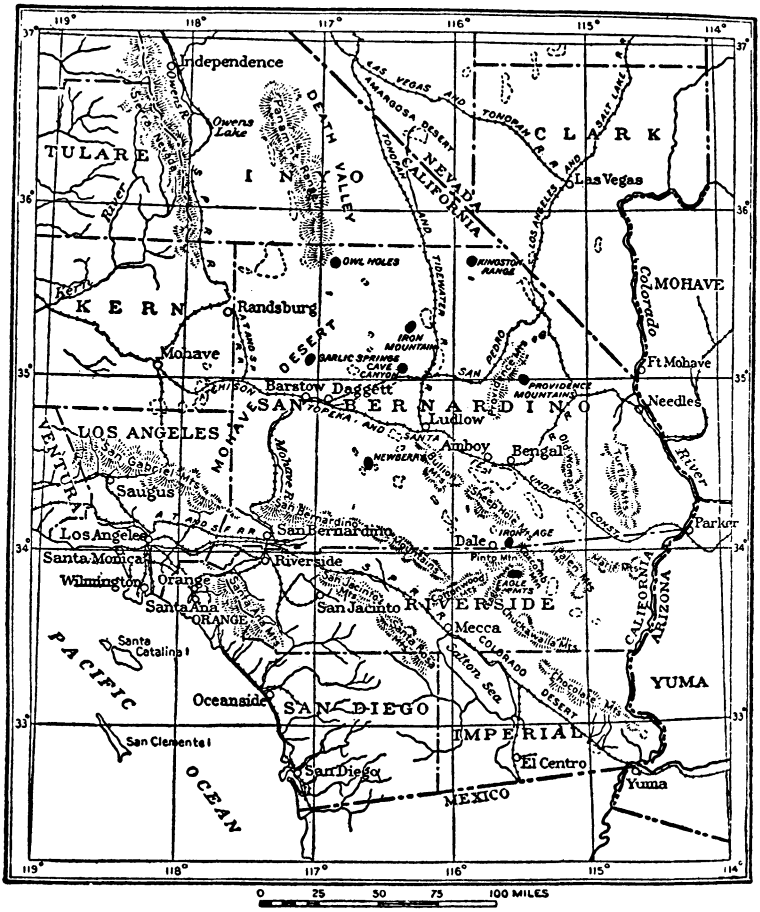

FIGURE 14.—Map of southern California iron districts, according to Harder (Ries).

TESTS OF CALIFORNIA PIGMENTS BY THE UNITED STATES BUREAU OF MINES

CALIFORNIA NO. 1

California no. 1 was a yellow ocher sample from the property of W. Barney, box 379, Elk Grove, Calif., near Indian Diggings, Eldorado County. Only about a 1-foot seam has been uncovered, which would

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[15] Aubury, L. E., Iron Ores of California: California State Min. Bur. Bull. 38, 1906, pp. 297-305.
Diller, J. S., Iron Ores of the Redding Quadrangle, Calif.: U.S. Geol. Survey Bull. 213, 1903, pp. 219-220.
Harder, E. C., and Rich, J. L., Iron-Ore Deposit near Dale, San Bernardino Co.: U.S. Geol. Survey Bull. 430, 1910, pp. 228-239.
Prescott, B., Iron Ores of Shasta County: Econ. Geol., vol. 3, 1908, pp. 465-480.
Daniels, Joseph, Iron and Steel Manufacture in Washington, Oregon, California, and Utah: Univ. of Washington Eng. Exp. Sta., Rept. No. 2, 1929, pp. 44-55.
Harder, E. C., Iron-Ore Deposits of the Eagle Mountains, Calif.: U.S. Geol. Survey Bull. 503, 1912, 81 pp.
California State Mineralogist Repts. 2, 4, 5, 10, 12-15 (incl.), 17, 18, 21-25; California State Mining Bureau Bulls. 38, 67, 91.
Mining and Scientific Press: Vol. 115, pp. 112, 117-122; vol. 123, pp. 94-96, 113-114.

have to be mined by underground methods. According to the Sacramento Chamber of Commerce, the material was examined by a California paint company and pronounced unfit for use as paint pigment.

Laboratory tests.—The small sample received consisted of soft chunks of yellow ocher 3 inches in diameter to dust, which dispersed easily in water; after the fines were floated off a residue of 36.5 percent of fine yellow sand was left. The material probably could be ground without much color loss. The fine material on drying gave a soft mass with moderate shrinkage. Twenty-three drops per gram or 0.53 part by weight of linseed oil produced a good-working, fine-grained paste for the glass slide. The original color with oil was gold-brown (60113) and when diluted to 10 percent with zinc oxide was near sunset (60088). The purified sample contained 4.5 percent of ferric oxide. The material was grouped with class 2, orange-yellow, ochers, slightly grayed. The full-strength hue varied from the standard toward red-brown. The let-down tint was a good medium-strength cream (60003). The test indicated commercial value, but underground mining costs of a 12-inch seam would be excessive.

CALIFORNIA NOS. 2, 3, AND 4

California nos. 2, 3, and 4 were red pigment samples from the property of W. Barney near Michigan Bar, Sacramento County. The deposit from which these samples were taken is reported to be 8 inches to 4 or 5 feet thick and covers a wide area with no overburden. The nearest railroad is 17 miles. Barney estimates the cost of mining the material by steam shovel at about 50 cents and f.o.b. railway cars at about $1 per ton. The relative location of the three samples was not given.

Laboratory tests.—No. 2 was soft and claylike. Washing removed 39.7 percent of red and black sand. This sample could probably be ground without much color loss. It required 19 drops or 0.44 part by weight of linseed oil to make a paste. The undiluted color in oil was near mahogany (60136), and the diluted color with zinc oxide was grayer than blossom (60171). The purified sample contained 6.3 percent of ferric oxide; although classed with class 1, old rose, mineral browns, it was too weak for ordinary commercial uses except cheaper mortars or stuccoes.

No. 3, an iron-stained red sandstone, was ground in the pebble mill in water and dried; 16 drops of oil per gram or 0.37 part by weight was needed to make a paste of a color close to henna (60135). When diluted with zinc oxide it was more cream (60003) than blossom (60171). The iron oxide content was only 8.2 percent, and the tinting strength was too weak for commercial paint purposes. This material was grouped with class 2, salmon, burnt siennas.

No. 4 was a banded mass of soft clay showing both red and blue-gray. Thirty-eight percent of sand was removed in washing; 0.53 part by weight of oil was used to make a paste. The colors produced alone and with zinc oxide were very close to those of sample no. 2. The pigment would have the same disadvantage as no. 2 in the market because of weak tinting strength. The iron oxide content was only 5.9 percent. Although this material was grouped with class 1, old rose, mineral browns, its tinting strength was weak for commercial purposes.

CALIFORNIA NO. 6

Sample no. 6 and data regarding it were furnished by B. W. Peterson, box 67, Camp Meeker, Calif. Samples nos. 6 and 7 were taken from Mrs. Peterson's ranch in Round Valley, Mendocino County. The deposit is close to the Eel River, 18 miles from the nearest railroad at Dos Rios, but connected by a good highway.

Laboratory tests.—Forty percent of red and gray sand was washed from the highly plastic and colloidal mass, which had high shrinkage on drying. Seventeen drops or 0.39 part by weight of linseed oil made a paste which gave henna (60135) undiluted and grayed blossom (60171) in a 10 percent mixture with zinc oxide. The purified sample contained 4.3 percent of ferric oxide. This material was grouped with class 1, red-brown, burnt ochers, but because of the weak tinting strength and low iron oxide content cannot be recommended for general commercial uses.

CALIFORNIA NO. 7

Sample no. 7 was from the same deposit as no. 6.

Laboratory tests.—Washing removed 46.4 percent of red-brown and lighter-colored sand from this sample. Sixteen drops or 0.37 part by weight of linseed oil made a tobacco (60143) paste. When diluted with zinc oxide the color was between blossom (60171) and chamois (60179). The ferric oxide content was 7.8 percent. Unless nos. 6 and 7 could be prepared separately their value is doubtful because continued uniformity of hue is very important. This material was grouped with class 1, red-brown, burnt ochers. The light neutral brown diluted to pink-gray, with such weak tinting strength that its commercial value is very doubtful.

CALIFORNIA NO. 9

California no. 9 (Steele sample no. 3) came from the NW¼SE¼ sec. 11, T. 15 N., R. 9 W., 6 miles from Colfax on an unimproved country road. Steele called it "float" above California no. 10 sample, and stated that the deposit lies on both sides of a small stream valley in a seam about 7 feet thick with 1 foot of overburden. The sample apparently represents a very large tonnage of easily mined material.

Laboratory tests.—Sample no. 9 was a soft claylike material that dispersed readily in water. Washing removed 41.2 percent of coarse light-colored sand. Fifteen drops per gram or 0.35 part by weight of linseed oil produced a gold-brown (60113) paste. When diluted with nine parts of zinc oxide the color was near chamois (60179). This material was grouped with class 2, orange-yellow, ochers, slightly grayed. The full-strength hue ranged from the standard toward red-brown, and the let-down color had only weak strength with cream tint, probably too weak to compete with present commercial ochers on a general market

CALIFORNIA NO. 10

California no. 10 (Steele no. 11) came from a seam at least 42 feet wide and about 40 feet above the road, at the same location as California no. 9. The colored-clay material apparently occurs on both sides of the road. The sample was taken from a prospect crosscut of this 40-foot seam.

Laboratory tests.—This sample was very plastic and dispersed in water with great difficulty. Numerous rewashings left 51.8 percent of residue, which was not entirely clean. A second sample was completely ground in the pebble mill. The dried fines from the washing test were mixed with 21 drops per gram or 0.49 part by weight of linseed oil to make a reddish gold-brown (60113) paste. When diluted with zinc oxide (1:9) the color was pinkish tan (60089). The sample contained 24.3 percent of ferric oxide and 0.18 percent of ferrous oxide. This material was grouped with the class 2, orange-yellow, ochers, slightly grayed. The full-strength, light red-brown diluted to a strong pink-tan, different from the usual commercial ochers. Its color strength and excellent hue should give it commercial value if economic conditions are satisfactory.

CALIFORNIA NO. 11

California no. 11 (Steele no. 11) was taken from the same extended crosscut as California no. 10 near the 42-foot mark. The location of this sample is given under California no. 9. This material represents that at a depth of 1 foot.

Laboratory tests.—After a difficult blunging and washing in water a light-red clay was removed from 33.8 percent of red-brown sand. The fines dried to a very hard mass with high shrinkage, indicating highly colloidal structure and plasticity. The powdered material was mixed with 18 drops per gram or 0.42 part by weight of linseed oil to make a henna (60135) paste. When diluted with nine parts of zinc oxide the color changed to peach (60157). This material was grouped with class 1, red-brown, burnt ochers. The light red-brown, full-strength color diluted to weak pink-gray and therefore could have only local value.

CALIFORNIA NO. 12

California no. 12 was taken from the same extension crosscut as California no. 11. The location is given under California no. 9. This sample represents the material at 3-foot depth and is very similar to no. 11.

Laboratory tests.—The working properties were like those of no. 11. Washing removed 27 percent of red-brown sand, which is of such color that it probably could be ground with the clay portion without injuring its value as pigment. The powdered fines were mixed with 19 drops of linseed oil to make a henna (60135) paste. When diluted with nine parts of zinc oxide the color changed to peach (60157). This material was listed with class 1, red-brown, burnt ochers. The full-strength color—bright red-brown—diluted to faint pink-gray, indicating weak tinting strength and only local value, if any.

CALIFORNIA NO. 13

California nos. 13 and 14 were small 20-gram samples sent by C. A. Peddycord, 708 Columbia Street, Seattle, Wash. The deposit is in NW¼ sec. 28, T. 6 N., R. 1 E., Humboldt County, Calif., ¼ mile from a railroad and 1½ miles from tidewater, with a wagon road to the prospect. Peddycord reports the material as covering 135 acres, with an overburden from a thin layer to 100 feet thick. The town site of Arcadia joins this property.

Laboratory tests.—Although the sample had been ground it contained grit. Washing removed 33.4 percent of yellow-brown sand. The fines were mixed with 26 drops per gram or 0.60 part by weight of linseed oil to make a terrapin (60091) paste, which when diluted with zinc oxide changed to light sunset (60088). Before the sample was washed the ferric oxide content was 10 percent; after washing the iron oxide rose to 24 percent. This material was grouped with class 2, orange-yellow, ochers, slightly grayed. The full-strength hue varied from the standard toward red-brown. The let-down color had medium strength and varied from the standard toward pink. If economic conditions are satisfactory, this pigment should have commercial value.

CALIFORNIA NO. 14

Peddycord also submitted California no. 14 (Peddycord no. 2).

Laboratory tests.—Washing removed 21.8 percent of dark-brown sand from this sample. The pulverized fines were mixed with 18 drops per gram or 0.42 part by weight of linseed oil to produce a brown (60114) paste. When diluted with zinc oxide the color changed to between bisque (60122) and monkey skin (60123). Before washing the ferric oxide content was 21.8 percent; after washing it rose to 47.4 percent. This material was classed with class 2, violet, mineral browns. Although the tinting strength was weak the hue was close to commercial standards, and further investigation may indicate better methods of preparation for improving the strength. The sample received was too small for exhaustive tests.

CALIFORNIA NO. 17

Sample no. 17 was received from J. M. McKnight, box 621, Scotia, Calif., one of the owners of the deposit, which probably covers about 500 acres and is approximately 2 miles from a State highway and 30 miles from Longvale, Humboldt County. It is about 10 feet deep, with no overburden. McKnight estimates the cost of mining and delivery to railroad cars at $5 per ton.

Laboratory tests.—The small sample received was deep red-brown clay containing hard, dark, iron-ore particles and some ½-inch yellow chunks. Washing removed 40.5 percent of dark-brown sand containing a small quantity of yellow and black particles. The remainder showed high shrinkage, but pulverized easily and when mixed with 16 drops per gram or 0.37 part by weight of linseed oil produced a mahogany (60136) paste. When diluted with nine parts of zinc oxide the color changed to between monkey skin (60123) and Grecian rose (60175). The ferric oxide content was 83.8 percent. This material was grouped with class 1, old rose, mineral browns. The dilution test changed the dark red-brown color to a violet tint plus old rose and indicated strong tinting strength worth further investigation for commercial uses.

COLORADO

Ocherous shales have been reported by the Colorado Geological Survey, but no ocher samples were received.

The occurrence of iron ore in Colorado has been summarized by Schrader, Stone, and Sanford [16] as follows:

> **Brown iron ore (limonite, brown hematite).**—Mined for flux, also for silver. Fremont County, Sedalia mine. Gunnison County, occurs in irregular masses along Tomichi Creek, Whitepine district. Hinsdale County, occurs near Lake City. Lake County, mined in silver-lead mines at Leadville; mostly manganiferous. Pitkin County, common in Aspen district mines. Saguache County, large body interbedded with limestone at Orient; was extensively worked; still producing few thousand tons annually. Summit County, has been mined for flux. Occurs in thousands of vein cappings. * * *.
>
> **Hematite (red iron ore).**—Gunnison County, prospects near Whitepine and north of Iola station. Lake County, has been mined at Breece iron mine, Breece Hill, near Leadville; very pure ore; large irregular deposits in porphyry. Pitkin County, very common in mines of Aspen district. Occurs at many other places in State.

The literature contains many references to Colorado iron ores.[17]

COLORADO NO. 1

Colorado no. 1 was a sample of biotite rock from F. H. Kansgen, 711 South Fourth Street, Montrose, Colo. The deposit is near Gunnison about 500 feet from a railroad and occurs as a 20-foot dike in granite. According to Kansgen, it is exposed for about 3,000 feet.

Laboratory tests.—The sample was pulverized and when mixed with 20 drops or 0.46 part by weight of linseed oil gave a paste between castor (60115) and reseda (60066). When diluted with nine parts of zinc oxide the color changed to light blue no. 2 (60017). The iron content calculated as ferric oxide was 11.4 percent. This material was classed with the umbers, although the tinting strength is too weak for commercial service. A green modifying hue shown in both the concentrated and let-down samples may indicate ferrous silicate. The dilution test might be used as a qualitative test for ferrous iron in such minerals.

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[16] Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful Minerals of the United States: U.S. Geol. Survey Bull. 624, 1917, pp. 82, 83, 89.

[17] Chauvenet, R., Preliminary Notes on the Iron Resources of Colorado: Colorado Sch. Mines Rept. for 1886, 1888, pp. 5–16.

Chauvenet, R., The Iron Resources of Colorado: Trans. Am. Inst. Min. Eng., vol. 18, 1890, pp. 266–273.

Devereux, W. B., Notes on Iron-Ore Deposits in Pitkin County, Colo.: Trans. Am. Inst. Min. Eng., vol. 12, 1885, pp. 638–640.

Endlich, F. M., Iron Carbonate of the Trinidad Region: Hayden Survey Rept. for 1875, 1877, pp. 204–205.

Harder, E. C., The Taylor Peak and White Pine Iron-Ore Deposits: U.S. Geol. Survey Bull. 380, 1909, pp. 188–198.

Leith, C. K., Iron Ores of Colo.: U.S. Geol. Survey Bull. 285, 1906, pp. 196–198.

Rolker, C. M., Notes on Certain Iron-Ore Deposits in Colo.: Trans. Am. Inst. Min. Eng., vol. 14, 1886, pp. 266–273.

Snedaker, J. A., Colorado Iron-Ore Deposits: Eng. and Min. Jour., Feb. 16, 1905, p. 313.

CONNECTICUT

The occurrence of iron ores in Connecticut has been summarized by Schrader, Stone, and Sanford [18] as follows:

> **Brown iron ore (bog iron ore, limonite).**—Litchfield County, mined at Davis at Orehill mines, near Lakeville; large deposits at Sharon and Salisbury have been mined. New London County, occurs at Colchester. Tolland County, bog iron mined and smelted in Stafford and Hebron Townships. Windham County, at Woodstock.

No ocher samples were submitted.

DELAWARE

The occurrence of brown iron ores in Delaware has been summarized by Schrader, Stone, and Sanford [19] as follows:

> **Brown iron ore (brown hematite, bog iron, limonite).**—Kent County, at East Dover. New Castle County, Iron Hill and Chestnut Hill near Newark, has been mined. Sussex County, Little Creek, 2 miles south of Laurel; near Georgetown; Collin's ore bed on Green Meadow Branch of Deep Creek; Green Branch, 10 miles west of Millsboro; Burton's Branch, 1 mile west of Burton. * * *.
>
> **Ocher.**—Sussex County, with limonite.

No pigment samples were submitted.

FLORIDA

The Florida State Geological Survey made a brief survey for pigment materials and concluded that no ocher deposits of commercial value are to be found in the State. A few years ago a small quantity of ocher was shipped from Flagler County, east Florida, but a recent examination by the geological survey showed that this was only a small deposit containing too much sand and other debris to have commercial value. A second deposit in Levy County, largely bog-iron ore with some ocher, was a source of iron for cannon balls during the Civil War. The deposit apparently did not warrant working for ocher alone, although it might be handled as a by-product of iron ore. No samples were received from either deposit.

The occurrence of iron ore in Florida has been summarized by Schrader, Stone, and Sanford [20] as follows:

> **Limonite (bog-iron ore).**—Duval County, found around Beauclerc. Volusia County, 12 miles east of Seville, and at several points on the Florida East Coast Railway. * * *
>
> **Mineral paint.**—Lee County, Estero Bay; not developed.

FLORIDA NO. 1

K. T. Felder, P.O. box 153, Atlanta, Ga., submitted a sample of red pigment from his property near Tampa. He reports that the material apparently covers about 75 acres, ranges from 6 inches to 5 feet in thickness, can be mined cheaply, and is accessible to either rail or water shipping.

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[18] Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful Minerals of the United States: U.S. Geol. Survey Bull. 624, 1917, p. 97.

[19] Work cited, p. 102.

[20] Work cited, pp. 105, 106.

Laboratory tests.—The sample as received was a red-brown clay containing hard, brittle particles, 2-mesh size and finer. Some of the larger particles are black inside, and others are yellow-brown. The sample contained a large quantity of root fibers and vegetable matter. A yellow-brown sample could probably be obtained by taking the oversize on a 10-mesh screen, but in these tests an average was ground in a pebble mill. This dried to a hard mass and required 14 drops per gram or 8.1 parts by weight of linseed oil to make the standard paste for the glass slide. This was brown (60114) plus a little mahogany (60136). When diluted with zinc oxide (1:9) the color was a mixture of old rose (60172) and silver (60050). The sample contained 19 percent of ferric oxide. The tinting strength as a class 2, red-brown, burnt ocher, was medium. Although the pigment differed in hue from commercial burnt-sienna samples, which also differ among themselves, it may have commercial value.

GEORGIA [21]

CARTERSVILLE DISTRICT, BARTOW COUNTY

The Cartersville ocher district (fig. 17) is limited to southeastern Bartow County, northwestern Georgia, about 50 miles northwest of Atlanta. It derives its name from Cartersville, the county seat. This district produces about 13,000 long tons of ocher annually, the largest amount in the United States.

EARLY HISTORY

The first authentic record of ocher mined in Bartow County dates back to 1877, when E. H. Woodward began mining it near the city limits of Cartersville. The crude ocher was hauled in wagons to Cartersville and prepared for the market.

After several small-scale local developments the Georgia Peruvian Ochre Co. started operations in 1890 and introduced improved methods of preparation. The first shipment of American ocher to Europe—a consignment of 50 tons to England—is reported to have been made in 1890. A number of companies—including the Standard Peruvian Ochre Co., the Cherokee Ochre & Barytes Co., the Blue Ridge Ochre Co., and the American Ochre Co.—operated between 1893 and 1903 but have since stopped, leaving only the Georgia Peruvian Ochre Co., the New Riverside Ochre Co., and the Cherokee Ochre Co.

GEOLOGY

The district lies between the Paleozoic formations on the west and the older crystalline and metamorphic rocks of the Piedmont Plateau and Appalachian Mountains on the east. These formations are separated by the Cartersville overthrust fault, the most important structural feature of the region. West of the fault the rocks are sedimentaries and include quartzites, sandstones, shales, and limestones of Cambro-Silurian age. No igneous rocks are known to occur in this area. East of the fault line the rocks are metamorphic crystallines derived in part from original igneous masses and in part from original sediments. The altered sediments include conglomerates, slates, schists, and probably some gneisses. The intrusive rocks range from the extremely basic types of diabase to acid granites, with perhaps diorite as the most common type. The sedimentary rocks have been regarded as Algonkian (Ocoee) in age. In the Paleozoic formations

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[21] The introduction is an abstract from Watson, T. L., A Preliminary Report on the Ocher Deposits of Georgia: Geol. Survey of Georgia Bull. 13, 1906, 81 pp.

on the west side of the fault the rock sequence is (see figs. 15 and 16, *A*):

Silurian	4. Knox dolomite.
Cambrian	3. Rome and Conasauga shale. 2. Beaver limestone. 1. Weisner quartzite.

The yellow-ocher deposits are limited to the Weisner quartzite; this formation is therefore the most important in the district. The principal area of the quartzite forms a narrow, continuous belt approximately 15 miles long and several miles wide. Its eastern limit is the Cartersville fault. The quartzite formation will average not less than 2,000 feet in thickness. It is not entirely uniform and homogeneous; in places it varies widely in composition, texture, and color. The formation is composed principally of heavy, fine-grained, vitreous quartzite ranging in color from light to dark gray; in places it contains beds of fine conglomerate. Numerous intercalated drab to darker beds of siliceous shales of varying thickness, much crumpled, contorted, and altered in places, characterize this formation. The quartzite is highly impregnated in places with large and small pyrite crystals. This mineral is equally abundant in both the quartzose and shaly portions of the formation. The two mineralogically unlike beds—shale and quartzite—are likewise ocher bearing and because of the

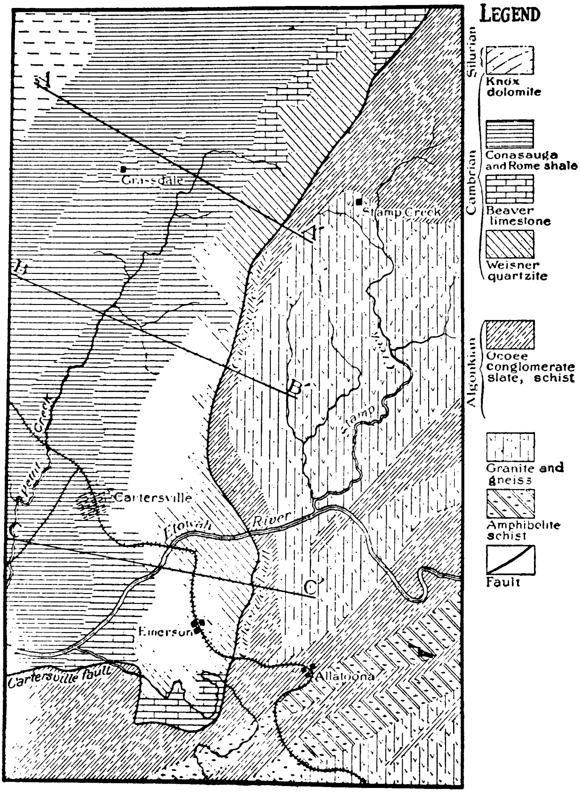

FIGURE 15.—Geological map of Cartersville district, Bartow County, Ga., according to Hayes (Watson).

difference in composition of the rock permit the production of two grades of ocher. The ocher occurring as a replacement of the shaly beds is prevailingly dark because of the large proportion of admixed clay derived from the shales which cannot be separated from the refined product, whereas the ocher replacing the quartzite proper is of uniformly light color because of less admixed clay. (See fig. 16, *B*.)

The effect of intense pressure metamorphism is evident in all parts of the quartzite formation. Compression forces have thrown the beds into numerous irregular folds; in addition, the greater part of the formation has been greatly crushed and brecciated, especially in ocher-bearing portions. So extensively crushed and shattered is the quartzite in certain larger ocher openings in the district that it is almost impossible to determine the original bedding. The resulting structural conditions of the quartzite have probably been particularly favorable to certain chemical and physical action relative to mineral formation. The chemical composition of the quartzite follows:

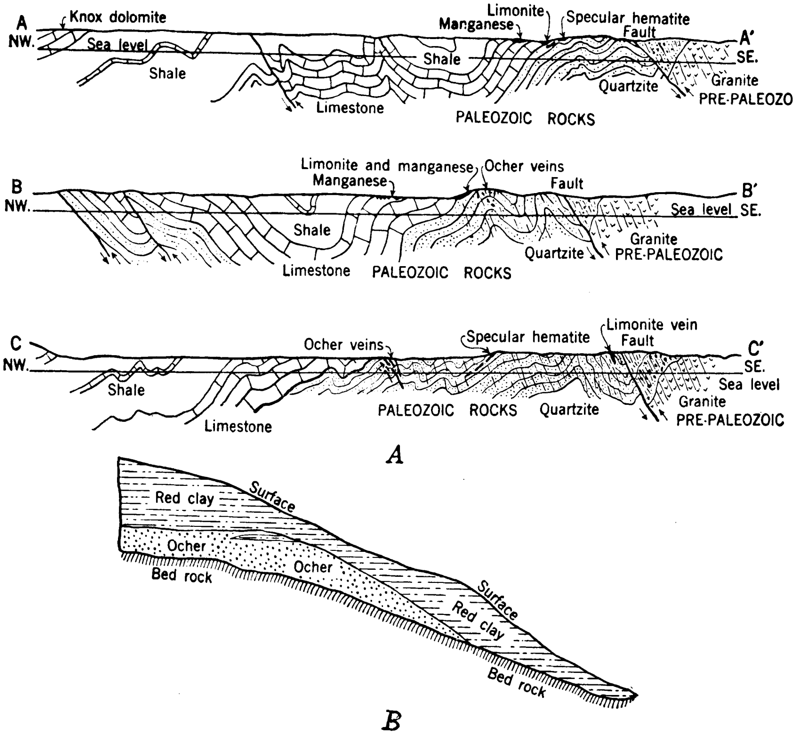

FIGURE 16.—*A*, Geological sections to accompany figure 15. *B*, section showing relation of ocher, quartzite, and clay near Cartersville, Ga., according to Watson (Ries).

Composition of quartzite

	Percent		*Percent*
SiO_2	90. 36	Alkalies	0. 59
Al_2O_3	1. 52	TiO_2	. 07
Fe_2O_3	. 57	$BaSO_4$	4. 46
FeS_2	1. 50	Water above 100° C	. 31
CaO	. 27		
MgO	. 27		99. 92

Attention is called to the absence of manganese dioxide and to the percentages of iron sulphide and barium sulphate in the rock. Barite occurs in all ocher deposits of the district.

Just above the Weisner quartzite lie 800 to 1,200 feet of gray, crystalline, magnesium limestone, which is shaly in places and contains occasional masses of chert. In the Cartersville district the limestone extends as a narrow belt of lowland along the western margin of the Weisner quartzite. The fresh limestone is seldom exposed, and the surface is covered by a deep mantle of residual red clay derived from the decay of the limestone. The limestone yields quite readily to atmospheric agencies producing decay, and its insoluble oxidized portions remain as a residual clay covering on the underlying surface of the fresh limestone. The Weisner quartzite and the Beaver limestone are the most important ore-producing formations in the Cartersville district. None of the ocher deposits are associated with the limestone, but are limited to the quartzite.

ROCK WEATHERING

The region bears evidence of having been continuously above sea level for a long time geologically; accordingly the rocks have been subjected for an equal period to the active agencies of rock decay. Formation and accumulation of residual decay have exceeded removal; hence the underlying rock surfaces over all parts of the area are usually covered with a thick mantle of residual decay composed of the insoluble parts of the rocks from which it was derived. Difference in hardness has resulted in a like difference in the readiness with which the terranes have yielded or resisted subaerial decay; the residual mantle is therefore correspondingly thick or thin. It is thickest over the areas of limestone and thinnest over the areas of quartzite and shale. The decayed product of the limestone is usually deep-red ferruginous clay. That derived from the harder, more resistant quartzite is light-gray siliceous clay in which the proportion of clay is relatively smaller than that derived from the limestone. The decay covering is more than 100 feet thick in many places in the district.

ORE DEPOSITS

In addition to ocher the district produces manganese, barite, and some iron ore. The ores are frequently associated with each other, although their genesis may be quite different. In many instances manganese oxide in very finely disseminated grains or powder is not entirely freed from the refined product, and it is claimed that a faint greenish cast is thereby imparted to the ocher. Large quantities of hard, porous, spongy masses of limonite occurring as thin lenses and irregular seams in the ocher beds have been mined with the ocher.

GEOGRAPHIC DISTRIBUTION OF OCHER DEPOSITS

The ocher belt extends about 8 miles nearly north-south and does not exceed 2 miles at its widest point. It begins west of Emerson about 2 miles south of the Etowah River (see fig. 17) and is easily traced northward about 1 mile east of Cartersville to a point northwest of Rowland Springs. Prospecting may reveal a northern extension of the belt. Exposures of the fresh Weisner quartzite indicate that the ocher occupies an extensively shattered zone. It is found in place in the hard, freshly shattered quartzite and in the residual clays derived from decay of the quartzite. Examples of both occurrences abound in the region. The theory that most satisfactorily explains the formation of these deposits would probably indicate that ocher occurs at considerable depths below the surface and might or might not prove workable. The lowest workings are near the water level of the river; no data have been found to indicate the ultimate depth.

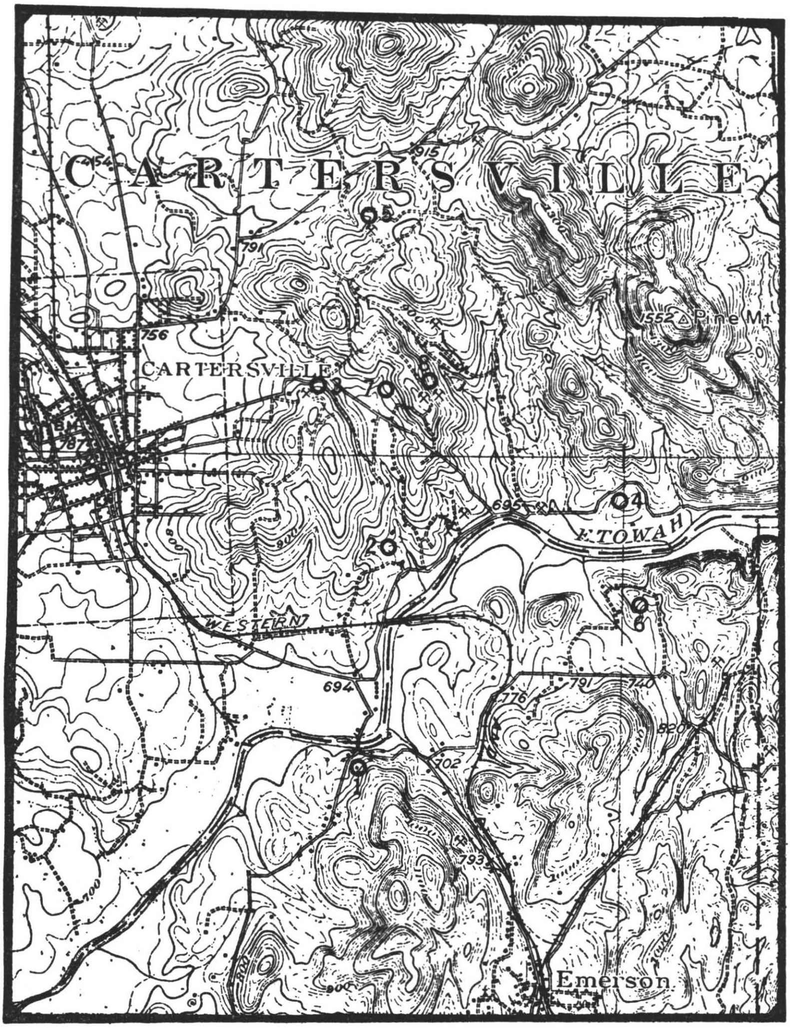

FIGURE 17.—Cartersville (Ga.) mining district, according to the United States Geological Survey and the Geological Survey of Georgia: *1*, Georgia Peruvian Ochre Co.; *2*, New Riverside Ochre Co.; *3*, Cherokee Ochre Co.; *4*, J. M. Knight Estate; *5*, Cartersville Ochre Co.; *6*, Cartersville Ochre Co.; *7*, J. R. Dellinger property; *8*, Etowah Development Co.

CHEMICAL COMPOSITION OF OCHER

TABLE 72.—*Chemical analyses of Cartersville (Ga.) ochers from various sources*

	Percent							
Fe_2O_3	[1] 72.29	[2] 56.29	[3] 65.49	[3] 54.60	[3] 67.37	[3] 61.40	[4] 67.32	[5] 62.79
Al_2O_3	5.55	10.15	7.20	6.68	6.85	7.14	5.86	6.94
FeO	.46	.39	--------	--------	--------	--------	--------	--------
MnO_2	.87	.54	1.80	1.50	2.04	2.00	--------	--------
SiO_2 free	6.65	8.94	7.76	17.42	6.54	11.89	9.14	6.20
SiO_2 combined	3.98	9.49	6.85	10.08	6.61	5.84	6.35	9.78
H_2O at 105° C	.55	2.08	.40	.48	.96	.46	.78	.50
H_2O above 105° C	9.22	11.34	10.50	9.24	9.63	9.37	9.60	--------
Total	99.57	99.22	100.00	100.00	100.00	98.10	99.05	86.21

[1] Crude ocher from Mansfield Bros. property, lot 462, 4th dist., 3d sec., Bartow County. Collected by Thomas L. Watson. Analyzed by N. P. Pratt laboratory.

[2] Crude ocher from property of John P. Stegall, near Emerson. Collected by Thomas L. Watson. Analyzed by N. P. Pratt laboratory.

[3] Analyses of old Blue Ridge Ochre Co. refined ocher. Lot 490, 4th dist., 3d sec., Bartow County. Analysis furnished by company.

[4] Refined ocher from the Cherokee Ochre & Barytes Co., 1 mile east of Cartersville. Analysis furnished by company.

[5] Refined ocher from the old American Ochre Co. Lots 475, 476, and 534, 4th dist., 3d sec., Bartow County. Analysis furnished by company.

If the several ingredients shown in analysis 2 of table 72 are proportioned and limonite is calculated as $2Fe_2O_3.3H_2O$, the probable mineral combination, in percent, will be as follows:

Limonite	65.79
Clay	25.27
Quartz	8.94
	100.00

SURFACE INDICATIONS OF OCHER

Over portions of the region where residual decay is most complete and the mantle is thickest the ocher shows at the surface little if at all. Here the presence of the ocher is indicated only by natural or artificial cuts and openings. Over much of the district, however, fragments and large masses of quartzite, rather highly impregnated with ocher and colored a distinct yellow, have been broken and dislodged from the ledges and reefs of the outcropping ocher-bearing quartzite and scattered over the surface. These masses of ocher-charged quartzite, locally known as "ocher bloom", furnish trustworthy evidence in tracing the ocher. Barite likewise offers another method of tracing the ocher. Wherever prospecting has been done in the localities containing barite rather extensive deposits of ocher have been revealed.

GENESIS OF OCHER DEPOSITS

The occurrence of ocher in the Cartersville district indicates that it has been formed by molecular replacement of the original quartzite. As a result of weathering the ocher bodies are enclosed in many places by residual clays derived from decay of the original rock. They thus appear to be residual deposits but are not, as the following discussion indicates.

Microscopic study shows the relations of the ocher to the Weisner quartzite and its mode of occurrence.

Doctor Hayes[22] states:

> When the transition rock is examined under a microscope the character of the transition can be seen even more clearly. The more compact portions, which are only slightly stained with iron, are seen to be composed of a transparent ground mass threaded with minute cavities, which penetrate the rock in all directions and contain a fine dendritic growth of iron oxide. The latter occurs only rarely in isolated grains, but generally in clusters of minute grains or fibers, attached to each other and branching irregularly from a central stem. They have no trace of crystal form. Passing toward the ore body, these minute passages become larger and increase in frequency, until only a finely branching siliceous skeleton remains, the greater part of the rock having been replaced by the iron oxide. Under polarized light, the transparent ground mass is broken up into an aggregate of small quartz grains, penetrated in all directions by iron oxide. The latter does not lie between the individual grains, but passes through them, as though the ground mass were quite homogeneous. The process of replacement is never complete, for all the ocher contains more or less sand. When this is washed clean from the iron oxide, it is found to differ from ordinary sand grains in having extremely irregular outlines. This sand, as might be anticipated from the microscopic structure of the slightly altered quartzite, is evidently composed, not of the original grains of the rock, but of detached portions of the irregular siliceous skeleton, which, in the intermediate stages of replacement, holds the iron oxide in its cavities.
>
> The contact between the ocher and the enclosing quartzite is never sharp and distinct, but always shows a more or less gradual transition from the hard vitreous quartzite to the soft ore which may be easily crushed between the fingers. The quartzite first becomes stained a light yellow, and loses its compact, close-grained texture. This phase passes into a second, in which the rock is perceptibly porous, having a rough fracture and a harsh "feel," and containing enough ocher to soil the fingers. In the next phase the ocher preponderates, but is held together by a more or less continuous skeleton of silica, although it can be readily removed with a pick. The final stage in the transition is the soft yellow ocher, filling the veins, which crumbles on drying, and contains only a small proportion of silica in the form of sand grains.
>
> The intermediate zone between the pure ocher and the quartzite is usually a few inches in thickness, although it may be several feet between the extremes, and on the other hand, sometimes only a fraction of an inch.

Microscopic study of ocher-charged quartzite collected from all parts of the area discloses, with few exceptions, the former or the existing presence of pyrite.

In many sections at least part of the pyrite is entirely fresh and unaltered; but in most sections it has been completely oxidized, leaving the original space occupied by the alteration product, iron oxide.

OCCURRENCE OF OCHER IN ORIGINAL CLAYS

When the ocher is enclosed in clay it forms a series of irregular branching deposits, which correspond to veins in the fresh rock. The ore bodies narrow and widen and thin and thicken throughout their extent. Distribution of the deposits, both vertically and laterally, is irregular. The contact between the ocher bodies and the surrounding clays is never sharp; rather, transition from the clays to the pure ocher is more or less gradual. Field conditions show clearly that the position of the ocher in the clays is in all respects similar to that in the fresh rock. Evidence is lacking to indicate leaching or concentration of these bodies upon weathering of the original enclosing hard quartzite that now forms the surrounding clays.

All evidence from field and laboratory study indicates that the ocher has been deposited not by simple filling of cavities and fissures in the rock but by molecular replacement of the original rock by

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[22] Hayes, C. W., Geological Relations of the Iron Ores in the Cartersville District, Georgia: Trans. Am. Inst. Min. Eng., vol. 30, 1901, p. 416.

"metasomatism"—"the conversion of a rock or mineral aggregate into another of partly or wholly different chemical composition." The form, structure, and texture of the original mineral or rock may be totally or partly changed.[23] The zone of crushed rock that accompanies nearly every exposure of fresh rock over the ocher belt affords a ready and natural passageway for underground circulating water, both of which favor increased chemical action.

SOURCE OF IRON OXIDE

The iron oxide was probably derived from two sources: (1) Rock-surface decay, which was carried downward by the percolating waters in the form of soluble iron salts and (2) the pyrite contained in the quartzite. Watson does not mention the iron accumulations resulting from the large amount of limestone which has been dissolved. S. W. McCallie states that "the Beaver limestone overlying the Weisner quartzite undoubtedly furnished some of the iron oxide to make up the ocher."

NOTES ON OCHER DEPOSITS OF CARTERSVILLE DISTRICT [24] [25]

By Richard W. Smith [26]

GEORGIA PERUVIAN OCHRE CO.

The mines and washing plant of the Georgia Peruvian Ochre Co. (E. P. Earle, president; Fred Chappel, manager) are 2 miles southeast of Cartersville, just south of the Etowah River, at the end of the old wooden bridge, in land lots 676, 692, and 693, fourth land district of Bartow County (fig. 17, *1*).

History of development.[27]—Ocher was first mined on this property in 1878. The first mining and drying methods were very crude. After several changes in ownership the Georgia Peruvian Ochre Co. acquired the property in 1890 and introduced improved methods of mining and preparing the ocher. The ocher that was accessible by opencut methods was exhausted long ago, and underground mining has since prevailed.

Occurrence of ocher.—According to Watson,[28] the ocher occurs as an inclined "vein" or body in the Weisner quartzite of Cambrian age. Where mined on this property the body of ocher has a general strike of about 12° N. 15° W. and an average dip of 45° to 60° SW. Sometimes it is nearly vertical. The line of strike is very wavy and often changes direction every few feet.

The footwall consists of nearly solid Weisner quartzite. Between the ocher and the quartzite is usually a layer of decomposed quartzite and sand a few inches to 2 or 3 feet thick. The ocher is a few inches to 65 feet thick and averages 15 feet. The ocher alone is soft enough to be mined with pick and shovel, but the deposit usually contains

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[23] Lindgren, Waldemar, The Gold and Silver Veins of Silver City, DeLamar, and Other Mining Districts of Idaho: U.S. Geol. Survey 20th Ann. Rept., 1898-99, pt. III, 1900, p. 217.

[24] Manuscript completed Nov. 10, 1928.

[25] Tests made by the U.S. Bureau of Mines at Seattle are incorporated in Smith's report.

[26] Assistant State geologist, Geological Survey of Georgia, Atlanta, Ga.

[27] Watson, T. L., A Preliminary Report on the Ocher Deposits of Georgia: Geol. Survey of Georgia Bull. 13, 1906, pp. 67-69.

[28] Watson, T. L., work cited.

considerable brownish quartzite rock ranging from small fragments to large boulders. In very rocky places it also contains streaks of barite in the form of nodules of the massive variety and drusy crystals, occasionally large perfect crystals, and streaks of manganese ore, usually hard but sometimes sooty. The ocher is bright, drying to golden yellow. In a few places it contains irregular dark-brown streaks; and in others the entire body grades into dark-brown umber, which is discarded in mining. The body of the ocher is sometimes interrupted by faults at right angles to the strike and with offsets up to 8 or 10 feet.

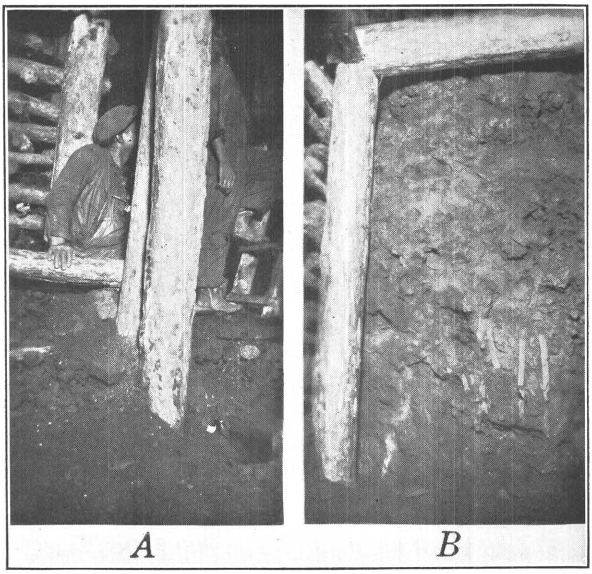
The hanging wall consists of yellow clay, usually with a sharp line of demarcation. This clay increases in thickness with depth and ranges from an average of 20 feet in the upper workings to 150 or 200 feet in the lower levels. Above the yellow clay is a barite formation ranging from a fraction of an inch to 30 feet in thickness and consisting of a mixture of lumps and nodules of barite and brownish sandy clay. Barite is mined elsewhere on the property, but near the ocher mines is said to have no commercial value. This in turn is overlain by mottled red, yellow, and white clay, above which are talus and red surface soil.

Mining methods.—At present the production comes from the no. 1 shaft near the washer and from the Schoolhouse mine 1 mile south of the washer. (See figs. 18, *A* and *B*, and 19, *A* and *B*.)

At the no. 1 shaft the upper levels, which are reached by an adit still kept open for ventilation, drainage, and a manway, are mined out. The vertical shaft is about 230 feet deep, extending below the level of the river. From the bottom of the shaft a main haulage level is turned off on each side, following the body of the ocher. At intervals of 60 feet raises are driven upward for about 20 feet and rooms turned off on each side. These are extended to join and form an intermediate level; meanwhile other raises are extended above the first and more rooms turned off. From the intermediate levels stopes are extended the width of the ocher body and to the height of the next intermediate level above. These are filled with waste as they are mined out.

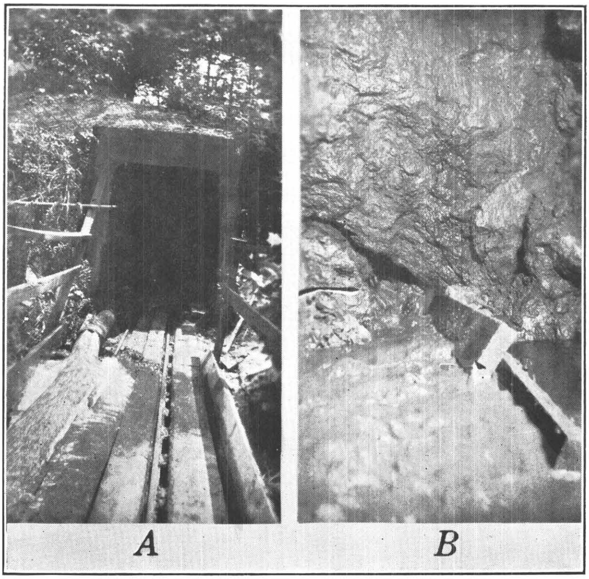
The ocher is mined by pick and shovel, using small shots—a stick or two of dynamite—to loosen the rock. The ocher is loaded into wheelbarrows in the intermediate levels and dumped through chutes in the raises into 1-ton mine cars in the main haulage level. These cars are pushed to the shaft and hoisted to the surface on a cage. As much waste rock as possible is separated from the ocher at the mine face; this waste, with that of the foot and hanging walls, which has to be removed to make the levels the necessary width, is used to fill the stopes or is separately hauled to the surface and dumped onto waste piles. Each raise has an ocher chute and a waste chute. In addition, every other raise has a manway. The main and intermediate levels are timbered with square-sets. The last ocher to be brought out of the shaft will be the roof of the main haulage level.

Each raise is extended up to the old workings; natural ventilation is thus supplied for most of the mining. Where the ventilation is poor a small blower and a canvas air tube bring fresh air to the working face.



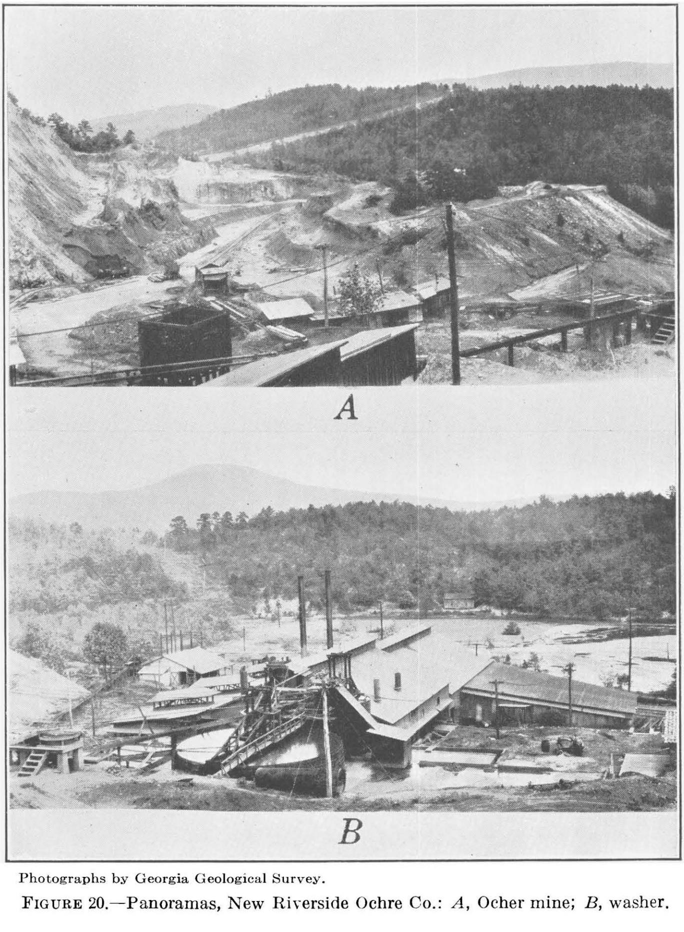
Photographs by Fred Chappel manager.

FIGURE 18.—Georgia Peruvian Ochre Co.: *A*, Face, breast stope, showing timbering method; *B*, stope off intermediate level, same mine.



Photographs by Fred Chappel, manager.

FIGURE 19.—*A*, Old adit to no. 1 shaft, Georgia Peruvian Ochre Co., now used as manway and drainage tunnel; *B*, water issuing from open fissure in main underground haulageway, no. 1 shaft.



Photographs by Georgia Geological Survey.

FIGURE 20.—Panoramas, New Riverside Ochre Co.: *A*, Ocher mine; *B*, washer.

As the main haulage level is below the river level considerable water is encountered, which is pumped to the old adit, whence it flows to the river. The amount is estimated as 180 gallons per minute.

The Schoolhouse mine is in virgin ground. The main haulage level is reached by two adits, one on each side of the hollow, and the mine cars are hauled out by a mule. The mine cars are hauled from both mines to the washer by a gasoline locomotive. Another shaft similar to the no. 1 has been sunk to the ocher near the old workings east of the washer. Production will soon begin from this shaft.

Preparation.—The flow sheet of the washer is shown in figure 21.

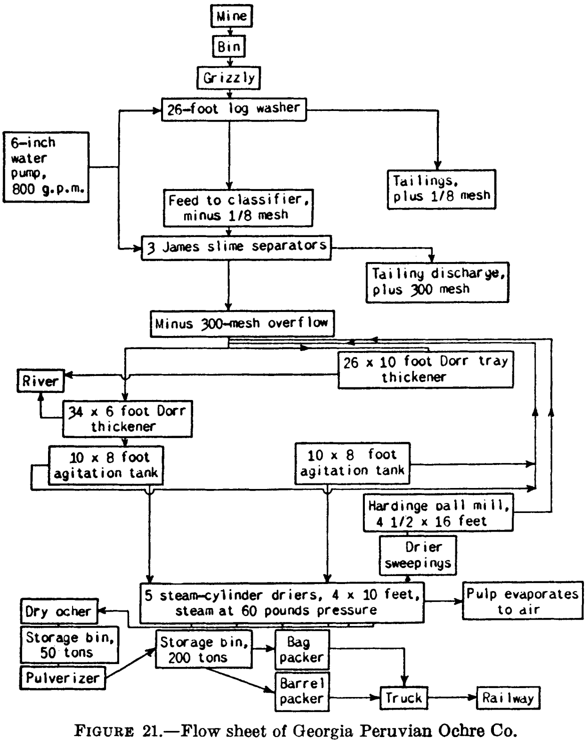


FIGURE 21.—Flow sheet of Georgia Peruvian Ochre Co.

The ocher from the mines is dumped into a bin, from which it is sluiced by hose through a grizzly with bars 3 inches apart into a 26-foot single-log washer. All the ocher goes into suspension and together with the fine impurities goes off with the overflow. The discharge is waste.

After being classified the overflow from the log washer is sent to three slime separators, inverted cones about 6 feet in diameter. The impurities settle against a slight upward current of water, and the water containing the ocher flows over the rim of the cone. The discharge empties into a small horizontal cylinder, which contains a revolving shaft with blades like a log washer; a countercurrent of clear water carries the remaining ocher particles up into the feed to the cones. The discharge from these cylinders is waste.

The overflow from the cones is partly dewatered in two thickeners, one single type 34 feet in diameter and one double-deck type 26 feet in diameter.

The discharge from the thickeners, in the form of a sludge of ocher, goes to agitation tanks, which feed to five 4- by 10-foot steam cylinder driers. Steam passes through these slowly revolving cylinders while the sludge is mechanically spattered on the outside; the dried ocher is scraped off after a complete revolution of the cylinder, passing to a 50-ton storage bin, which feeds to a hammer mill to break up the lumps. The pulverized ocher goes to a 200-ton storage bin. The sweepings from around the driers are ground in a ball mill and fed to the thickeners.

About 30 percent of all run-of-mine material is recovered as commercial ocher. Of the 70 percent waste approximately 30 percent is removed by the log washer and the remainder by slime separators.

The annual production of the plant averages about 7,000 long tons. It is shipped in barrels, heavy burlap sacks holding 224 pounds, and paper-lined burlap sacks holding 112 pounds. Most of the output is used in the manufacture of linoleum, although some is shipped for pigment and for coloring paper. About a third of the production is exported, principally to Scotland and England, although some goes to Holland, Germany, Belgium, and Australia.

The company has no railroad siding at the plant but transports the barrels and sacks in trucks to a siding a quarter of a mile away, whence it is shipped over the Nashville, Chattanooga & St. Louis Railway, the Louisville & Nashville Railroad, and the Seaboard Air Line Railway.

Tests of samples by the United States Bureau of Mines.—Five pounds of washed ocher (no. 1A) were collected from several sacks while the ocher was being loaded. Fourteen drops per gram or 0.32 part by weight of linseed oil was required to produce a paste of a color between mummy (60081) and gold (60164). When diluted with nine parts of zinc oxide the color changed to between sunset (60088) and tan (60089). The ferric oxide content was 46.4 percent. The manganese dioxide content was only 1.09 percent. This pigment was grouped with Georgia, class 2*a*, light ochers or siennas described under the general discussion.

NEW RIVERSIDE OCHRE CO.

The mines and washing plant of the New Riverside Ochre Co. (Mrs. W. C. Satterfield, president; J. R. Dellinger, secretary-treasurer and general manager) are on the River Road north of the Etowah River and the Nashville, Chattanooga & St. Louis Railway about 2 miles a little southeast of Cartersville (fig. 17, *2*). The property includes land lots 461, 477, and the west half of 476, fourth land district of Bartow County.

History of development.—Part of this property was described by Watson [29] as the W. H. Lanham property, then undeveloped. The present company was organized and started mining on the property in 1912.

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[29] Watson, T. L., A Preliminary Report on the Ocher Deposits of Georgia: Georiga Geol. Survey Bull. 13, 1906, 78 pp.

Occurrence of ocher.—The geologic occurrence of the ocher is much the same as that on the property of the Georgia Peruvian Ochre Co., except that alteration from quartzite has been more complete and much less quartzite rock is found in the body of the ocher. The latter appears to strike nearly due north and to dip east at an angle of 60° to 70°. The width of the vein averages about 15 feet but varies considerably. The ocher is much darker than the product of the Georgia Peruvian Ochre Co.

The foot wall consists of the Weisner quartzite. The hanging wall contains considerable barite, which has been removed where the ocher is being mined. The company is mining barite in a cut southwest of the washing plant. (See fig. 20.)

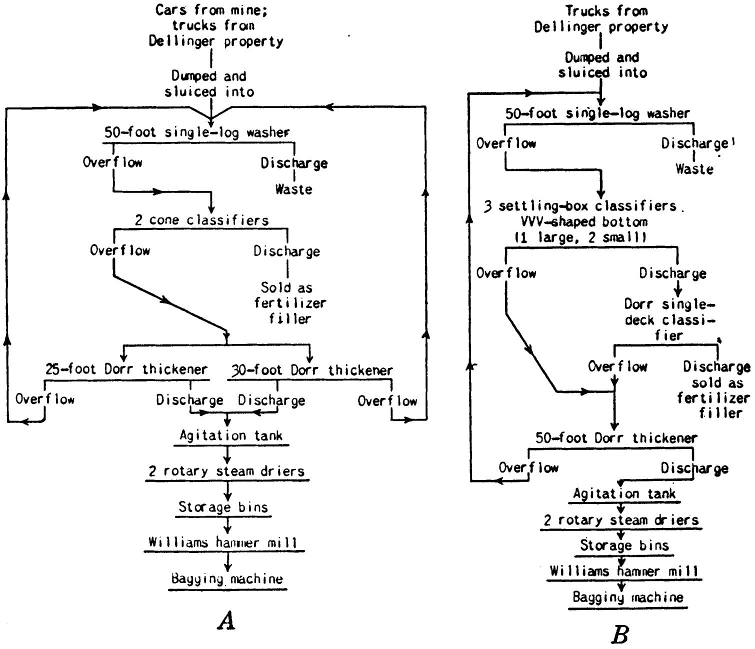

FIGURE 22.—Flow sheets of New Riverside Ochre Co.: *A*, No. 1 unit. *B*, No. 2 unit.

Mining methods.—The mining is entirely by opencut methods. The overburden is removed and the overlying barite formation mined with a steam shovel. The ocher is dug by pick and shovel and thrown into a 2-ton mining car, which is hauled up an incline and automatically dumped into the feed bin of the washer.

Preparation.—The washing plant comprises two separate units, which may be operated separately or simultaneously. The flow sheets of both units are given in figure 22. Unit no. 1 (*A* in the flow sheet) is used to wash the ocher from the mine and a brighter ocher bought on a royalty from the J. R. Dellinger property to the north, described later. This material constitutes about nine tenths of the production of the company. Unit no. 2 (*B* in the flow sheet) is used to wash a specially selected bright ocher bought on a royalty from the Dellinger property, which supplies the demand of certain customers who wish the brightest yellow possible.

The no. 1 unit of the washer is similar to that of the Georgia Peruvian Ochre Co. previously described, except that the cone classifiers do not have the small log-washer cylinder at the bottom to wash the discharge further. (See fig. 22, *A*.) The no. 2 unit, instead of having cone classifiers, has one large and two smaller settling-box classifiers with triple V-shaped bottoms. (See fig. 22, *B*.) The discharge from the settling boxes goes to a single-deck classifier. The discharge therefrom, with that from the cone classifier of the no. 1 unit, is sold for filler in the manufacture of fertilizer. About 50 percent of the run-of-mine material fed to the washer is recovered as commercial ocher. (See fig. 22, *B*.)

The output of the company is said to average about 4,000 long tons a year. Most of it is sold in this country (New York, St. Louis, etc.) for use as a mortar color. The selling price is stated to range from $15 to $20 per long ton, f.o.b. cars at the mine. The ocher is shipped principally in paper-lined burlap sacks and in barrels. The plant is served by a spur track from the Nashville, Chattanooga & St. Louis Railway.

Tests of samples by the United States Bureau of Mines.—Five pounds of washed ocher (no. 2A) of the darker color, which constitutes nine tenths of the production of the company, were collected. Twelve drops per gram or 0.28 part by weight of linseed oil was required to produce a paste between deer (60100) and bronze (60165). When diluted with zinc oxide the color changed to between beige (60098) and sunset (60088). The ferric oxide content was 49.2 percent. The material was grouped with Georgia, class 2*b*, siennas described under the general discussion.

CHEROKEE OCHRE CO.

The mines and plant of the Cherokee Ochre Co. (J. T. Norris, secretary-treasurer) are in land lot 406, fourth land district of Bartow County, 1 mile east of Cartersville (fig. 17, *3*). The property includes several other lots with a total of 170 acres.

History of development.—The Cherokee Ochre Co. was established in 1898 and began mining the same year under the name of the Cherokee Ochre & Barytes Co.[30] Ocher and barite were long mined from the property by underground and opencut methods, but later the company leased the mineral rights to the barite and confined its attention to ocher.

Occurrence of ocher.—The ocher occurs as a tabular body striking in the general direction of 15° N. to 30° E. and dipping 45° to 90° NW. The line of strike is very irregular and often varies every few feet. The foot wall consists of weathered Weisner quartzite and residual sand derived therefrom. The hanging wall is a mixture of brown clay, sooty manganese ore, and iron ore. The ocher averages 15 to 20 feet in thickness and is soft; it contains no quartzite boulders such as were found in the ocher on the property of the Georgia Peruvian Ochre Co. The color ranges from bright yellow to brownish yellow with frequent streaks of dark-brown umber, most of which is discarded in mining.

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[30] Watson, T. L., A Preliminary Report on the Ocher Deposits of Georgia: Geol. Survey of Georgia Bull. 13, 1906, 78 pp.

Mining methods.—Mining at present is entirely by opencut methods. The ocher is mined by hand and loaded into wheelbarrows; these are dumped into a 1-ton car, which is hoisted on an incline and dumped into a bin whence it is sluiced to the washer.

Preparation.—Methods of preparing ocher at the Cherokee Ochre Co. mine are much more primitive than at the mines of the other two producing companies. Crude ocher is sluiced by hose into a single-log washer 22 feet long. The discharge from the log washer is dumped as waste. The overflow passes through a long trough in which the sand settles and is dug out at the end of each day's run into 1 of 6 large concrete settling tanks, each holding 50 tons of ocher. When one of these tanks is full the feed is diverted to another tank and the ocher allowed to settle, as much water as possible is siphoned off, and the rest of the water is evaporated until the ocher is of the consistency of very stiff mud. It is then dug out by hand, loaded into wheelbarrows, and carried to open-air drying racks or large vats heated by waste steam from the power plant, where the remaining water is evaporated.

The dried ocher is dumped in a stock pile; as needed for shipment it is pulverized in a cage mill and stored in a bin, which feeds by gravity through chutes to barrels or sacks. It is shipped in barrels and burlap sacks holding 120 and 240 pounds; the smaller sacks are paper-lined. These are trucked to Cartersville for shipment. One crew operates the entire plant, alternating between mining, washing, and packing.

The average annual production of the company is 1,500 to 2,000 long tons. Most of it is exported for use in the manufacture of linoleum and oilcloth and in coloring paper.

Tests of samples by the United States Bureau of Mines.—Five pounds of washed ocher (no. 3A) were collected from several sacks during loading. Fourteen drops per gram or 0.32 part by weight of linseed oil was required to produce a paste between olive wood (60082) and bronze (60165). When diluted with zinc oxide the color changed to nude (60121). The ferric oxide content was 46 percent. This material was grouped with Georgia, class 2*b*, dark siennas described under the general discussion.

J. M. KNIGHT ESTATE

The J. M. Knight estate (in charge of J. M. Knight, Jr., route 4, Cartersville, Ga.) covers 91 acres of land in land lots 471, 472, 537, and 538, fourth land district, Bartow County; it is on the River Road 2 miles northeast of the Dixie highway and 3 miles (air line) east of Cartersville, just north of the Etowah River (fig. 17, *4*).

A number of small pits and tunnels or adits left by sporadic mining for manganese ore at various times in the past expose considerable ocher. In addition, a little prospecting for ocher has been done.

A small underground working for manganese ore exposes 3 feet of ocher at the mouth of the opening, while at the face the top of the ocher is just showing. A hole dug with a post-hole auger is said to have been still in ocher when stopped 10 feet below the mouth of the opening. The ocher is overlain by red clay containing streaks and isolated nodules of manganese ore. An ocher sample was collected from this exposure.

A small open pit with two underground headings about 200 yards southwest of the house shows 6 feet of fair-grade yellow ocher containing some streaks and small pockets of manganese ore; the ocher is overlain by 12 to 15 feet of weathered clay containing manganese ore. The contact between the ocher and the overlying clay appears to strike northeast and to dip 15° to 20° NW. A hole dug with a post-hole auger is said to have gone 6 to 8 feet below the bottom of the opening and to be still in ocher when stopped. Samples were collected from the opencut and one of the headings.

On the north side of the River Road about 200 yards northwest of the last place another small open pit with two underground headings extending back about 10 feet shows about 6 feet of ocher containing considerable manganese ore and quartzite rocks; the ocher is overlain by 3 to 10 feet of clay containing considerable manganese ore. When first made the opening is said to have exposed a total thickness of 12 feet of ocher. A sample was cut from this deposit.

Other old pits and openings which were not visited are said to show more or less ocher. The openings visited, however, indicate that the property contains a considerable tonnage of ocher of apparently good quality. Whether or not the tonnage is large enough and the quality such as to warrant extensive mining can be determined only by more extensive prospecting.

Watson [31] described part of the property as the Larramore property.

Tests of samples by the United States Bureau of Mines.—About 100 pounds of ocher (no. 4) were collected from four places—a 30-foot cut at the mouth of the working back of the barn, a 6-foot cut from the open pit southwest of the house, a 4-foot cut from a heading from the open pit, and a 6-foot cut from the pit west of the house.

The sample consisted of two parts, a light-colored one which floated and a darker one which sank in water. One part of the sample was washed, and 48.2 percent of residue consisting of coarse and fine and light- and dark-brown sand was removed. When dried the resulting fines gave a soft mass of low shrinkage. When pulverized they required 13 drops per gram or 0.30 part by weight of linseed oil to make a paste between deer (60100) and bronze (60165). When diluted with zinc oxide it changed to between champagne (60097) and sunset (60088). The iron oxide content was 22 percent. All of another portion of the sample was ground in water in the ball mill; when dried and pulverized 11 drops or 0.26 part by weight of oil was required to make a paste between deer and bronze. When diluted with zinc oxide the color changed to nude (60121). The ferric oxide content was 21 percent. Both samples were grouped with Georgia, class *2b*, dark ochers or siennas described under the general discussion.

CARTERSVILLE OCHRE CO.

The Cartersville Ochre Co., recently organized under the direction of Paul Gilreath, Cartersville, Ga., owns two undeveloped ocher properties, on which it expects to start mining operations shortly and to build large and well-equipped washers. (See fig. 23.)

Property northeast of Cartersville.—The property northeast of Cartersville covers 360 acres in land lots 115, 175, 187, 188, 189, 245, and 246, fourth land district of Bartow County, including portions of the

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[31] Watson, T. L., A Preliminary Report on the Ocher Deposits of Georgia: Geol. Survey of Georgia Bull. 13, 1906, pp. 54-55.

old Georgia Manganese & Iron Co. property [32] and of the R. B. Satterfield property (fig. 17, *5*). It forms a rectangle approximately 3 miles long north and south and ½ mile across east and west. The western boundary line is approximately 1 mile northeast of the city limits of Cartersville, and the Rowland Springs Road crosses the property from west to east. The property is crossed by two ridges. The westernmost ridge enters from the north, strikes south, and splits in the southwestern part of the property; one prong extends south and the other swings southeast, leaving the property near the southeastern corner. A body of ocher follows the eastern slope of this ridge to the fork and then follows the southeastern prong. The easternmost ridge enters from the north and strikes southward until a little below the middle of the property, where it swings and strikes due east. A body of ocher is said to strike southeast across the valley between the two ridges, thence following the western slope of the ridge until the ridge swings east and continuing its southern strike across the valley to the other ridge.

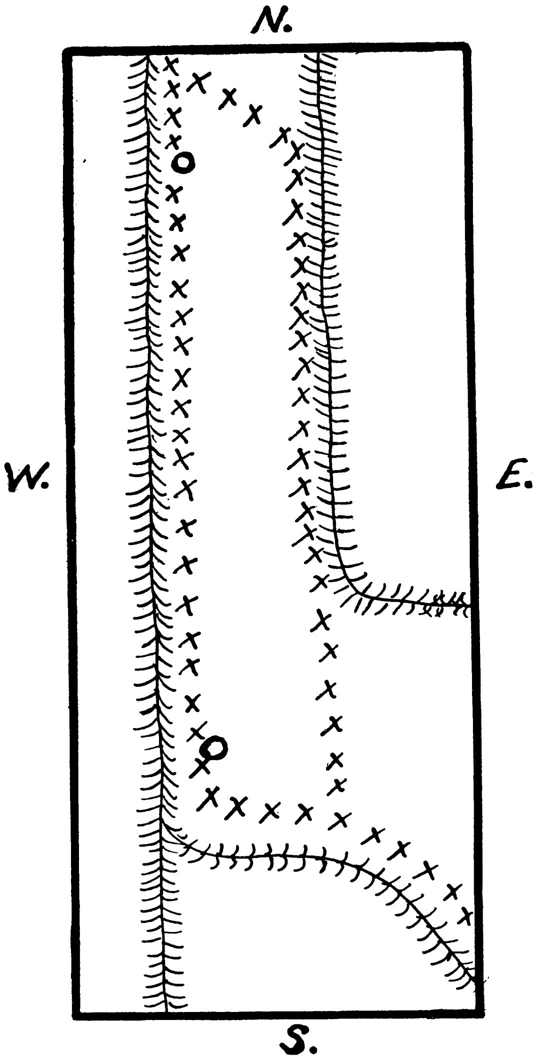

FIGURE 23.—Sketch of Cartersville Ochre Co. property. "X" indicates ocher deposits; "O" indicates sample locations.

The property has been thoroughly prospected by wells, trenches, or borings every 400 feet or closer along the bodies of ocher. The combined length of the two bodies of ocher is said to be 4½ to 5 miles and the average width 35 feet. On both ridges the body of ocher is said to dip about 70° E.-NE. The prospecting was done by Paul Gilreath; later the prospect holes were visited, samples taken, and reports made by Doctor Banks, of Columbia University, New York, and J. W. Brown, of San Francisco, Calif.

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[32] Watson, T. L., work cited, pp. 49–50.

A number of prospect pits and trenches on both ridges were visited. Most of the pits had partly slumped in, and a sample of the ocher in place could not be taken. At two locations, one at the north end of the western ridge and the other at the split of this ridge near the southern end of the property, enough ocher had been thrown out of the pits to make a pile large enough to resist weathering; a sample (no. 5) of about 50 pounds of crude ocher was taken from each place after the top of the pile had been scraped off. At every pit visited the ocher was an excellent bright yellow.

The company proposes to build a washer in the middle of the property in the valley between the two ridges, about 1⅛ miles from the railroad yards at Cartersville. The plant will be equipped with a washer, bowl classifier, and thickener and will have 2½ tons per hour capacity. The mining will be by underground methods.

Tests of samples by the United States Bureau of Mines.—Washing removed 53 percent of yellow-brown sand from sample 5, leaving a soft product of moderate shrinkage. Some difficulty was experienced in dispersing the ocher in water. The pulverized fines were mixed with 12 drops per gram or 0.28 part by weight of linseed oil to produce a maple-sugar (60080) paste. When diluted with zinc oxide the color was slightly darker than sunset (60088). The ferric oxide content was 21.25 percent.

All of another portion of the sample was ground in water. It required practically the same amount of oil to make a paste of virtually the same hue as the washed sample, both when concentrated and diluted. The ferric oxide content was 37.4 percent. Both the ground and washed samples were grouped with Georgia, class 2*a*, light siennas described under the general discussion.

Property north of Emerson.—The property north of Emerson covers 131 acres of land in land lots 537, 538, 543, and 544, fourth district of Bartow County, south of the Etowah River and east of the Nashville, Chattanooga & St. Louis Railway, 1 mile north of Emerson, Ga. (fig. 17, *6*). The Etowah River forms the northern boundary of the property. More adjoining property has been optioned.

Numerous prospect pits, trenches, borings, and tunnels are said to have proved a body of ocher three fourths of a mile long on the southeastern slope of a ridge that crosses the property. The body of ocher is said to average 45 to 55 feet in width and to dip at approximately the same angle as the slope of the ridge; ocher has been found from the valley level almost to the top of the ridge. The strike of the body is said to be approximately N. 30° E. One tunnel is said to have been driven 110 feet at right angles to the strike and in ocher all the way. Several prospect pits and tunnels at various elevations on the slope were visited; all showed more or less slumping, and it was impossible to take a sample in place without too much digging. The ocher exposed was of excellent color. Large piles of ocher had been dumped at the mouths of two tunnels; a sample (no. 6) of about 50 pounds of this ocher was taken from each place after the debris had been scraped from the surface of the piles.

The company intends soon to build a washer similar in design and size to that proposed for the other property. This washer will be in the middle of the property, 1⅛ miles from Emerson and between one quarter and one half mile from the nearest point on the railroad. Water will be pumped from the river.

Tests of samples by the United States Bureau of Mines.—Washing removed 45.1 percent of white, gray, and brown sand, containing only a small amount of ocherous-colored material, from Georgia no. 6. Grinding the entire sample undoubtedly would lighten the color by diluting the ocher with more siliceous material. The soft, purified material, having only a moderate shrinkage, required 12 drops per gram or 0.28 part by weight of linseed oil to produce a mummy (60081) paste. When diluted with 9 parts by weight of zinc oxide the color was slightly darker than sunset (60088). The ferric oxide content was 18.7 percent. The pigment was grouped with Georgia, class 2*a*, light siennas described under the general discussion on ocher.

J. R. DELLINGER PROPERTY

The J. R. Dellinger (Cartersville, Ga.) property covers 40 acres, land lot 404, in the fourth land district of Bartow County; it is north of and adjoins the property of the New Riverside Ochre Co., east of the property of the Cherokee Ochre Co., and 1½ miles east of Cartersville at the head of the small valley that drains south to the Etowah River at the plant of the New Riverside Ochre Co. (fig. 17, 7).

A small opencut mine is being operated on the east side of the valley; the crude ocher is sold to the New Riverside Ochre Co. and is trucked to its plant. The relation between the ocher and the surrounding material is rather obscure. The body of the ocher seems to strike north and to dip in two directions away from a core of quartzite rock; that is, it has the form of an anticline (see fig. 24). The dip eastward on the east side of the mine is apparent. Mining has not progressed far enough to determine definitely whether or not the ocher dips west on the west side of the mine.

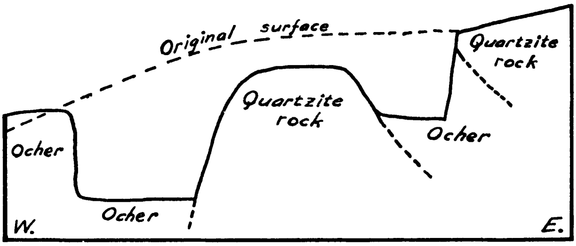

FIGURE 24.—Cross section through quarry of J. R. Dellinger property.

No information could be obtained as to the possible extension of the body through the rest of the property, and no estimates have been made of the probable tonnage remaining.

The ocher varies considerably in color. At some places it is bright and at others contains streaks and large masses of dark brownish yellow. Streaks of red clay and sooty black manganese are common. Bright-yellow ocher of good quality is mined and washed separately at the New Riverside Ochre Co. It constitutes about one fourth of the production of this mine. The light and dark ocher is mixed in washing with the ocher from the mine of the New Riverside Ochre Co., and the proper proportion was included with sample 2A collected there. This second-quality ocher is brighter than that mined at New Riverside.

Tests of samples by the United States Bureau of Mines.—A 100-pound sample (no. 7) of the best quality and brightest color was obtained from several pockets in the mine. The pockety nature prohibited taking a groove sample; that collected was a grab sample taken where mining was under way.

Washing removed only 16.4 percent of brown residue. The material dispersed very easily. The resulting fines when dried gave a soft mass of moderate shrinkage, requiring 14 drops per gram or 0.32 part by weight of linseed oil to produce a mummy (60081) paste. When diluted with zinc oxide the color changed to pablo (60090). The iron oxide content was 28.20 percent. This material was grouped with Georgia, class 2*a*, light ochers or siennas.

ETOWAH DEVELOPMENT CO.

The property of the Etowah Development Co. (C. T. Peebles, president) is in land lot 403, fourth land district of Bartow County; it is east of and adjoins the Dellinger property and is 1¾ miles east of Cartersville (fig. 17, *8*).

A small opencut ocher mine is on the east slope of the high ridge that separates this property from the Dellinger. The body of ocher appears to strike north and south and to dip east with the slope of the ridge. The cut is about 100 feet long, and there is a vertical difference of some 40 or 50 feet between the top and the bottom. In many places the face of the cut is so weathered and covered with sliding material that it is impossible to determine whether ocher or the footwall is exposed. Although some ocher of apparently good quality is exposed much of it contains light and dark streaks and considerable red iron stains and sooty black manganese.

The mine is worked by hand intermittently when orders are received; and the ocher is shipped crude, being trucked 2 miles or more to the railroad. Probably mining will not average more than 10 weeks in a year.

Tests of samples by the United States Bureau of Mines.—A 100-pound grab sample (no. 8) of crude ocher was obtained at several places where ocher had last been mined. The material dispersed readily in water; washing removed 56.5 percent of both light and dark residue. The resulting fines gave a soft mass of moderate shrinkage, requiring 13 drops per gram or 0.30 part by weight of linseed oil to produce a paste between olive wood (60082) and mummy (60081). When diluted with zinc oxide the color changed to champagne (60097). The ferric oxide content was 26.1 percent. This material was grouped with Georgia, class 2*b*, dark ochers or siennas already described.

R. K. MILLER MINERALS CORPORATION

Tests of samples by the United States Bureau of Mines.—Georgia no. 9 was a 5-pound sample of prepared ocher from the R. K. Miller Minerals Corporation, Cartersville, submitted by Edward Doty, president. The washing test gave 6.4 percent of residue. The fines required 13 drops per gram or 0.30 part by weight of linseed oil to produce a mummy (60081) paste. When diluted with zinc oxide the color changed to between tan (60089) and sunset (60088). The ferric oxide content was 56.5 percent. This material was listed with Georgia, class 2*b*, dark ochers or siennas and if representative of a commercial body of available ore has market value.

CLINTON OR RED FOSSIL ORES OF GEORGIA

Some years ago a considerable tonnage of red fossil iron ores was mined in northwest Georgia near Chattanooga and used for pigments, but the mines are now inactive.[33]

The occurrence of the iron ores of Georgia has been summarized by Schrader, Stone, and Sanford [34] as follows:

> **Brown iron ore (limonite).**—Bartow County, extensively worked near Hermitage and other places in Barnsley district. Fannin County, Blue Ridge. Floyd County, extensive deposits in Cave Spring district, mined at Atkinson mine. Murray County, large deposits in sandstone ridges north of Cohutta Springs. Polk County, extensively mined near Cedartown, Ledbetter and Reed mines. Pulaski County, deposit at Hawkinsville. Whitfield County, openings near Tunnel Hill. Reported in Gilmer, Gordon, Hall, Haralson, Milton, Whitfield, and other counties. * * *.
>
> **Hematite (red ore, fossil ore).**—Bartow County, in minable quantities between Emerson and Etowah Rivers, also near Warford, not mined. Catoosa County, abundant as float ore in Dicks Ridge; also occurs in Taylors Ridge and White Mountain. Chattanooga County, mined along base of Lookout Mountain and 3½ miles east of Summerville; also on Dirtseller Mountain. Dade County, mined on Johnson Creek. Polk County, occurs north of Rockmart. Walker County, mined at West property, tenth district. Has been mined also in Floyd and Whitfield Counties.

Much has been written on the geology of various deposits of economic importance found in Georgia. Many of these articles contain data pertaining to pigment materials.[35]

IDAHO

No known work has been done on the pigment materials of Idaho. Both limonite and hematite are reported to be common in the outcrops of lode deposits, but neither is mined for iron. The limonite at Muldoon, Blain County, has been used as a flux, and hematite occurs in massive deposits in Iron Mountain, Washington County.[36]

Two samples were submitted for testing.

IDAHO NO. 1

Sample no. 1 and the data relative thereto were received from Thomas Trathen, Mountain Home, Idaho. This material was taken from a deposit about 18 miles north of Mountain Home on Government land near a good road. The deposit appears to be a seam about 1 foot wide at the outcrop, but as no development work has been done the extent and quantity are unknown. Trathen estimated that the material could be loaded on cars at Mountain Home at a cost of $4 to $6 per ton.

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[33] Williamson, E. D., and Adams, L. H., Density Distribution in the Earth: Jour. Washington Acad. Sci., vol. 13, no. 19, 1923, pp. 413–428.

Posnjak, Eugen, and Merwin, H. E., The Hydrated Ferric Oxides: Am. Jour. Sci., 4th ser., vol. 47, 1919, p. 1965.

[34] Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful Minerals of the United States: U.S. Geol. Survey Bull. 624, 1917, pp. 107, 111.

[35] Hayes, C. W., Overthrust Faults of the Southern Appalachians: Bull. Geol. Soc. America, vol. 2, 1891, pp. 141–154; Geological Relations of the Iron Deposits in the Cartersville District, Ga.: Trans. Am. Inst. Min. Eng., vol. 30, 1901, pp. 403–419.

Spencer, J. W., The Paleozoic Group, Bartow County: Geol. Survey of Georgia, 1903, pp. 99–107.

McCallie, S. W., A Preliminary Report on a Part of the Iron Ores of Georgia (Polk, Bartow, and Floyd Counties): Geol. Survey of Georgia Bull. 10-A, 1900, pp. 109–176; Report on the Fossil Iron Ores of Georgia: Geol. Survey of Georgia Bull. 17, 1908.

Watson, T. L., Geological Relations of the Manganese Ore Deposits of Georgia: Trans. Am. Inst. Min. Eng., 1903, 78 pp.

Eckel, E. C., The Clinton or Red Ores of Georgia: Iron Trade Rev., Jan. 7, 1909.

[36] Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful Minerals of the United States: U.S. Geol. Survey Bull. 624, 1917, pp. 118 and 119.

Laboratory tests.—The ¼-pound sample as received consisted of yellow and dark-brown shalelike lumps one half inch and smaller in size. They were hard enough to resist washing and hence were ground in water. After being dried the pulverized material was mixed with 18 drops per gram or 0.42 part by weight of linseed oil to produce a brown (60114) paste. When diluted with nine parts of zinc oxide the color changed to champagne (60097). Although the ferric oxide content was 41.1 percent the tinting strength was so weak that the pigment had no commercial value. If stronger, the pigment would be placed with the yellow ochers (class 2).

IDAHO NO. 2

Idaho no. 2 and information regarding it were supplied by L. W. Johnson, 590 North Fourth East, Provo, Utah, or box 127, Paris, Idaho, owner of the deposit. The latter is in the Bulldog mining claims about 6 miles west of Paris, Idaho, in sec. 1, T. 14 S., R. 42 E., Bear Lake County, Idaho. A main highway and the Oregon Short Line Railway lie in the same valley, and a good road runs to the property. The material apparently crosses a number of mineral claims. Cuts indicate a width of more than 40 feet and a depth of more than 8 feet. The acreage is apparently large, and the overburden is thin. Johnson estimated that the cost per ton, f.o.b. cars, would not exceed $2.

Laboratory tests.—The 1-pound sample was a mixture of yellow-brown clay in 2-inch-diameter lumps with reddish-brown, rocklike fragments. The red material was discarded and the more valuable yellow-brown clay material tested. Cleaner material must be supplied for trade purposes. After being ground in water it produced a high-shrinking, hard, dried mass, which required 21 drops per gram or 0.49 part by weight of linseed oil to produce a terrapin (60091) paste. When diluted with nine parts of zinc oxide the color lightened to sunset (60088). The ferric oxide content was 21.20 percent. This material was classed with Pennsylvania or class 2, dark orange-yellow, ochers, slightly grayed. The full-strength color varied from the standard toward red-brown. The dilution test indicated medium tinting strength varying from the standard toward gray. This pigment should have at least local value if handled properly and may meet the requirements of the general market.

ILLINOIS [37]

The history of mineral pigments in Illinois is very brief; no deposits were being worked in August 1928. A deposit of limited extent, formerly exploited by the International Silica Co. of Cairo, has recently been abandoned on account of caving roof and other mining difficulties. J. E. Lamar studied and sampled seven deposits just north of Cairo.

Inasmuch as all the deposits are comparatively close to either the Mississippi or Ohio Rivers the loess associated with these streams covers the deposits more or less completely. The obscuring effect of the loess makes the extent of the deposit indeterminate. Most of the deposits would doubtless yield a few hundred tons if work followed the outcrop, but it is probable that mining will eventually be necessary.

TESTS OF ILLINOIS PIGMENTS BY THE UNITED STATES BUREAU OF MINES

ILLINOIS NO. 29

Three feet of yellow ocherous clay, Cretaceous-Tertiary in age, underlying pink clay of unknown thickness, were sampled. The exposure occurs in T. 14 S., R. 2 W., SE¼NE¼ sec. 2, along the south

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[37] The geographic and geologic data for 7 of these samples were furnished by J. E. Lamar, geologist, section of nonfuel products, Illinois State Geological Survey Division.

branch of Cooper Creek; inasmuch as this is the only outcrop in the vicinity the extent of the deposit is uncertain. It can probably be mined along the base of the hill in which it occurs to obtain a considerable quantity by open-pit workings. The deposit is about 1½ miles west of the Mobile & Ohio Railway 2 miles west of Mill Creek.

Laboratory tests.—The sample as received could probably be washed damp direct from the mine with a blunger, but the dried sample dispersed with difficulty in water and yielded 34.5 percent of residue containing a large portion of ocherous material. For the final tests another portion was ground in water in a pebble mill and gave a high-shrinking, hard, strong residue after drying. When mixed with 22 drops per gram or 0.51 part by weight of linseed oil the color was a deeper yellow-brown than topaz (60112). When diluted with zinc oxide the color was near sunset (60088) and chamois (60179). The ferric oxide content was 8.2 percent washed and 10.88 percent ground. This material was grouped with French, class 1, dark-yellow, ochers. The full-strength color varied from the standard toward orange. The dilution test indicated medium tinting strength, and the let-down color varied from light French ocher toward pink. It therefore has possible commercial value if the economic features are satisfactory.

ILLINOIS NO. 82

The deposit from which Illinois no. 82 was collected is in a railroad cut in T. 14 S., R. 2 E., SE¼ sec. 29, 1 mile northeast of Grand Chain, on the Cleveland, Cincinnati, Chicago & St. Louis Railway. This is a Cretaceous-Tertiary clay, exposed in the following section:

5. Gravel, brown chert	feet	3–7
4. Sand, red, medium-grained	do	6–8
3. Ocher, yellow, hard, brown	inches	8–12
2. Clay, gray and pink	feet	3+
1. Sand, red	inches	6

The sample of this ocher was taken in anticipation of the possibility of working the gravel, clay, and ocher as three units in one operation.

Laboratory tests.—The sample was yellow-brown, hard, and shalelike and required pebble-mill grinding rather than washing. The dry powder was mixed with 25 drops per gram or 0.58 part by weight of linseed oil to make a strong gold-brown topaz (60112) paste. When diluted with zinc oxide (1: 9) the color was sunset (60088). The ferric oxide content was 59.2 percent. This material was grouped with class 1, dark orange-yellow, siennas. The dilution tests indicated a stronger tinting strength than that for the French ochers and at least that of the 28 percent iron oxide artificial ochers. This material undoubtedly has commercial value if it can be produced and marketed economically.

ILLINOIS NO. 83

Illinois no. 83 was taken from a deposit at the head of a small valley in T. 15 S., R. 1 E., E½ sec. 13, southeast of the road, about 2 miles northeast of Olmstead, ½ mile from the Ohio River, and ½ mile from the Cleveland, Cincinnati, Chicago & St. Louis Railway. This outcrop is part of the Porter's Creek formation of Cretaceous age. The exposure consists of:

3. Gravel, brown	feet	6–10
2. Fuller's earth	do	4
1. Ocher	do	2½

It is thought that this ocher might be recovered with the gravel and possibly the fuller's earth. The deposit occurs in the area where fuller's earth is being actively mined in Illinois.

Laboratory tests.—This sample was too hard and shalelike to be washed and was therefore ground in water in the pebble mill; on drying it produced a hard pulverized mass of high shrinkage. Twenty-five drops per gram or 0.58 part by weight of linseed oil was used to make a stiff paste approaching topaz (60112). When diluted with nine parts of zinc oxide the color was nearly sunset (60088). The ferric oxide content was 17.6 percent, just within Government limits. This material was grouped with Pennsylvania or class 2, light orange-yellow, ochers, slightly grayed. The dilution test indicated medium tinting strength, and the color varied from the standard toward pink. It therefore has commercial possibilities if the economic features are satisfactory.

ILLINOIS NO. 84A

Sample 84A came from an exposure of clay, probably of Tertiary age, in a railroad cut of the Illinois Central Railway in T. 13 S., R. 1 W., sec. 11, SW¼, about 1½ miles southeast of Balcom.

The section is as follows:

3. Gravel, white chert, locally ferruginous	feet	⅔–2
2. Clay, red plastic	do	4
1. Covered		---

The outcrop occurs in a hill, and its extent is not known.

Laboratory tests.—This material dispersed easily in water and when washed left 47.4 percent of red sand with some white sand. Another sample was likewise ground in the pebble mill because of the abundance of red sand, which should not dilute the color. When dried the fines from the pebble mill gave a hard mass of high shrinkage, requiring 19 drops per gram or 0.44 part by weight of linseed oil to make a poor-working mahogany (60136) paste. When diluted with zinc oxide the color was light pink no. 1 (60013). The ferric oxide determination was likewise low (4.4 percent), and the tinting strength was entirely too weak for a commercial pigment. The pigment was listed as class 1, weak red-brown, burnt ocher.

ILLINOIS NO. 111

Illinois no. 111 was an ocher sample from rotted Vienna chert on the Travis farm on a hard road 1 mile north of Vienna in NW¼ sec. 32, T. 12 S., R. 3 E.

It was buff clay of Upper Mississippian age found along the base of a large hill about 1¼ miles west of the Cleveland, Cincinnati, Chicago & St. Louis Railway. The extent of the clay is indeterminate; it is probably the result of disintegration of ferruginous chert.

Laboratory tests.—The sample as received was yellow-brown clay which dispersed easily in water after a little soaking and gave 21.1 percent of brown-sand residue. A second portion was ground in water in the pebble mill and gave a high-shrinking hard residue after drying, requiring 20 drops or 0.46 part by weight of linseed oil to make a poor-working olive-wood (60082) paste; when diluted with 9 parts of zinc oxide this gave a champagne (60097) color. The ferric oxide content was only 8.5 percent washed and 10.2 percent ground and the ferrous oxide content 0.09 percent. The color strength was below Government requirements. This material was grouped with Georgia, class 2*a*, light siennas. The dilution test indicated weak tinting strength, and the color varied from the standard toward gray. The pigment therefore has the disadvantage of the darker hue of Georgia materials and weak strength, which indicates only limited commercial value.

ILLINOIS NO. 202

No. 1 sample sent by Lamar was designated Illinois no. 202. It was collected from the center of sec. 28, T. 15 S., R. 3 W., near Fayville, Alexander County, Ill. The deposit is part of the LaGrange formation, Eocene age, the youngest member of this system in Illinois. The ocher deposit exposed in the outcrop is 3 to 6 feet thick. Prospect reports indicate a thickness of 10 to 20 feet. The outcrops are comparatively well distributed over at least 160 acres; and apparently a considerable amount of ocher can be obtained from the property, although mining problems may limit tonnage.

Laboratory tests.—The 2-pound sample as received consisted of soft, claylike, light-yellow, ocher-brown lumps 2 inches or less in diameter. No carbonates were present. After being ground in water the pulverized fines required 19 drops per gram or 0.44 part by weight of linseed oil to produce a gold (60164) paste. When diluted with zinc oxide the color changed to between leghorn (60005) and polar bear (60004). The ferric oxide content was 6.9 percent. This material was grouped with Pennsylvania, class 2, light orange-yellow, ochers, slightly grayed, but was close to the light French class. The dilution test indicated weak tinting strength, but the let-down color had a cream hue. The tinting strength could probably be improved by better preparation; in this test, however, it was too weak for best-grade yellow ochers.

ILLINOIS NO. 203

Illinois State Geological Survey sample no. 2, shipment of May 15, 1930, was designated Illinois no. 203. It came from the same deposit as no. 202. Lamar reports that this sample is an ocher of somewhat uneven color distribution but is typical of the deposit being developed. Samples 202 and 203 are lateral variations of each other.

Laboratory tests.—The 25-pound sample as received consisted of 12-inch or smaller lumps with a hard, rocklike structure and a dark-brown, sienna color. No carbonates were present. After being ground in water the fines required 20 drops per gram or 0.46 part by weight of linseed oil to produce a dark topaz (60112) paste. When diluted with zinc oxide the color changed to dark sunset (60088). The ferric oxide content was 28.0 percent. This material was grouped with class 1*a*, siennas. The full-strength hue varied from the standard toward orange-brown and was close to French ocher. On dilution it showed a very strong tinting strength and varied from the French color toward cream-pink. (See fig. 12, *B*, and table 28.) It undoubtedly has commercial value if economic and mining conditions are satisfactory.

INDIANA

The occurrence of iron ore in Indiana has been outlined by Schrader, Stone, and Sanford [38] as follows:

> **Brown iron ore (bog-iron ore, limonite).**—Clay County, Harmony and in T. 10 N., R. 6 W. Daviess County, several localities. Green County, vicinity of Cincinnati and along creeks. Lawrence County, a few workable deposits. Martin County, south of Shoals near Coal Hollow, extensive deposits near Baltimore & Ohio Southwestern Railroad have been mined. Monroe County, small deposits along Indian Creek, formerly used in furnaces. Noble County, Ore prairie. Orange County, in many hills. Vermillion County, Nortons Creek and Hilton prairie. Occurs also in several localities in Jasper, Kosciusko, Laporte, and St. Joseph Counties but is not mined. * * *.
>
> **Hematite (red iron ore).**—Greene County, along Ore Branch, Richland Creek, and vicinity of Cincinnati. Lawrence County, sec. 28, T. 5 N., R. 2 W.; Martin County, south of Shoals; not used. * * *.
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> **Ocher (mineral paint).**—Dearborn County, deposits near Dillsboro. Dubois County, excellent quality has been mined near Ferdinand. Greene County, occurs near Washington. Martin County, has been extensively worked 1 mile west of Dover Hill. Miami County, in several places near Denver and in large quantities in vicinity of Chili. Vigo County, has been mined in Pierson Township.

The geographic and geologic data of 21 samples from Indiana were furnished by W. N. Logan, State geologist, department of conservation, division of geology. The first 19 samples were clays and shales, but their tinting strength was too weak for commercial service.

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[38] Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful Minerals of the United States: U.S. Geol. Survey Bull. 624, 1917, pp. 126, 127, 129.

INDIANA NO. 20

Sample no. 20 was a sienna-colored clay from a deposit 2½ miles west of Huron, Martin County. This material occurs at the horizon of the Chester or Reelsville limestone, which is commonly enclosed in shale beds. Formation of the colored clay has resulted from decomposition of the pyrite in the limestone and deposition of a type of hydrous aluminum silicate commonly termed "halloysite."

Laboratory tests.—It is brown (60114) when ground with oil and chamois (60179) when mixed with zinc oxide. The color strength was weak. The iron oxide content was 9 percent. The pigment was classed with the weak umbers and varies from the standard toward light brown-gray. It could have only local commercial value.

INDIANA NO. 21

Sample no. 21 was a sienna-colored material from section 16, Center Township, Martin County. The origin is similar to that of no. 20.

Laboratory tests.—When ground in oil the color was tobacco (60143), and when diluted with zinc oxide it was between silver (60050) and chamois (60179). Although the iron oxide content was 31.80 percent the dilution test indicated weak tinting strength; therefore general commercial use is doubtful. The pigment was classed with the umbers, varying from the standard toward pink.

IOWA

According to information obtained from the Iowa Geological Survey, several attempts have been made to use colored Pennsylvania shales as pigments, but none of these have been developed on a commercial scale.

The occurrence of iron ore in Iowa has been summarized by Schrader, Stone, and Sanford [39] as follows:

> **Brown iron ore (limonite).**—Allamakee County, Iron Hill. Clayton County, in lead and zinc regions. Dubuque County, in lead and zinc regions. Henry County, a lean ore on Skunk River. Jackson County, not in workable quantity. Webster County, in limited quantities. * * *.
>
> **Hematite.**—Allamakee County, principal ore body at Iron Hill; widely distributed through shales and sandstones of the Pennsylvanian ("Coal Measures"). Jasper County, has been mined near Monroe for manufacture of metallic paints. * * *.
>
> **Ocher (mineral paint).**—Allamakee County, deposits at Iron Hill and various points along Paint Creek. Jasper County, has been quarried at Fairview Township. Keokuk County, undeveloped deposit near Hayesville. Monroe County, deposits near Hamilton. Webster County, mined at Fort Dodge.

The Waukon limonite, the only iron deposit of commercial size in the State, occurs in Iron Hill, 1,340 feet above sea level, north of Waukon, Allamakee County, northeastern Iowa. This occurrence is described in full by Howell.[40] The metallic iron content of typical specimens is approximately 32 percent; the iron content of other specimens ranges from 52 to 6 percent. The iron ore is directly in contact with bedrock and lies unconformably on limestone and dolomite formations. In the main, it is a brown, coarsely cellular limonite with irregular cavities containing masses of clay, sand, chert, and some hematite. The ore masses are believed to have been formed as bog-iron ore during the Tertiary period, when northeastern Iowa had been reduced virtually to a peneplain whose drainage was slug-

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[39] Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful Minerals of the United States: U.S. Geol. Survey Bull. 624, 1917, pp. 131, 132.

[40] Howell, J. E., The Iron-Ore Deposits near Waukon, Iowa: Iowa Geol. Survey Ann. Rept., vol. 25, 1914, pp. 33–102.

gish and weathering exceeded the transportation of sediments. The iron oxide of the clayey residuum was dissolved by organic acids and carbon dioxide and deposited in large bogs. The uplift at the close of the Tertiary rejuvenated the streams and drained the swamps, and in places the iron oxide was leached by percolating waters and precipitated in the residuum below.

The deposit has been worked intermittently since 1899. The most successful attempt was made by the Missouri Iron Co. in 1907 and later. A recovery of 37 to 62 percent was reported, with an average metallic-iron content of 55 percent. According to a report in 1929 by the Iowa Geological Survey, the property was owned at that time by the Mississippi Valley Iron Co., of St. Louis, Mo., but it has not been operated since the war. No samples could be obtained from anyone known to be acquainted with the property. Possibly a marketable grade of metallic brown pigment could be produced from the original ore or one of the red oxides of the hematite variety by light calcination in a roasting furnace. (See the tests of iron ores from Texas, New York, Michigan, Wisconsin, and Tennessee.)

KENTUCKY

The occurrences of brown, yellow, and red iron ores in Kentucky have been summarized by Schrader, Stone, and Sanford [41] as follows:

> **Brown iron ore (bog-iron ore, limonite).**—Bath County, mined at Preston ore banks; occurs in Red River iron region, between Licking and Kentucky Rivers—ores at base of Pennsylvanian series ("Coal Measures"); Hanging Rock region, embracing whole or parts of Boyd, Carter, Greenup, Johnson, and Lawrence Counties, in northeastern part of State. * * *. In abundance from Ohio River southward to southern part of Carter County; Cumberland River iron region, embracing whole or parts of Caldwell, Crittenden, Livingston, Lyon, and Trigg Counties, in western part of State; occurs in clay and chert above Mississippian limestones; irregular shape and uncertain extent, but aggregate of ore immense; most extensive deposits are between the Tennessee and Cumberland Rivers and of excellent quality. Nolin district, in Butler, Edmonson, Grayson, Muhlenberg, and Ohio Counties; ores occur near base of the Pennsylvanian rocks ("Coal Measures"). "Oriskany" ore on north slope of Pine Mountain, Bell County, has been mined. * * *.
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> **Hematite (red iron ore).**—Bath County, mined near Owingsville. Graves County, small quantity in gravel beds 2½ miles south of Hard Money. Was mined in Fleming County. Marshall County, small quantity near Birmingham. * * *.
>
> **Ocher.**—Ballard County, yellow ocher was mined in ravine east of Wickliffe. Calloway County, near Murray. Carlisle County, yellow ocher was mined in the bluffs of creeks near Laketon. Crittenden County, 5 miles southwest of Marion. McCracken County, mined 3 miles east of Paducah. Marshall County, on banks of Tennessee River at Highland Landing.

No samples were submitted from Kentucky.

LOUISIANA

Schrader, Stone, and Sanford [42] have summarized the occurrence of iron ores in Louisiana as follows:

> **Brown iron ore (brown hematite, limonite).**—In Tertiary sands in Bienville, Bossier, Caddo, Claiborne, Lincoln, and Union Parishes; not used. * * *.
>
> **Hematite.**—Occurs in Bienville, Grant, Natchitoches, Rapides, Red River, Sabine, Winn, and other parishes; not used.

No samples were submitted from Louisiana.

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[41] Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful Minerals of the United States: U.S. Geol. Survey Bull. 624, 1917, pp. 139, 141, 142.

[42] Work cited, p. 144.

MAINE

Schrader, Stone, and Sanford [43] have summarized the occurrence of iron ore in Maine as follows:

> **Brown iron ore (bog-iron ore).**—Lincoln County, occurs on Pemaquid Ledge. Oxford County, at Rumford. Piscataquis County, Dover; several deposits of large size. Somerset County, Skowhegan; several large deposits. York County, New Limerick, and Newfield.
>
> **Brown iron ore (brown hematite, limonite).**—Aroostook County, occurs at Houlton and Linneus. Hancock County, most abundant oxidized mineral in Blue Hill and Brooksville district. Piscataquis County, has been mined at Katahdin mines. Washington County, has been mined at Trescott and at Lubec lead mine; at latter place trace of gold, some silver. * * *.
>
> **Hematite (red iron ore).**—Aroostook County, occurs at Curriers. Piscataquis County, has been mined at Katahdin mines. * * *.
>
> **Ocher.**—Androscoggin County, has been mined at Lisbon. Cumberland County, occurs at Bridgton, Naples, and Sarmonite.

No samples were submitted from Maine.

MARYLAND

Schrader, Stone, and Sanford [44] have summarized the occurrence of iron ore in Maryland as follows:

> **Brown iron ore (bog-iron ore).**—Found at several localities in small quantity. Was mined and made into pig iron many years ago at Federalsburg, Caroline County, and on Nassawango Creek, Worcester County, latter locality producing as high as 700 tons in one year.
>
> **Brown iron ore (brown hematite, limonite).**—Was formerly mined more or less extensively at the following places: Allegany County, Nicholas Mountain, and Shriver Ridge. Baltimore County, near Bosley, 2 miles west of Cockeysville, 2 miles west of Glencoe, near Lutherville, Stevenson, and Towson. Carroll County, at Avondale, Bachman Mills, Ebbvale, Lineboro, Melrose, and Westminster. Frederick County, east foot of Catoctin Mountains near Thurmont, near Feagaville, Frederick Junction, Unionville, and Washington Junction. Harford County, at Hess and 2 miles southwest of Jarrettsville. Washington County, 1 mile south of Boonsboro, 3 miles north and 4 miles southwest of Clear Spring, 1 mile and 3 miles northwest of Harpers Ferry, near Green Spring, 2 miles northeast and 1 mile southeast of Indian Spring, 1 mile and 2 miles south of Pondsville. * * *.
>
> **Hematite (Clinton oölite).**—Allegany County, was stripped many years ago on west side of Wills Mountain, near Roberts and near Cumberland; it occurs in Wills Mountain, Evitts Mountain, and Tussey Mountain. * * * .
>
> **Ocher.**—Anne Arundel and Prince Georges Counties, was formerly mined from Patapsco and Arundel formations. Frederick County, considerable shipments from Catoctin Furnace pits.

No samples were submitted from Maryland.

MASSACHUSETTS

Schrader, Stone, and Sanford [45] have summarized the occurrence of iron ore in Massachusetts as follows:

> **Brown iron ore (limonite, bog-iron ore).**—Dukes County, deposits in swamps and in Tertiary rocks in Marthas Vineyard. Hampden County, formerly worked near Brimfield.
>
> **Brown iron ore (brown hematite).**—Berkshire County, numerous and extensive beds in Richmond, has been mined to some extent; also in vicinity of Lenox and Stockbridge, and in an area which extends 6 or 7 miles northward from these towns toward Pittsfield; it has been mined at a dozen or more places. Bristol

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[43] Work cited, pp. 146, 148, 149.
[44] Work cited, pp. 153, 155, 156.
[45] Work cited, pp. 158, 160.

County, large quantities at Dartmouth and Easton; has been mined at West Stockbridge.

Hematite.—Franklin County, has been mined in small way Bernardston, Montague, and Warwick. Hampshire County, at Hawley.

No samples were submitted from Massachusetts.

MICHIGAN

HEMATITE DEPOSITS OF LAKE SUPERIOR REGION [46]

GENERAL CHARACTER AND DISTRIBUTION

The iron ores mined in the Lake Superior region in Minnesota, Michigan, and Wisconsin amounted to 62,824,768 long tons in 1930 or about 86 percent of the total domestic supply. The ore is mainly hematite with small admixtures of limonite and magnetite. It occurs as masses, lenses, or flat deposits in pre-Cambrian sedimentary rocks of Algonkian and Archean age. The deposits are concentrated by the oxidizing and silica-dissolving effect of waters of meteoric origin in original sediments called "iron formations," which were rich in carbonate and silicate of iron. They are products of pre-Cambrian weathering which, probably under arid conditions, reached depths not approached elsewhere. Only to a small degree and near the surface does this ore-forming activity of the waters persist at the present time.

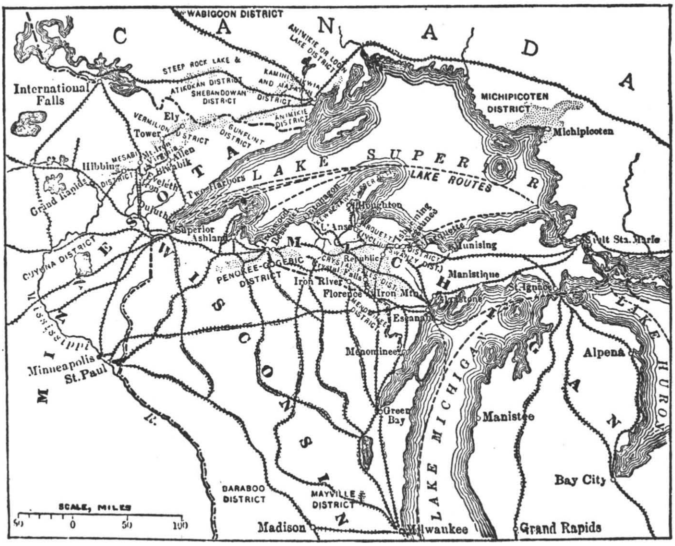

FIGURE 25.—Map of Lake Superior iron regions, according to Van Hise and Leith (Ries).

There are four principal districts in this region, as follows (fig. 25):

1. The Mesabi, Vermilion, and Cuyuna ranges of northern Minnesota.
2. The Penokee-Gogebic, Marquette, Iron River, and Menominee ranges, mainly in northern Michigan.

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[46] Abstract from Lindgren, Waldemar, Mineral Deposits: McGraw-Hill Book Co., New York, 1919, pp. 357–374.

3. The Baraboo range of southern Wisconsin.
4. The Michipicoten, Gunflint Lake, and other minor districts in Canada.

GEOLOGY

The principal rocks of the Lake Superior iron-ore region are divided as follows:

Cambrian: Potsdam sandstone.
Algonkian: Keweenawan series (sediments, basic flows, gabbro).
Huronian series:
  Upper Huronian (quartzite, iron formations, and slate).
  Middle Huronian (quartzite, iron formations, and slate).
  Lower Huronian (quartzite, conglomerate, dolomite, slate, iron formations, and intrusives).
Archean:
  Laurentian series (granite, gneiss, and porphyry).
  Keewatin series (greenstone, amphibolite, and iron formations).

IRON FORMATIONS

Of the rocks of the region only the Upper and Middle Huronian and the Keewatin contain deposits of hematite. The iron ores are believed to be derived by concentration from lean iron formations containing about 25 percent of iron and ranging in thickness from a few feet to 1,000. The ores are products of enrichment of chemically deposited sediments, such as siderite and hydrated iron silicates, for the most part interbedded with normal clastic sediments, such as slate and quartzite.

Other phases of iron formation, subordinate in quantity, are (1) ordinary clay slates, showing every possible gradation through ferruginous slates into ferruginous cherts; (2) paint rocks, oxidized equivalents of the slates; (3) cherty iron carbonate (siderite) and hydrous ferrous silicate (greenalite); and (4) the iron ores themselves. Almost the entire bulk of the iron formations now consists of iron oxide and silica, with carbonates and alumina present in subordinate quantity. The theories of Van Hise, Leith, and their associates on the origin of the Lake Superior iron ores are generally accepted, but to understand the formation of the iron ores by removal of silica from ferruginous cherts it is necessary to emphasize that the concentration process took place mainly before the Cambrian. The ores are not the product of present circulation and oxidation but of forces acting in ancient periods when conditions probably differed widely from those of today. The present ground waters are not now transporting or dissolving iron or notable quantities of silica in the temperate climate of this part of North America.

The only time that large bodies of rock could be oxidized to hematite by descending waters would seem to be during epochs of great aridity, when the water level was exceptionally low; possibly, just such conditions prevailed in pre-Potsdam time. Other evidences of deep oxidation during the same pre-Cambrian age have been reported in Wyoming, Arizona, and India.

TESTS OF MICHIGAN PIGMENTS BY THE UNITED STATES BUREAU OF MINES

MICHIGAN NO. 1

F. G. Pardee, mining engineer, department of conservation, State of Michigan, submitted sample no. 1 and its description. This limonite sample came from the James mine, just north of the village of Iron River, Iron County. This mine is one of a group of properties operating in what is called the Mineral Hills area; all of these carry some limonite. The age of these deposits is given as Upper Huronian. The yellow ocher and limonite have not been used extensively for paint pigments, as the difficulty of separating limonite from the varieties of hematite that occur with the ore is too great. This mine alone has produced more than 3,000,000 tons, and the district has shipped many times this amount. Analysis of the ore shows 50 to 52 percent of iron, 7 to 9 percent of silica, 6 to 7 percent of moisture, and more than 0.4 percent of phosphorus.

Laboratory tests.—The 10-pound sample as received consisted of a mixture of yellow and brown, nearly steel-hard, 4-inch lumps mixed with smaller lumps of soft ocherous material. The sample was ground with water to the proper fineness in a porcelain ball mill and on drying gave a rather hard mass of medium shrinkage. When pulverized it required 10 drops per gram or 0.23 part by weight of linseed oil to make a smoothly working deer (60100) paste. When diluted with nine parts of zinc oxide the color changed to tan (60089). The ferric oxide content was 83.7 percent. This material was grouped with Georgia, class 2*b*, dark ochers. The full-strength color varied from the standard toward red-brown. The dilution test indicated strong tinting strength, and the hue varied from the standard toward brown. Undoubtedly this material and other iron ores of this district, like the Georgia sienna pigments (class 2), can be used commercially after proper grinding and flotation. (See table 36.)

MICHIGAN NO. 2

Pardee also submitted sample no. 2 and its description. This red-hematite sample was from the Warner mine in Iron County, Mich. The Warner mine is in the sediments of Middle Huronian age, which extend southeast from Amasa, Mich. More than 1,200,000 tons of ore have been shipped from the Warner mine, and a small part of this shipment has been sold to paint manufacturers. The ore carries approximately 50 percent of metallic iron and 6 to 10 percent of silica. The moisture ranges from 7 to 10 percent.

Laboratory tests.—The 3-pound sample as received consisted of purplish-red shale lumps 3 inches or less in size. It was ground in water in a ball mill, and the dried pulverized powder was mixed with 7 drops per gram or 0.16 part by weight of linseed oil to make a paste that would spread readily. The color of the paste lay between mahogany (60136) and heliotrope (60137). When diluted with nine parts of zinc oxide it changed to between old rose (60172) and crocus (60186). The ferric oxide content was 88.7 percent. This material was grouped with maroon pigments. The concentrated or full-strength color was light maroon (60072) and when diluted or let down with zinc oxide changed to maroon plus old rose. The tinting strength was medium or equal to the commercial red oxides. This pigment has already received commercial attention.

MICHIGAN NO. 3

Sample no. 3 also was submitted by Pardee. This graphic slate comes from Baraga County, Mich. The particular deposit from which the sample was taken was in the Arvon district a short distance south of L'Anse. A small amount of this slate is used in paint manufacture. There is a large amount of this slate, some suitable for roofing. This formation is described as being of Upper Huronian age.

Laboratory tests.—The 2-pound sample of black slate (5-inch lumps) was ground with water in the ball mill, and the dry pulverized powder was mixed with 24 drops per gram or 0.56 part by weight of linseed oil to make poorly working, poorly plastic paste between midnight (60060) and smoke (60036). When diluted with nine parts of zinc oxide the color changed to between gobelin (60077) and steel (60052). The ferric oxide content was 10.9 percent and the carbon content 18.4 percent. This material was classed with neutral black and blue-gray pigments. The full-strength color was not as black as the Vandyke concentrated color, but was more neutral and darker or lower in value than graphite. When diluted it had the same hue, but was stronger than graphite 697 and Vandyke brown. This material has possible commercial value in this limited class of pigments and should be investigated further.

MINNESOTA

The occurrence of iron ore in Minnesota has been summarized by Schrader, Stone, and Sanford [47] as follows:

> **Brown iron ore** (limonite).—St. Louis County, large production from Mesabi and Vermilion ranges. Large quantities in contact plane of Cretaceous on Silurian and Devonian, as in Brown, Lesueur, Fillmore and other counties; also in Cuyuna district. * * *.
>
> **Hematite** (red iron ore).—St. Louis County, large quantity, many mines in Mesabi, Vermilion, and Cuyuna ranges. Shipments amount to millions of tons annually. * * *.
>
> **Mineral paint.**—Redwood County, kaolinized gneiss and granite were used for paint at Redwood Falls.

No samples were submitted from Minnesota.

MISSISSIPPI [48]

Mineral pigments in Mississippi occur chiefly in two geologic horizons. The first horizon, including samples 1, 2, and 3, is the Tuscaloosa formation, which lies at the base of the Upper Cretaceous and is composed chiefly of chert gravel, with some sand, and a few beds of clay. The outcrop of the Tuscaloosa is limited to the extreme northeast corner of Mississippi, including parts of Tishomingo, Itawamba, Alcorn, Prentiss, Monroe, and Lowndes Counties.

The other horizon carrying mineral pigments of importance is the lower part of the Wilcox formation, Eocene age. This lower member of the Wilcox has been called the Ackerman and is composed chiefly of clay, with some sand and bauxite. It outcrops in a belt running through Benton, Tippah, Union, Lafayette, Pontotoc, Calhoun, Chickasaw, Webster, Choctaw, Winston, Kemper, and Lauderdale Counties. Samples 4, 5, 6, 7, 8, and 9 are from this horizon in the extreme north central part of Tippah County and about 50 miles west of the point from which the first three samples were taken.

Table 73 shows the location of the formations carrying the ocher strata.

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[47] Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful Minerals of the United States: U.S. Geol. Survey Bull. 624, 1917, pp. 169, 170.

[48] The following samples and geographic and geologic data were supplied by Ralph E. Grim, assistant State geologist, and David C. Hester, collector of the Mississippi Geological Survey. The tests were made in Seattle.

Table 73.—*Geologic column for Mississippi*

Recent	River alluvium.
Pleistocene	Loess.
	Port Hudson.
Pliocene	Citronelle.
Miocene	Pascagoula.
Oligocene	Hattiesburg.
	Catahoula.
	Vicksburg.
Eocene	Jackson.
	Upper Claiborne.
	Lower Claiborne.
	Wilcox (ocher).
	Midway.
Cretaceous	Ripley.
	Selma.
	Eutaw.
	Tuscaloosa (ocher).
Paleozoic.	

TESTS OF MISSISSIPPI PIGMENTS BY THE UNITED STATES BUREAU OF MINES

MISSISSIPPI NO. 1

Mississippi no. 1 came from a deposit owned by John Nunley, R.F.D., Iuka, Miss. The deposit is in Tishomingo County 2 miles south of Gravel Siding on the Iuka-Florence road, 3 miles south of the Southern Railway and 1¼ miles west of a graveled road. It is exactly on the Mississippi-Alabama line, and the adjoining land in Alabama is owned by W. B. Leatherwood, Iuka, Miss. The yellow-brown ocher color is constant throughout the 4 feet of outcrop, uncovered, and is free of grit. Borings indicate a thickness of 9 to 11 feet, and the deposit can be followed 300 yards south and 200 yards west of the sample location. The overburden is estimated at about 20 feet of gravel, clay, and ferruginous sandstone, forming a wooded ridge which covers and hides the deposit. In 1917–18 Leatherwood shipped two carloads of this material to the Quaker Mineral & Paint Co., Kansas City, Mo., which reported the material to be of high quality.

Laboratory tests.—The material received at the laboratory consisted of lumps of soft, fine-grained, buff-brown clay that disintegrated easily in water and left only 1.4 percent of clean sand when washed. The dried powder required 15 drops per gram or 0.35 part by weight of linseed oil to make a stiff and rather poor-spreading paste for the color slides. When ground in oil the color was golden topaz (60112) and when diluted with nine parts of zinc oxide was a leghorn (60005)-chamois (60179) mixture. The ferric oxide content was 3.6 percent. This material was classed with Pennsylvania, class 2, light orange-yellow, ochers, slightly grayed. The dilution test, however, indicated weak tinting strength of cream hue. It therefore could be used only in weaker-grade yellow ochers.

MISSISSIPPI NO. 2

Armstead Allsbrook, Corinth, Miss., is the owner and W. B. Leatherwood, Iuka, Miss., the agent in charge of a deposit in Tishomingo County, sec. 30, T. 2 S., R. 11 W., from which sample no. 2 was collected. The deposit is 4½ miles north of the Southern Railway and 1 mile west of a gravel road. The material is red, gritty clay spotted by small masses of white clay and thin sheets of blue-black iron oxide. The vein shows a thickness of 11 feet for about 200 yards, partly covered. The overburden, ranging from 2 to 30 feet and averaging about 25 feet, consists of 6 inches of ferruginous sandstone covered by clay and gravel. An opening known as the Leatherwood Red mine was opened in 1917–18, and 25 tons were shipped to an unknown destination. The deposit is 6 feet above the base level of drainage.

Laboratory tests.—The sample as received was reddish-brown clay with a few black iron mineral spots and some white kaolin inclusions. The material dispersed readily in water; washing removed 16 percent of brown sand. The dried fines were mixed with 17 drops per gram or 0.39 part by weight of linseed oil and made into a mahogany (60136) paste. When mixed with nine parts of zinc oxide the color was grayed honeydew (60062). The ferric oxide content was 4.7 percent. This pigment was listed with class 1, red-brown, burnt ochers, but the tinting strength was weaker than any burnt-sienna colors tested, although stronger than raw siennas or ochers. It could therefore have only local value.

MISSISSIPPI NO. 3

E. P. Craddock, Iuka, Miss., owns a deposit from which Mississippi no. 3 was collected, in Tishomingo County, S½ sec. 17, T. 3 S., R. 11 W., 2 miles north of the Southern Railway and one fourth mile north of a gravel road. The deposit shows an irregularly colored, red, gritty clay, with some thin sheets of blue-black iron oxide scattered throughout the mass. A 9-foot thickness shows at the water line of a small creek for about 35 feet along the bank; the seam apparently extends through the ridge approximately 150 yards and 100 yards upstream from the point of sampling. A well-wooded ridge, consisting of sandstone, clay, and gravel a fraction of an inch to 40 feet thick, averaging 30 feet, covers the material. The deposit has not been developed.

Laboratory tests.—The sample as received consisted of soft, light reddish-brown clay lumps with numerous buff streaks. It blunged fairly easily; washing removed 13.4 percent of gray and brown sand. The fines were very plastic and required 14 drops per gram or 0.32 part by weight of linseed oil to make a henna (60135) paste. When diluted with nine parts of zinc oxide the color was between blossom (60171) and sunset (60088). The ferric oxide content was 2.5 percent. The pigment was grouped with class 2, red-brown, burnt ochers, but its color strength was inferior to that of others tested in this study. Its pink hue was about the strength of the tan hues of the ochers. Its commercial value is therefore more doubtful than that of Mississippi no. 2.

MISSISSIPPI NO. 4

Mississippi no. 4 was collected from a deposit owned by Rucker Bros., Ripley, Miss., in W½ sec., T. 4 S., R. 3 E., Tippah County, Miss., 2 miles west of the Gulf, Mobile & Northern Railroad and 1 mile west of a gravel road. The material shows a constant color, except for a blue tint noted along the cleavage planes. A thickness of 4 feet of ocher has been uncovered, which probably widens to more than 15 feet under the center of the ridge. Three outcrops 150 to 175 yards apart have been noted around the sides of the ridge. The overburden probably will average about 30 feet in thickness, ranging from a fraction of an inch to 52 feet; the latter depth is shown in a well on top of the ridge. The overburden consists of 2 inches of ferruginous sandstone and a layer of clay and gravel. The ocher has been sampled extensively, but the deposit has never been opened for commercial development.

Laboratory tests.—The material as received was similar to sample 1. It washed easily, and 0.7 percent of gray sand was removed. Sixteen drops per gram or

0.27 part by weight of linseed oil was used to make a golden topaz (60112) paste. When diluted with nine parts of zinc oxide the color was between chamois (60179) and leghorn (60005). The ferric oxide content was 3.5 percent. The color strength was classed with the weaker commercial yellow ochers, but the material had a very acceptable golden hue. If mining and transportation costs are reasonable this pigment has commercial possibilities. It was grouped with Pennsylvania, class 2, light orange-yellow, ochers, slightly grayed, and was close to light-grade French ochers. The dilution test indicated medium tinting strength with a cream hue.

MISSISSIPPI NO. 5

S. Walter Jackson, Blue Mountain, Miss., owns an ocher deposit in Tippah County 5½ miles west of Blue Mountain, ½ mile southwest of Flatrock church, 3¾ miles north of the Bankhead highway, 5 miles north of the Frisco Railway at Hickory Flat, and 5½ miles west of the Gulf, Mobile & Northern Railroad at Blue Mountain. Two and a half feet of ocherous material are exposed for 150 feet. Its depth is unknown. The seam shows irregular coloring with white streaks along the fractures. The overburden is estimated to average about 18 feet, ranging from 1 to 25 feet; it consists of 2½ feet of ferruginous sandstone (called "paint rock" locally) and gravel, sand, and clay. The property is under option to the Blue Mountain Mining Co. but has never been developed.

Laboratory tests.—The sample was similar to Mississippi no. 1. When dispersed in water 26.8 percent of light-gray sand and mica was removed. The fines were dried and pulverized and when mixed with 22 drops per gram or 0.51 part by weight of linseed oil gave a golden topaz (60112) paste. When diluted with nine parts of zinc oxide the color was chamois (60179). The ferric oxide content was 7.4 percent. The material was grouped with Pennsylvania, class 2, light orange-yellow, ochers, slightly grayed. The dilution test indicated medium tinting strength of cream hue. If it were not for the low ferric oxide content this material would have commercial possibilities.

MISSISSIPPI NO. 6

Mississippi no. 6 came from the property of F. T. Dickson, Blue Mountain, Miss., in Tippah County, 3¼ miles north of Bankhead highway, 4¾ miles north of the Frisco Railway at Hickory Flat, and 5¾ miles west of the Gulf, Mobile & Northern Railroad at Blue Mountain. The material is irregularly colored, gritty clay. A 2- to 4-foot outcrop of unknown depth extends 250 yards. The overburden averages about 30 feet in thickness and consists of 2 to 3 feet of ferruginous sandstone and a layer of sandy clay and gravel. The deposit has never been developed, although it is under option to the Blue Mountain Mining Co.

Laboratory tests.—This material is likewise a soft, claylike ocher, which disperses readily in water; washing removed 41.7 percent of brown and black sand particles. The powdered fines were mixed with 20 drops per gram or 0.46 part by weight of linseed oil to make a stiff golden topaz (60112) paste. When diluted with nine parts of zinc oxide the color was dark chamois (60179), deeper in strength than previous Mississippi ochers tested. The ferric oxide content was 12.6 percent. The material was grouped with Pennsylvania, class 2, light orange-yellow, ochers, slightly grayed, close to French in quality. The full-strength color was even yellower than French light grade. The dilution test indicated good tinting strength with a yellow hue. Although the ferric oxide content was below Government requirements physical tests indicated good commercial value.

MISSISSIPPI NO. 7

Mississippi no. 7 came from the deposit of W. D. Shelton, R.F.D. 2, Faulkner, Miss., in Tippah County, sec. 17, T. 3 S., R. 3 E., 4 miles west of the Gulf, Mobile & Northern Railroad and 4 miles west of a gravel road at Faulkner. The material is pale, irregularly colored, gritty clay. A bed 4 to 6 feet thick is exposed for one quarter mile on both sides of a spring ravine. The overburden averages about 25 feet in thickness, ranging from a fraction of an inch to 35 feet; it is composed of ferruginous sandstone, gravel, and red, sandy clay.

Laboratory tests.—The sample as received was a soft, very light, buff-gray clay containing a few streaks of lighter-colored clay. It dispersed readily in water; washing removed 17 percent of clean gray sand. Twenty-two drops per gram or 0.51 part by weight of linseed oil was required to produce a golden topaz (60112) paste. When diluted with nine parts of zinc oxide the color was only dark cream (60003). The iron oxide content was 4.7 percent, and the color strength was a little low for commercial-pigment service. This material was grouped with Pennsylvania, class 2, light orange-yellow, ochers, slightly grayed. The full-strength color varied from the standard toward gray. The dilution test indicated weak tinting strength with cream hue. Its use in industry is therefore doubtful.

MISSISSIPPI NO. 8

W. D. Shelton, R.F.D. 2, Faulkner, Miss., submitted Mississippi no. 8, a sample from an ocher deposit in Tippah County, sec. 17, T. 3 S., R. 3 E., 4 miles west of the Gulf, Mobile & Northern Railroad and 4 miles west of a gravel road at Faulkner. The color of the ocher was fairly constant, except for a scattering of white bauxitic nodules. The material forms a weak, rocklike structure and feels gritty. A seam 6 to 14 inches thick is estimated to cover about 1,000 square yards, overlain with 2 to 6 feet of red, sandy clay.

Laboratory tests.—The yellow-brown chunks showing the bauxitic nodules were too hard for dispersion in water; after being crushed a sample was therefore ground in water in the pebble mill. Eighteen drops per gram or 0.42 part by weight of linseed oil was needed to make a golden-brown topaz (60112) paste. When diluted with nine parts of zinc oxide the color was brownish tan (60089). The iron oxide content was 41.3 percent, and the color strength very good. If enough of this material can be obtained it should have commercial value. According to data furnished by the Mississippi Geological Survey, only about 490 tons of ocher of a dry-bulk specific gravity of 2.11, as determined from small chunks, could be obtained from this deposit. This material was grouped with French, class 1, dark orange-yellow, ochers. The dilution test indicated that the tinting strength was better than that of dark-grade French ochers with a variation toward orange. If more of this material were available it would have commercial value.

MISSOURI

H. A. Buehler, State geologist, reports that from time to time mineral pigments have been produced from the soft red-iron ores of central Missouri but have been used chiefly in mortar.

At Iron Mountain, Mo.,[49] Paleozoic rocks rest upon a deposit of boulders of iron ore and porphyry, which in turn lie upon pre-Cambrian porphyry. The porphyry also contains deposits of hematite. These hematite deposits are believed by Geijer to have been derived by alteration from magnetite and point to the association with apatite and the occurrence as dike-shaped masses in the pre-Cambrian porphyry.[50]

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[49] Nason, F. L., Report on Iron Mountain Sheet: Missouri Geol. Survey, vol. 9, 1912.

[50] Lindgren, Waldemar, Mineral Deposits: McGraw-Hill Book Co., New York, 1919, pp. 246, 803.

Limonites have been reported in the Ozark region of Missouri and Arkansas; they occur in residual clays over Cambrian limestone, but have little economic value.[51]

The occurrence of iron ore in Missouri has been summarized by Schrader, Stone, and Sanford [52] as follows:

> **Brown iron ore (limonite).**—Franklin County, mixed with ocher and chert in cavities at Bowlen Bank, Iron Hill, and Stanton Hill Bank, dug from pits near Moselle, and shipped; Howell County, Lamons mine, near West Plains, mined and shipped to lead smelters in Kansas City; Madison County, Mine Lamotte, formerly used mainly for flux. Found chiefly in Cambrian limestones widely distributed over counties of the southern and central parts of the State; has been mined in numerous localities * * *.
>
> **Hematite (red iron ore).**—Crawford County, in sandstone at Craig mine. Dent County, Flank, Hawkins, and Sligo mines. Franklin County, at Leslie mine. Phelps County, at De Camp. Reynolds County, good quality in sandstone on west limit of Bee Fork of Black River in January mine. Also in Callaway, Cooper, Henry, Lincoln, and Saline Counties. * * *.
>
> **Ocher.**—Henry County, common in the Pennsylvanian rocks of western part of the State, near Calhoun. Johnson County, Knobnoster, many exposures in this vicinity. A red ocher in Andrey County, Amazonia, and Jackson County, Hickman Mills. Others in Buchanan, Lafayette, and Ray Counties. Produced to some extent in hematite mines of central Ozark region.

No samples were submitted from Missouri.

MONTANA

The occurrence of iron ores in Montana has been summarized by Schrader, Stone, and Sanford [53] as follows:

> **Brown iron ore (limonite).**—Cascade and Meagher Counties, found at a number of localities in Little Belt Mountain district. Deer Lodge County, at Cable mine. Fergus County, formerly mined in Judith Mountains, prospected at Woodhurst Mountain and in Little Belt Mountains. Jefferson County, at many places in Elkhorn and Wickes districts; mined at Elkhorn Peak iron mine. Philips County, occurs in oxidized ores of gold deposits near Landusky and Alabama. * * *.
>
> **Hematite (red iron ore).**—Deer Lodge County, found in Cable mine. Jefferson County, with magnetite, in iron mine on Elkhorn Peak, Elkhorn district.

One sample was received and tested.

MONTANA NO. 1

Montana no. 1 and its description were received from R. T. Ogle, 1100 Missouri Avenue, Butte, Mont. Apparently the ocher or limonite lies at the contact of limestone and diorite near a shale seam. The ore body is about 4 feet wide and outcrops several hundred feet. The deposit is about 3 miles from Waterloo station on the Northern Pacific Railway branch line. An iron content of 43 percent is reported. No work has been done on this deposit.

Laboratory tests.—The 4-pound sample as received was a mixture of hard, rocklike, dark-brown or black limonite and softer, yellow-brown, ocherous material. A vesicular structure was noted in certain portions. The sample was ground to the proper fineness in water and when dry produced a hard mass of rather high shrinkage. The pulverized powder was mixed with 15 drops per gram or 0.35 part by weight of linseed oil to produce a paste between terrapin

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[51] Ries, H., Economic Geology: John Wiley & Sons, Inc., New York, 4th ed., 1916, p. 556. Penrose, R. A. F., The Tertiary Iron Ores of Arkansas and Texas: Geol. Soc. America Bull. 3, 1892, pp. 44-50. Crane, C. W., The Iron Ores of Missouri: Missouri Bureau Geol. and Mines, 2d ser., vol. 10, 1912, pp. 107-144. Geijer, Per, Some Problems in Iron-Ore Geology in Sweden and America: Econ. Geol., vol. 10, 1915, pp. 107-144.

[52] Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful Minerals of the United States: U.S. Geol. Survey Bull. 624, 1917, pp. 174, 176, 177.

[53] Work cited, pp. 180, 183.

(60091) and topaz (60112). When diluted with nine parts of zinc oxide the color changed to dark sunset (60088). The ferric oxide content was 51.6 percent. This material was grouped with class 1*a*, pink, siennas. The full-strength color was darker than the French ocher, varying toward orange, but was much cleaner or clearer than Pennsylvania ochers. The dilution test indicated a tinting strength equal to that of the strongest French ocher, with a variation toward gray-pink. If economic conditions are satisfactory this material should have commercial value.

NEBRASKA

Ocher occurs in a number of places in the northeastern counties on the Platte River and along the Republican River. The most promising deposit is supposed to be that at Indianola, Red Willow County. Here it is reported to be 20 to 40 feet thick, very uniform, and free from sand and silt. A mill was built, which is still standing, and excellent paint was produced; the citizens of the State hoped that a useful industry would be developed. For a time the output was considerable, but for several years the mill has been closed. In the region about Indianola well diggers report that this bed of ocher is encountered everywhere; according to accounts the deposit is large. By roasting the ocher various colors are produced, ranging from light-yellow tints to medium and deep shades of red and brown. Iron paints are cheap and particularly serviceable.[54]

This ocher has been manufactured in various forms and at one time was exhibited at all Nebraska State fairs. No samples were submitted from Nebraska.

NEVADA

No general report on the iron occurrences of Nevada has been published, but the following deposits have been noted: [55]

> **Brown iron ore (limonite).**—Not mined as an ore of iron but occurs abundantly in the oxidized portions of deposits worked for other metals and may carry gold and silver, as in the following districts: Esmeralda County, Cuprite and Goldfield districts, Gold Mountains district. Eureka County, carries free gold, principal component of Ruby Hill ores. Humboldt County, with argentite at Brown Palace mine, Rosebud district. Lander County, Mud Springs, 4 miles north of Lander. Lyon County, Mason Valley mine, Yerington district, also with hematite and magnetite near Dayton. Nye County, Bullfrog and Silverbow districts. * * *.
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> **Hematite.**—Clark County, low-grade oölitic near Las Vegas, not mined. Eureka County, mined at Barth, shipped. Humboldt County, mined near Lovelock; reported 30 miles south (?) of Golconda. Lyon County, high-grade hematite abundant in surface outcrops 12 miles northeast and 2 miles southwest of Dayton. Ormsby County, Bessemer mine.

The Barth iron-ore deposit has been described by Jones [56], and the iron ores near Dayton have been discussed by Harder.[57]

TESTS OF NEVADA PIGMENTS BY THE UNITED STATES BUREAU OF MINES

NEVADA NO. 1

The Solid Metals Mining & Leasing Co., 319 State Street, Reno, Nev., furnished two samples of Nevada ocher. According to Edwin Arkell, secretary and manager, the seam can be traced for about 650

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[54] Barbour, E. H., Report of State Geologist: Nebraska Geol. Survey, vol. 1, 1903, pp. 181-186.

[55] Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful Minerals of the United States: U.S. Geol. Survey Bull. 624, 1917, pp. 191, 195.

[56] Jones, —, The Barth Iron-Ore Deposit: Econ. Geol., vol. 8, 1913, pp. 247-263; abs. Geol. Soc. America Bull. 24, 1913, pp. 96-97.

[57] Harder, E. C., Iron Ores Near Dayton, Nev.: U.S. Geol. Survey Bull. 430 E, 1910, pp. 240-245.

feet and shows several openings in the Wedekind mine, which has been worked for lead and silver. The mine is at Wedekind, Nev., 2 miles north of Sparks, on the Southern Pacific Railroad. The county highway is 300 yards from the deposit. The ocher vein is said to be about 35 feet thick, with a smaller seam of red pigment adjoining it (see Nevada no. 2). It is doubtful if enough red material can be found for commercial purposes.

Laboratory tests.—The sample as received was yellow-brown, coarsely ground ocher which dispersed readily in water, leaving 39.7 percent of lighter-colored sand. The resulting fines were soft and pulverized easily when dried. Seventeen drops per gram or 0.39 part by weight of linseed oil was required to produce a gold-brown (60113) paste. When diluted with nine parts of zinc oxide the color was pink sunset (60088). The ferric oxide content was 26.9 percent. This material was grouped with Pennsylvania, class 2, light orange-yellow, ochers, slightly grayed. The dilution test indicated weak tinting strength, with a variation from the standard toward pink-gray, whereas the iron oxide content indicated strong color.

NEVADA NO. 2

Nevada no. 2 came from the same location as Nevada no. 1.

Laboratory tests.—The sample as received was a brown-red material ground to pass about a 10-mesh screen. It dispersed readily in water, leaving 35.2 percent of lighter-colored sand. The fines dried to a rather hard mass, with moderate shrinkage. Nineteen drops per gram or 0.44 part by weight of linseed oil was required to make a poorly working stiff mahogany (60136) paste. When diluted with nine parts of zinc oxide the color was grayed Grecian rose (60175). The ferric oxide content was 11.5 percent. This material was grouped with the class 2, violet, mineral browns. The full-strength color was light, bright, brown-red, close to red oxides in hue. The tinting strength was medium or about equal to commercial metallic browns, and the let-down hue varied from the standard toward violet. If enough material in uniform quantities can be mined with the ocher of Nevada 1 this material may have commercial value.

NEVADA NO. 12

Yellow ocher was submitted by A. F. Green, Lovelock, Nev.

Laboratory tests.—The sample was ground in water in the pebble mill and produced a very plastic mass of high shrinkage when dried. When pulverized and mixed with 20 drops per gram or 0.46 part by weight of linseed oil it formed a brown topaz (60112) paste. When diluted with nine parts of zinc oxide the color was light sunset (60088). The ferric oxide content was 17.5 percent. This material was classed with Pennsylvania, class 2, light orange-yellow, ochers, slightly grayed. The dilution test indicated medium tinting strength, with a cream hue. The pigment therefore has commercial possibilities if economic conditions are satisfactory.

NEVADA NO. 14

Nevada no. 14 was sent by John T. Reid, Lovelock, Nev., who also described the deposit. The pigment occurs as mud for 3,000 feet along an exploration tunnel in White Cloud Canyon, Stillwater Range, in the west center of T. 23 N., R. 34 E., Churchill County. The mine is 1½ miles from the mouth of the canyon at an elevation of about 5,200 feet; the adjacent valley floor is about 4,000 feet. The mine is marked "Coppereid" on United States Geological Survey quadrangle sheet Carson Sink; it is 33 miles across another mountain range to Lovelock, but 45 miles on a comparatively level road to Fallon and the railroad.

The size of the seam is not known. The exploration work was done for copper, zinc, and iron ores. The pigment is supposed to have originated from decomposition of pyrite; according to Reid a seam 100 feet thick, composed of pyrite and iron oxide, occurs between quartzite and igneous rock.

Laboratory tests.—The sample as received was a light-weight, very soft, brown, powdery material, which tended to float when mixed with water. It acted like weathered volcanic ash. When ground in the pebble mill in water it foamed from some salt action and was hard to screen through a 300-mesh sieve. The dried powder was mixed with 28 drops or 0.65 part by weight of linseed oil to make a dark mahogany (60136) paste. When diluted with nine parts of zinc oxide the color was darker than tan (60089) but not as dark as gold-brown (60113). The ferric oxide content was 22 percent. These data indicated medium tinting strength, and the pigment was grouped with class 1, red-brown, burnt siennas; if enough cheap, uniform material of this quality can be found it will have commercial value. The medium neutral brown of the full-strength oil mixture diluted to a medium-strength yellow-brown.

NEVADA NO. 15

Nevada no. 15 was received from C. F. Hendricks, Sparks, Nev. The deposit is on a good wagon road 2½ miles from the Virginia & Truckee Railroad station of Lakeview near Carson City. The Virginia & Gold Hill water pipe line runs through the claims. Hendricks estimated that this deposit contains 85,000 to 90,000 tons of red pigment covered with 12 to 18 inches of black loam. The pigment contains some large boulders.

Laboratory tests.—The sample received was a single 6-inch lump of deep-red clay. It was very difficult to disperse the pulverized material in water and to wash it without losing a large quantity of good red pigment, so a sample was ground in water in the pebble mill. Little impurity was added by this procedure. The material could probably be washed more easily if dispersed in water as soon as removed from the ground. When ground with 23 drops per gram or 0.53 part by weight of linseed oil it formed a poor, very plastic mahogany (60136) paste. When diluted with nine parts of zinc oxide the color was tea rose (60021). The ferric oxide content was only 2.3 percent; the indicated color strength was weak, and the pigment was classed as weak burnt ocher of no general commercial value.

NEVADA NO. 16

The sample received from Owen Weaver, Deeth, Nev., was taken from a deposit about 50 miles north of Deeth.

Laboratory tests.—The 4-ounce sample consisting of 1-inch or smaller brown particles with indications of carbonates was ground in water. The dried, pulverized fines were mixed with 20 drops per gram or 0.46 part by weight of linseed oil to make a gold-brown (60113) paste. When diluted with zinc oxide the color changed to chamois (60179). The ferric oxide content was 23 percent. This material was grouped with Pennsylvania, class 2, dark orange-yellow, ochers, slightly grayed. It might also be classed as weak sienna. The dilution test indicated good tinting strength with a variation in hue toward gray. If mining and economic conditions are satisfactory, this material has commercial value.

NEVADA NO. 21

Nevada no. 21 was submitted by Roxton Whitmore, St. Thomas, Clark County, Nev.; the deposit, which is about 4 feet thick, lies along a wagon road 7 miles east of St. Thomas and the railroad in Clark County. According to Whitmore, the estimated cost of delivery to cars is about $2 per ton.

Laboratory tests.—The 1-pound sample consisted of red, brown, and black lumps of nonplastic material. No carbonates were present. The pulverized material, after being ground in water, required 12 drops per gram or 0.28 part by weight of linseed oil to produce a brown (60114) paste. When diluted with nine parts of zinc oxide the color changed to champagne (60097). The ferric oxide content was 31.6 percent, yet the tinting strength was too weak to be classed with commercial-grade, class 1, red-brown, burnt siennas. Perhaps more efficient methods of preparation could be devised to bring out the stronger tints indicated by the chemical analysis.

NEVADA NO. 22

Another sample submitted by Roxton Whitmore, St. Thomas, Nev., was a hematite occurring 12 miles from St. Thomas and the railroad. The deposit is reported to be very large, with a limestone contact and no overburden.

Laboratory tests.—The ⅛-pound sample as received was a deep-red, lightweight porous material, with a slight indication of carbonates. After being ground in water and dried it required 33 drops per gram or 0.73 part by weight of linseed oil to make a brown (60114) paste. When diluted with zinc oxide the color changed to terrapin (60091) (also reddish). The ferric oxide content was 70.3 percent. This material was grouped with class 1, red-brown, burnt siennas. The dark neutral brown of the undiluted pigment in oil diluted to strong yellow-brown of commercial value. The tinting strength was equal to those of commercial burnt siennas.

NEVADA NO. 25

The sample submitted by G. Scrugham from the property of Roxton Whitmore, St. Thomas, was probably a duplicate of Nevada no. 22.

Laboratory tests.—The 4-pound sample as received consisted of 6-inch and smaller lumps of very soft, uniformly colored, sienna-brown material, so light it floated in water like pumice. When ground in water and dried the pulverized material required 28 drops or 0.64 part by weight of linseed oil to produce a tobacco (60143) paste. When diluted with zinc oxide the color changed to terrapin (60091). The ferric oxide content was 63.2 percent. This material was grouped with class 1, red-brown, burnt siennas. The full-strength, dark, neutral brown diluted to strong yellow-brown comparable to standard burnt siennas. The tinting strength was very good, and, if economic and marketing conditions are satisfactory, this material should have commercial value.

NEVADA NO. 26

Nevada no. 26 and data regarding it were submitted by H. W. Rast, Austin, Nev., owner of a deposit in the SE¼ sec. 9, T. 23 N., R. 43 E., M.D.M., Lander County, Nev., about 1½ miles southwest of Walter's station on the Nevada Central Railroad. Rast has held the property, consisting of 100 acres, for 38 years and worked it chiefly for lead-silver ore, which occurs as pockets in the iron oxide. The surrounding rock is limestone; the ore occurs as a seam, which is thought to extend to ground-water level 800 to 1,000 feet below. An adit 420 feet long has already been driven; this is expected to strike the ore at 450 feet. The vein ranges from 1 to 10 feet in width. Thousands of tons of ocher of both types (nos. 26 and 27) are reported to be exposed. Rast estimated that the cost, f.o.b. railroad cars, would be less than $20 per ton and if handled on a large scale would probably be one half that figure.

Laboratory tests.—The 2-pound sample as received consisted of very hard 3-inch lumps to 10-mesh dark-brown to yellow-brown material that needed grinding. When pulverized it developed a much lighter color and required 15 drops per gram or 0.35 part by weight of linseed oil to produce a gold (60164) paste. When diluted with nine parts of zinc oxide the color changed to dark maize (60006). The iron oxide content was 87.5 percent. This was the strongest natural pigment of yellow ocher-sienna type noted in this report and is similar to the artificial yellow-brown colors produced by chemical means. It was placed with class 1, orange-yellow, siennas. If economic conditions are satisfactory, it undoubtedly has a commercial future.

NEVADA NO. 27

Another sample submitted by Rast was reported to be "extremely fine-grained jarosite, containing little or no loess." Rast states that it occurs in the same vein as no. 26 and contains gypsum.

Laboratory tests.—The 2-pound sample as received consisted of deep, yellow-brown lumps 2 inches in diameter to a powder. The lumps were compact but lightweight and soft. The acid reaction indicated a small amount of carbonate. A small portion was washed, but the residue contained so much of the strongly colored material that the remainder was ground in water. The dried material was a hard, high-shrinking mass. The pulverized fines required 16 drops per gram or 0.37 part by weight of linseed oil to produce a paste of a color between gold (60164) and maple sugar (60080). When diluted with zinc oxide the color changed to pablo (60090). The ferric oxide content was 61 percent. The dilution test indicated that the tinting strength was stronger than the tinting strengths of any Pennsylvania or French ochers; the pigment was classed with the 80 percent iron oxide artificial ochers. If economic conditions are satisfactory it should have commercial value. It was likewise grouped with the class 1, tan, siennas.

NEW JERSEY

IRON OXIDE DEPOSITS[57a]

Four oxides of iron are found in commercial quantities in New Jersey: (1) Bog-iron ore occurs mainly as surface accumulations in bogs and swampy places in the southern portion of the State; (2) limonites or brown hematite are associated with the Kittatinny limestone (Cambrian) which occupies the valleys between the Highland ridges; (3) magnetites occur in the Algonkian gneisses and crystalline limestone of the Highland area; and (4) red hematite is found in the siliceous sedimentary rocks associated with the Franklin limestone (Algonkian) in a few scattered areas, distributed irregularly over the western part of the Highlands, mainly in Sussex County.

The limonites are associated with the Kittatinny limestone and are usually found near its contact with the underlying gneisses or with the overlying formations. While magnetite is the most important iron ore of the State, limonite is the most interesting for this study because of the yellow, yellow-brown, and brown-black colors.

LIMONITES

Although mined to a limited extent in 1910 limonite was formerly an important ore, being much in demand for mixing with magnetite in iron furnaces. Production probably reached the maximum in 1871, when 15,000 tons were mined, but occurrence of the ore in small, pockety deposits made the supply so unsatisfactory that furnacemen stopped using it because they could not obtain steady deliveries of constant composition.

[57a] Abstract from Bayley, W. S., Iron Mines and Mining in New Jersey: Vol. 7 of Final Report, State geologist, Trenton, N.J., 1910, pp. 34–47.

Pure limonite is a compact, reddish-brown or black, metallic mineral that sometimes occurs in globular, stalactitic, or kidneylike masses with a fibrous structure. More frequently it is found in irregular reddish-brown lumps with a dull luster or as a red or brown earth, which when pure is known locally as "ocher." In general appearance this form of the mineral resembles some varieties of hematite, but can easily be distinguished from the latter by its streak or powder, which is brownish yellow instead of red.

The ore as mined consists of nodular masses and small fragments of the more compact varieties mixed with different proportions of ocherous earth, sand, and other impurities, such as small particles of rock and small quantities of various minerals.

Brown hematite differs from bog-iron ore in greater compactness and purity, texture, and method of formation. Both are composed essentially of the same substance, but bog ore is loose and porous and contains much clay and organic matter derived from the vegetable material of the marshes where it occurs. The ore as usually found contains so much impurity that more than 45 percent of iron is rarely present.

Occurrence.—New Jersey limonite ores are usually associated with blue or Kittatinny limestone, more particularly near its upper and lower contacts. It occurs in very irregularly shaped layers or flat lenses that follow the general direction of the contact planes—as steeply inclined, veinlike deposits when the contact planes dip and as gently inclined, bedlike deposits when the contact planes are more nearly horizontal. The lenses are separated by ferruginous clay or highly decomposed barren limestone. Small masses of compact, rich, fibrous ore are often embedded in the clay, but the greater portion of the ore is a mixture of porous, earthy nodules, stalactitic masses, ocherous material and lenses, and sharp-edged fragments of jasper or chert. When the ore is in joint fractures sharp-edged fragments of adjacent rocks are often intermingled in this mixture, and the whole mass is cemented by compact ore.

The boundaries of the deposits are extremely irregular, the ore often extending into the limestone along its bedding planes or along joint cracks for considerable distances beyond the main mass of the deposit.

Distribution.—Most limonite is in the Kittatinny limestone, which in New Jersey occupies the valleys between the Highland ridges and extends from these northward into the Kittatinny Valley; south of the Highlands it occurs between the crystallines and the younger Newark beds. Limestone constitutes part of the great belt of the Cambro-Ordovician beds that stretches from Vermont to Alabama along the Great Appalachian Valley. Everywhere this belt is characterized by limonite deposits.

Origin.—The source of the ore in New Jersey is probably almost exclusively the limestone. Most gneisses of the Highlands are quite fresh. Their ferruginous components have altered little and therefore have not yielded a great quantity of iron to the solutions that deposited the limonite. Moreover, they contain an extremely small quantity of pyrite or its alteration products. The magnetite in the ore lenses is likewise fresh and unaltered and shows little evidence of solution. With these three sources of iron eliminated only the limestone remains to be considered. It always contains a small quantity of iron; in some instances it may have 1.25 percent of Fe_2O_3, and at one place—the Beatyestown mine—it contained 82.23 percent of $FeCO_3$. When comparing the composition of the limestone with that of the limonites one should remember that limonites represent accumulation of the undissolved residue of great masses of the limestone; therefore the original rock need not be very rich in iron to furnish abundant material for the production of huge ore deposits.

The limestones contain all the materials found in the ores except those occurring in very small quantities, and even these might have been discovered if analyses with that purpose in view had been made.

In a few instances the brown hematites have apparently been formed from the decomposition of pyrite, just as ferruginous sulphide veins everywhere are altered near the surface to limonitic compounds. Although this mode of origin is unusual for New Jersey limonites it is well established for certain Pennsylvania and Virginia ores.

Reserves.—Unquestionably, there is still much good limonite in the valleys between the Highland ridges. Many mines formerly worked were abandoned, not because the deposits were exhausted but because the low prices at which ore was selling a score of years ago made mining unprofitable. Iron can be manufactured from the Lake Superior and Alabama ores at a cost which prevents competition by eastern furnaces using local ores, except where abundant supplies can be obtained cheaply.

SUMMARY

Schrader, Stone, and Sanford[57b] have summarized the occurrence of the iron ores and mineral pigments in New Jersey as follows:

> **Brown iron ore (limonite).**—Many old limonite mines were formerly worked: Cumberland County, Shiloh; Hunterdon County, Califon and Bird mines; Morris County, German Valley, Denmark mine, Copper and Chester mines, Hacklebarney; Sussex County, Andover mine, Edsall mine near Hamburg, Pochuck mine near McAfee; Warren County, Beatyestown, Marble Mountain, Fittz, and Shoemaker mines. * * *.
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> **Hematite (red iron ore).**—Sussex County, was formerly mined in Simpon and Cedar Hill mines near McAfee; Warren County, small quantities mined at Marble Mountain. * * *.
>
> **Ocher.**—Camden County, occurs at Camden. Middlesex County, Lincoln. Warren County, mined recently near Phillipsburg. Shale paint has been worked at Bound Brook in Somerset County.

An attempt was made to obtain a sample of the iron ore left on the dump of the abandoned iron mine near Oxford Furnace; but O. B. Hewitt, Hewitt Realty Co., 50 Church Street, New York City, stated that the entire supply of this material had been sold for pigment and gas-cleaning purposes.

The foregoing description of New Jersey limonite ores indicates that a large supply of sienna brown, umber, brown-blacks, and possibly lighter-colored ochers can be found but that development awaits favorable economic conditions; meanwhile, New York, Pennsylvania, and Georgia will supply the demand for these materials.

No samples were submitted from New Jersey.

[57b] Schrader, F. C., Stone, R. W., and Sanford, Samuel. Useful Minerals of the United States: U.S. Geol. Survey Bull. 624, 1917, pp. 204-206.

NEW MEXICO

Schrader, Stone, and Sanford[57c] give the following occurrences of iron ores and mineral pigments in New Mexico:

Brown iron ore.—Common in all oxidized ores. Grant County, at Silver City, small quantity mined with magnetite near Fierro, Union mines; formerly mined in Glorieta district, Central district, Clarks Peak district. Lincoln County, occurs northeast of White Oaks, in Capitan Mountains, and at Lone Mountain, Jicarilla district, near Jack Mountain, Red Cloud (Gallinas) district, and at the Rock Island group of iron mines, 3 miles north of Tecolote station on the line of the El Paso & Southwestern System. Santa Fe County, east slope of Tuertos Mountains, Limestone district, about midway between Hermosa and Chloride; Mount Spring district, midway between Estey and Jarvis, near Santa Fe; near Glorieta; Perry deposits near San Pedro. Sandoval County, Placitas district, in Sandia Mountains (of bog-iron character). Socorro County, Jones district in north end of Sierra Oscura, Canyoncito, Wilcox, 15 miles southeast of Cooney. Sierra County, in Cuchillo Range, south of Chloride, large body of Iron Mountain group reported. Otero County, Jarilla. San Miguel County, Rociada, and reported near Las Vegas and on upper Rio Pecos. Torrance County, west of the Gran Quivira. Valencia County, prospected at head of Smelter Gulch, Zuni Mountains.

Hematite.—Common in oxidized ores throughout the State. Colfax County, in Iron Mountain at Elizabethtown, large deposit. Grant County, mined at Fierro. Santa Fe County, formerly mined in Glorieta district. Socorro County, Iron Mountain (Tenmile) district, 10 miles west of Magdalena. Taos County, Twining (Rio Hondo) district. Some of good grade in dikes of diorite porphyry.

Ocher (mineral paint).—Bernalillo County, near Coyote Springs, in the Sandia Mountains, east of Albuquerque, occurs in beautiful red and yellow beds, several feet in thickness. Santa Fe County, near San Pedro, large deposits with different tints.

New Mexico iron-ore occurrences are also described by Pauge[58] and Keyes.[59]

NEW MEXICO NO. 1

New Mexico no. 1 and data regarding it were sent by George H. Utter, 1834 East Second Street, Long Beach, Calif., through the Intermountain Experiment Station of the United States Bureau of Mines. This iron ore outcrops 13 miles northeast of Duncan, Ariz., near the road between Duncan and the Carlisle mines. It is part of the Three Brothers patent, of the Jim Crowe-Imperial group of eight patents in Steeple Rock mining district, Grant County, N.Mex. Duncan, Ariz., is the nearest railroad shipping point. The iron ore is reported to be about 100 feet thick with a hanging wall of monzonite. The outcrop of ore is probably 100 feet higher and about 600 feet west of Carlisle Creek and the road. The Three Brothers patent ore body is 20 feet wide and is exposed for more than 100 feet.

Laboratory tests.—The 3-ounce sample of hard, dark-brown ore was ground in water in a ball mill and dried and the pulverized powder mixed with 18 drops per gram or 0.41 part by weight of linseed oil to produce a henna (60135) paste. When diluted with 10 parts of zinc oxide the color changed to tea rose (60021). The ferric oxide content was 10 percent. This material was classed with the class 2, salmon, burnt ochers; but as the light, red-brown, full-strength color diluted to only weak cream-pink its general commercial value is very doubtful.

[57c] Work cited, pp. 210, 215, 217.

[58] Pauge, S., The Hanover Iron-Ore Deposits: U.S. Geol. Survey Bull. 380, 1909, pp. 199–214.

[59] Keyes, C. R., Iron Deposits of the Chupadera Measures: Eng. and Min. Jour., vol. 78, 1904, p. 632.

NEW YORK

Newland[60] States:

The raw materials or bases of the natural mineral paints that occur in New York include iron ores, shale or slate, and ochers.

Metallic paint may be made from hematite of earthy or massive nature, or from limonite. It is also prepared by calcination of siderite, ferrous carbonate or spathic iron ore, of which the natural gray color changes to red in the operation through the conversion of the carbonate into hematite. The iron sinter from the roasting of pyrite in acid manufacture is also sometimes employed for the purpose. * * *.

The principal material for metallic paint that occurs in the State is the Clinton hematite, which is mined quite extensively for iron ore. There are two kinds of the ore—the oölitic variety that occurs in the section about Clinton, Oneida County, and the fossil ore from the western part of the belt in Wayne County. The former has a silica base, the latter a carbonate one, and the ground product of each has a somewhat different color and quality. The manufacturing operations consist of roasting to get rid of the moisture and volatile matter and grinding to fine powder. The product is mostly sold in dry state.

The red hematite from the St. Lawrence-Jefferson County district has been employed for metallic paint to a small extent. This ore differs from the Clinton hematite in its structure, being finely divided and without oölitic or fossil characters. Much of it is too hard for paint, but some deposits yield soft material which can be ground successfully. The paint stock has been produced mainly at Rossie, St. Lawrence County.

No metallic paint is being made at present from limonite or carbonate ores, although these occur in quantity in southeastern New York.

Mortar colors are prepared from the same materials as metallic paint. They are used in tinting mortar, concrete, and artificial stone.

Some kinds of slate and shale possess decided colors by reason of the iron oxides they contain, as well as suitable textures for grinding into paints. Such slate pigments, as they are known in the trade, have a weaker coloring capacity than the ground ores, although they may contain enough iron to give a close resemblance to metallic paints. They yield a somewhat wider variety of tints, being found in purple, bluish gray, red, brown, and even black colors, the last being the result of admixed carbonaceous matter. They have an argillaceous base like ocher, but contain less water and are more compact.

The principal material used for slate pigment is the Cambrian red slate of Washington County, well known as a roofing slate and possessing a durable deep-red color. There are quarries of it in Granville and Hebron Townships. The waste material from the spoil banks is used for grinding and it is to be had in practically unlimited supply. Lately, the material is being utilized for making prepared roofing as well as for pigment. The red color comes from hematite in finely divided condition and as coating of the quartz and silicates which make up the body of the slate. The slate is hard and contains very little water. Shales that are intermediate between slate and clays in hardness occur in the Silurian and Devonian beds. At Roxbury, Delaware County, an occurrence of red shale in the Catskill series has supplied material for paint. Another source is the red Vernon shales which have been worked in Herkimer County. In the Chemung formations of Cattaraugus County occur red, brown, and bluish shales that have been worked in the vicinity of Randolph.

Ocher * * * is not plentiful in New York owing to the fact that the residual materials of rock decay have been mostly swept away by the Pleistocene ice sheet. An occurrence on Crane Mountain, Warren County, represents one of the few deposits of residual clays that escaped erosion by its protected position in a deep notch. It was worked years ago, but little is known as to the operations, and the pits are now inaccessible.

Ocherous clay occurs as a cover to some of the limonite deposits of Dutchess and Columbia Counties; its quality for paint purposes has not been investigated so far as can be learned.

The only recorded occurrence of sienna is near Whitehall, which was worked for a short time 10 years or more ago. The deposit consisted of a seam in the surface clays and was said to have been exhausted.

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[60] Newland, David H., The Mineral Resources of the State of New York: New York State Museum Bulls. 223 and 224, 1919, pp. 156–158.

IRON ORES OF NEW YORK

Iron ores are first in the list of metallic minerals mined within the State, outranking all others in extent of distribution and industrial importance. Mineral Resources for 1930 gave the following iron-ore production for the United States, in long tons:

Lake Superior district, hematite	62, 824, 768
Birmingham district, hematite and brown ore	6, 281, 565
Northern New Jersey and southeastern New York, magnetite	353, 612
Chattanooga, hematite and brown ore	155, 953
Adirondack district	[61] 749, 976
Other districts	[61] 2, 661, 846
Total	73, 027, 720

Iron mining and manufacturing in New York began in the southeastern section during the colonial period. In 1750 a limonite deposit near Mellerton, Dutchess County, part of the Salisbury district, was opened. A furnace was erected on the famous Sterling property in 1751, and the iron ore made there during the Revolution played an important part in supplying munitions for the Continental army. Production was active and totaled more than 1,250,000 long tons annually until 1890, when the industry began to decline because of competition with the new fields in the Middle West. For several years the district experienced a profound depression, which brought mining almost to a standstill. In 1898 the production for New York State was only 179,951 long tons. The revival started about 1900, and in recent years the annual production has exceeded 750,000 long tons. Future progress of the iron-mining industry in this district will depend largely on utilization of the low-grade ores—those containing as low as 20 to 25 percent of crude iron. There are immense resources of such ores; the total quantity can not even be estimated closely but is known to be hundreds of millions of tons, many times the amount mined so far.

DISTRIBUTION OF ORE

The workable deposits are found in the following areas given by Newland,[62] from whose reports most of the following section is abstracted.

1. **Adirondack region.**—Magnetite ores with locally associated hematite (martite) in pre-Cambrian acid igneous rocks; also in schists and gneisses of sedimentary origin. Mixtures of magnetite and ilmenite (titaniferous ores) in basic igneous rocks of the gabbro-anorthosite class, intrusive in the older gneisses. (See fig. 26.)
2. **Highlands of the Hudson.**—Magnetite in pre-Cambrian gneisses, in acid igneous rocks, and along the contact of igneous rocks and limestones.
3. **St. Lawrence and Jefferson Counties.**—Hematite associated with Grenville limestone and schist as replacement bodies.
4. **Central and western New York.**—Fossil and oölitic hematite, interstratified with Clinton limestones and shales in horizontal beds.
5. **Dutchess and Columbia Counties.**—Limonite associated with crystalline limestones, slates, and schists, representing metamorphosed sediments of early Paleozoic age. Siderite (carbonate of iron) accompanies the limonite in many places and in one or two of the mines in the principal ore. The deposits are secondary or of later age than the enclosing rock.
6. **Staten Island.**—Limonite in residual accumulations resting on serpentine.

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[61] Some hematite from "other districts" included with magnetite from Adirondack district.

[62] Newland, David H., The Mineral Resources of the State of New York: New York State Museum Bulls. 223 and 224, 1919, pp. 101-140.

Only types that may be a source of pigment materials will be discussed further.

HEMATITES OF ST. LAWRENCE AND JEFFERSON COUNTIES

Both soft and hard hematite is found in quantity in the pre-Cambrian of St. Lawrence and Jefferson Counties on the outskirts of the main Adirondack pre-Cambrian area. On this side the pre-Cambrian reaches from the highland into the St. Lawrence Valley and even extends across the latter into Canada. The hematite is associated more particularly with the sedimentary portion of the series, which is classed with the Grenville and is distributed in long belts running northeast-southwest. The wall rocks are usually rusty gneisses or schists, the same beds that contain the pyrite ores, but occasionally they are bordered on one or both sides by limestone. The ore bodies occur as seams that follow the schistosity of the gneiss and as irregular impregnations of the latter. They are apparently replacements of the country rocks formed by invading ferruginous solutions.

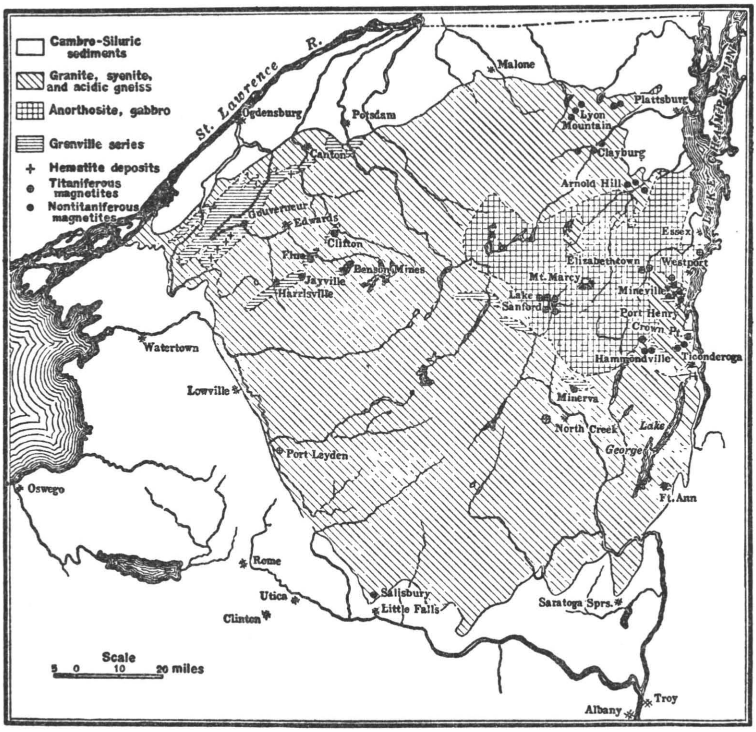

FIGURE 26.—Geologic map of Adirondack region, New York, according to Newland.

Occurrence.—There are a large number of mines and prospects within the area covered by Antwerp and Theresa, Jefferson County, and Gouverneur, Rossie, Hammond, Macomb, Fowler, Edwards, Hermon, De Kalb, and Canton, St. Lawrence County. The more important occurrences from the standpoint of the mining engineer are found in the gneiss belt, which extends from Philadelphia on the southwest into and across southern St. Lawrence County and includes the Antwerp-Keene deposits, which have been exploited most extensively.

The hematites contain over 40 percent of iron, the richest averaging from 55 to 58 percent, and a variable phosphorus content, too high for Bessemer ore. The main drawback for metallurgical work seems to be a rather high percentage of silica, arising from unreplaced quartz and silicates of gneiss and their alteration products. About 2,500,000 tons have been taken from this district since 1825.

Little systematic exploration has been attempted in this section; in fact less is known about its resources than of any other iron-ore district in the State. Most of the deposits opened so far were exposed at the surface or showed indications of their presence by the character of the soil, which usually shows a deep iron stain wherever in contact with the hematite below. The cover of drift on the uplands is thin, a few feet of sand and gravel with some boulder clay constituting the glacial deposit in most places. Some soft ore from the Old Sterling mine was used for paint. Most operations ceased about 1910.

CLINTON HEMATITES OF CENTRAL AND WESTERN NEW YORK

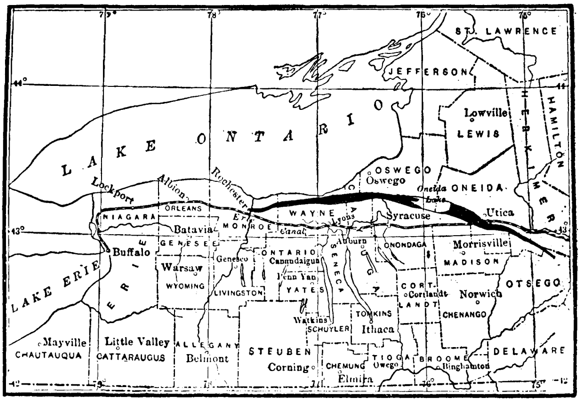

FIGURE 27.—Map showing outcrop of Clinton ore formation in New York, according to Newland (Ries).

The Clinton formation comprises an assemblage of shales and limestones mainly, with which one or more seams of hematite are commonly associated. The iron ore is not universally present, but occurs quite generally in the portion of the outcrop between Herkimer and Monroe Counties, a distance of 120 miles, about two thirds of the entire length of the belt. (See fig. 27.) The Clinton hematite is termed a "fossil" ore, as in many specimens fossil organisms originally of calcareous nature, but now partly or completely replaced by iron oxide, are discernible. The iron content of this ore ranges from 20 to 45 percent. In the eastern section of the outcrop, in Oneida and Oswego Counties, an oölitic bed is usually encountered. This ore has granular texture, as it contains small iron oxide particles with cores of quartz cemented with iron oxide. The seams throughout the whole formation range from 12 to 36 inches in thickness. In their entirety the Clinton ores constitute the largest known ore reserve in the State. It is estimated that approximately 600,000,000 tons of the ore exist in the principal areas already opened in ore seams at least 18 inches thick and under less than 500 feet of cover.

In 1921 the principal mine operations in the eastern section were those of C. A. Borst at Clinton. Part of the output was used in paint, for which the Clinton ore is excellently adapted, but most of it was sold to iron furnaces in Pennsylvania,

LIMONITES OF DUTCHESS AND COLUMBIA COUNTIES

The limonite deposits of Dutchess and Columbia Counties are a part of a long series of similar deposits that extend from Vermont through Massachusetts, Connecticut, New York, and south to Alabama along the main Appalachian uplift. They occur in the belt of metamorphosed Paleozoic sediments which lies to the west of the pre-Cambrian crystalline belt represented in New York State by the Hudson Highlands.

There are two principal groups of deposits; the one running northeast from Fishkill in the valley of Fishkill Creek, Dutchess County, and the other farther east following the north-south valley traversed by the Harlem Railroad from the Highlands in Dutchess County to Hillsdale, Columbia County. The latter group is the more important. The geologic formations within the vicinity comprise pre-Cambrian gneisses and stratified quartzites, limestones, and schists. The quartzites lie immediately on the gneiss and have been assigned to the Lower Cambrian; the limestones and schists above are supposed to range from Cambrian to Ordovician in age.

According to Smock, who visited many of the mine localities when operations were in progress and thus had advantages for observation not now obtainable, the ore occurs in limestones or along the contact of limestone and schist, or it lies wholly within the latter; as a rule the contact affords the most favorable locus for the ore occurrence. The limonite occurs in small irregular pockets as well as large bodies and is accompanied by ocherous clay.

The more important mines of the district lie within or close to the limestone valley that borders the high ridges of the Berkshires on the west and extends north and south along the New York and Massachusetts-Connecticut State line. The valley is narrow and broken in places by minor ridges of schist which rise on the west side into a series of prominences somewhat less rugged than those on the east side. This valley is followed by the Harlem Railroad (New York Central lines) and most of the mines are close by. The list of the larger productive properties includes the Dover, Amenia, Manhattan, Maltby, Mount Riga, Dakin, and Kelly mines in Dutchess County and farther north the Morgan, Reynolds, Weed, Copake, Hillsdale, Mitchell, and Haight mines in Columbia County. In the Fishkill-Clove Valley are the Shenandoah, Sylvan Lake, Pawling, Beekman, and Clove mines, all in Dutchess County.

The mines are mainly open pits, but drifts may be run from the sides or bottom along the course of the ore and mining carried on partly underground. The stripping varies from a few feet to over 100 feet. In the deeper bodies it would appear that underground work with caving might be introduced and would be more economical than stripping so much cover. A few mines were worked through vertical shafts. The abandoned open pits are now filled with water to within a few feet of the surface; some are 500 to 600 feet long and 100 to 200 feet wide. As much as 200,000 tons of ore have been mined from a single pit within 150 feet of the surface. Few, if any, of the deposits were exhausted by the previous operations; the production of ore became unprofitable with the loss of the local markets supplied by the Poughkeepsie and other near-by furnaces and through competition with the Lake Superior ores. The active period of exploitation may be said to have ended about 1893.

The ores occur in coherent masses and in earthy condition, the former called "rock ore" which is sorted by hand and the latter "wash ore", being the residue obtained after the removal of the clay and sand by washing. The masses occur in spheroidal, stalactitic and irregular shapes. The iron content of the shipping product ranges from 40 to 50 per cent. * * *.

There is little doubt that in the course of time the ores will again be in request. Some of the more accessible properties possibly could be worked under present conditions.

A complete description of the mines in this district can be found on pages 135, 136, 137, and 138 of New York State Museum Bulletin 223.

STATEN ISLAND LIMONITES

The limonites of Staten Island supply an interesting example of ore occurrence but are no longer of commercial importance. In character and probably in genesis they are closely parallel to the limonite ores of eastern Cuba which have recently come into prominence; their restricted distribution, however, excludes them from consideration as a basis for present-day mining. They are found on the serpentine ridge which constitutes the backbone of the island, the higher ground between St. George on the north shore and Richmond in the central part. The serpentine represents the altered product of a basic intrusive of the peridotite class of rocks. Little of the original silicates is now left, although occasionally particles of pyroxene and olivine bear witness to the original character of the mass, as does also the chromite which is distributed in small grains all through the serpentine. The ore lies in depressions upon the serpentine and is covered by clays and sand; a small percentage of chromium is present, according to the published analyses which show 38 to 55 percent iron; also cobalt and nickel. The old mine localities are about 1 mile north of New Dorp station (New Dorp mine) at the Four Corners on the Richmond turnpike (Tyson's mine) and on the Ocean Terrace road (Cooper & Hewitt mine). A detailed account of the occurrences is found in Putnam's article in the Tenth Census reports. The ore yield is placed at 250,000 tons. Mining terminated about 1880.

SUMMARY

Schrader, Stone, and Sanford [63] summarize the occurrence of iron ores and mineral pigments in New York as follows:

Brown iron ore (limonite, brown hematite).—Dutchess County, Amenia mine, the only producer in 1914. Was formerly produced in Columbia County, at Ancram, Boston Corner, Copake, Hillsdale, and Millerton. Dutchess County, at the Dover, Sylvan Lake, and other mines. Orange County, Townsend mine, Cornwall. Richmond County, Castleton, Four Corners, and New Dorp and Todt Hill, Staten Island. * * *.

Hematite (red iron ore).—Hematite associated with schists and limestone has been mined. Jefferson County, near Philadelphia, and Antwerp. St. Lawrence County, near DeKalb, Rossie, Hermon, and Somerville. Iron ore of Clinton formation outcrops through Herkimer, Monroe, Niagara, Oneida, Orleans, Oswego, and Wayne Counties; mined at Clinton, Oneida County, and at Ontario, Wayne County. * * *.

Mineral paint.—Manufactured from shales, iron ores, slate, and talc. Cattaraugus County at Randolph, from red shales of Chemung formation. Delaware County, red shales of Catskill formation at Roxbury. Oneida County, red iron ore mined at Clinton. Otsego County, hematite at Oneonta. St. Lawrence County, hematite. Washington County, Cambrian red slate. Wayne County, Clinton hematite at Ontario.

Numerous references of the New York iron ores are to be found in the geologic literature.[64]

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[63] Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful Minerals of the United States, U.S. Geol. Survey Bull. 624, 1917, pp. 221, 223, 225.

[64] Eckel, Edwin C., Limonite Deposits of Eastern New York and Western New England: U.S. Geol. Survey Bull. 260, 1905, pp. 335-342.

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TESTS OF NEW YORK PIGMENTS BY THE UNITED STATES BUREAU OF MINES

NEW YORK NO. 1

New York sample no. 1 was sent by John Mott, vice president, Clinton Metallic Paint Co., Clinton, N.Y.

Laboratory tests.—This 5-pound lump of hard (not knife-hard) reddish-brown iron ore with a purplish shade showed oölitic structure; the acid test indicated carbonates. It was ground in water and dried, and the pulverized powder was mixed with 11 drops per gram or 0.25 part by weight of linseed oil to produce paste between henna (60135) and brown (60114) in color. When diluted with zinc oxide the color changed to between blossom (60171) and crocus (60186). The ferric oxide content was 21.1 percent. This material was grouped with class 2, violet, metallic browns. The tinting strength was medium or near that of the commercial mineral browns, and the let-down hue varied from the standard toward violet. Although it contained lime carbonate this sample represents material already in commercial service.

NEW YORK NO. 2

Sample no. 2 was received from C. A. Hartnagel, New York State Museum, and was marked "Limonite mine (?), Dutchess County, New York."

Laboratory tests.—The ¼-pound sample consisted of an irreguarly colored limonite ore ranging from nearly black to light ocher yellow. It had a combined vesicular, striated, and stalactitic structure and broke readily into thin, roughly platelike masses. The fracture planes of the hard skeleton showed glistening black limonite. The sample did not react with acid. A portion was ground in water, and the dried powder was mixed with 12 drops per gram or 0.28 part by weight of linseed oil to produce a seal (60084) paste. When diluted with zinc oxide the color changed to ecru (60181). The ferric oxide content was 58.7 percent. This material was classed with the umber pigments. The dilution test indicated good tinting strength, and the let-down color was a fair match for some commercial umbers except that it was stronger. The pigment therefore has commercial value in this limited field if it could be produced in uniform quantities to meet market prices.

NEW YORK NO. 3

New York no. 3 was a small envelope sample of the prepared "red iron oxide pigment" produced by Stanley Doggett, Inc., 99 John Street and 11–13 Cliff Street, New York City. The original material came from their mines at Sterling Station and Ontario, N.Y.

Laboratory tests.—The pulverized sample was mixed with 9 drops per gram or 0.21 part by weight of linseed oil to produce a paste between bois de rose (60176) and henna (60135). When diluted with zinc oxide the color changed to old rose (60172). The ferric oxide content was 42.6 percent. This material was grouped with class 1, old rose, mineral browns, although it is on the market as a red oxide. The tinting strength was good, and the let-down hue varied from the standard toward deep old rose. The material is already on the market, although it contains 12.7 percent of CaO in the form of calcium carbonate.

NEW YORK NO. 4

New York no. 4 was a sample of crude ore from the same mines as no. 3.

Laboratory tests.—This sample of oölitic ore was very similar to no. 1 and was treated in the same way. The powdered material was not as bright red as no. 3, which was supposed to be the commercial product from this same ore. Carbonates were present. The CaO content was 8.9 percent. Twelve drops per gram or 0.28 part by weight of linseed oil was required to produce a paste of lighter color than henna (60135). When diluted with zinc oxide the color changed to between crab apple (60158) and Grecian rose (60175). The ferric oxide content was 51.8 percent. This material was grouped with the class 2, salmon, burnt siennas. The original light brown-red was close to that of commercial red oxides and diluted to strong, bright brown-red, also close to red oxide. The tinting strength was of commercial grade. This material is already in commercial service.

NEW YORK NO. 5

Sample no. 5 was received from C. A. Hartnagel, assistant State geologist, New York State Museum, and was labeled "Limonite—Clove mine, Clove Valley, Dutchess County, N.Y."

Laboratory tests.—The ½-pound sample as received consisted of two 2- to 3-inch chunks of dark-brown, nearly black knife-hard material containing only a small surface of impure, lighter-colored sandstone. It showed nodular, crystalline growths of very dark iron oxide. After being ground in water the pulverized fines required 13 drops per gram or 0.30 part by weight of linseed oil to produce an olive-wood (60082) paste. When diluted with zinc oxide the color changed to bisque (60122). The ferric oxide content was 70 percent. This material was classed with umber pigments. The tinting strength was medium or equal to that of present commercial umbers, but the let-down color differed from commercial umbers in that it was a peculiar mixture of yellow-brown and gray. More thorough grinding might increase the tinting strength, but the market value of this color is questionable.

NEW YORK NO. 6

Another sample submitted by Hartnagel was described as "Limonite—National (Pawling) mine, Pawling, Dutchess County, N.Y."

Laboratory tests.—The ¼-pound sample as received was a variable mixture of light yellow-brown and dark-brown steel-hard ore; it appeared granular instead of crystalline like no. 5. After being ground in water the fines required 15 drops per gram or 0.35 part by weight of linseed oil to produce a gold-brown (60113) paste. When diluted with zinc oxide the color changed to between sunset (60088) and tan (60089). The ferric oxide content was 44 percent. This material could not be classed with any present commercial ochers but was placed with class 1*a*, pink, siennas. The full-strength hue was dark red-brown, which when diluted changed to strong pink-tan. The tinting strength was good. (See fig. 12, *B*, and table 32.) Although this material cannot duplicate present commercial pigments the hue was pleasing, the iron concentration was very strong, and the oil requirements were moderate; however, it was only a laboratory sample, and commercial duplication may be difficult. Nevertheless it indicated that some limonites of this district may prove of value as mineral pigments, though valueless as iron ores.

NEW YORK NO. 7

New York no. 7, submitted by Hartnagel, was described as "Limonite associated with hematite deposits at Rossie, St. Lawrence County—mine not productive."

Laboratory tests.—The ½-pound sample as received was a brown-black, steel-hard, fairly uniform mass of crystalline ore covered with ½-inch and smaller oölitic rounded growths. The sample was ground in water, and the dried fines required 11 drops per gram or 0.26 part by weight of linseed oil to produce a mummy (60081) paste. After dilution with zinc oxide this changed to bisque (60122). The ferric oxide content was 82.5 percent. This material was classed with umbers. Its tinting strength equaled that of the umbers, but the let-down color was a mixture of light yellow-brown and gray. The market value of this hue is doubtful. (See New York no. 5.)

NORTH CAROLINA

The occurrence of iron ores in North Carolina has been summarized by Schrader, Stone, and Sanford[65] as follows:

> **Brown iron ores (limonite, bog-iron ore).**—Many deposits in eastern part of the State in Duplin, Jones, Nash, New Hanover, Pender, and other counties. * * *. Ashe County, has been mined in upper part of Ore Knob copper mines, accompanying copper lodes. Burke County, many beds in a northeasterly direction from Jacobi Fork of Catawba River to Brushy Mountains in Wilkes County; large beds in Chatham County, at Ore Hill. Cherokee County, at Nottla, and along Valley River. Gaston County, Highshoals. Johnston County, near Smithfield. McDowell County, has been mined in Linville Mountains. Many localities have been worked in Buncombe, Burke, Caldwell, Catawba, Gaston, Lincoln, McDowell, Mitchell, Surry, Watauga, and other counties.
>
> * * *.
>
> **Hematite.**—Has been mined in Chatham County, Ore Hill. Gaston County, Ormond mine. Harnett County, Buckhorn mine.

TESTS OF NORTH CAROLINA PIGMENTS BY THE UNITED STATES BUREAU OF MINES

NORTH CAROLINA NO. 1

North Carolina no. 1 and data regarding it were submitted by W. G. Johnson, Hot Springs, N.C. The deposit is on a mountainous property belonging to Frank H. Lance, T. 8, Madison County, N.C., 2.3 miles from the Southern Railway, with a fair highway for trucking. The vein is approximately 11 feet wide.

Laboratory tests.—The ⅛-pound sample as received was light-buff clay of color strength too weak for testing.

NORTH CAROLINA NO. 2

A second sample sent by Johnson was from the same source as no. 1.

Laboratory tests.—The 1½-pound sample as received was soft, reddish-brown or purplish clay with some white streaks and stained portions. The acid test indicated no carbonates. After being ground in water the materials gave a high-shrinking residue of moderate strength when dry. The dry powder required 20 drops per gram or 0.46 part by weight of linseed oil to produce a paste between brown (60114) and henna (60135). When diluted with zinc oxide the color changed to between blossom (60171) and crocus (60186). The ferric oxide content was 8.9 percent. This material was grouped with class 2, violet, mineral browns. Although the tinting strength was weak the pigment agreed in hue with commercial standards and may have at least local commercial value.

NORTH CAROLINA NO. 3

A third sample was sent by Johnson from the same locality as nos. 1 and 2.

Laboratory tests.—The 5-pound sample as received was sandy, buff, soft clay showing the original bedding planes and gray streaks. Washing removed 22.8 percent of yellow-brown sand from the soft, buff fines, which when dried and powdered required 15 drops per gram or 0.35 part by weight of linseed oil to make a gold (60164) paste. When diluted with zinc oxide the color changed to polar bear (60004). The ferric oxide content was 3.8 percent. This material was grouped with light-grade, Pennsylvania or class 2, orange-yellow, ochers, slightly grayed. The dilution test, however, indicated the weakest of tinting strengths, too far below that of commercial ochers to have market value. The diluted hue was cream.

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[65] Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful Minerals of the United States: U.S. Geol. Survey Bull. 624, 1917, pp. 229–233.
Nitze, H. B. C., Iron Ores of North Carolina: North Carolina Geol. Survey Bull. 1, 1893, 235 pp.

OHIO

The occurrence of iron ores in Ohio has been summarized by Schrader, Stone, and Sanford [66] as follows:

> **Brown iron ore** (limonite).—Occurs in form of concretions known as "kidney ore", in thin beds as "block ores", and as "limestone ores." The "Lower Coal Measures", "Barren Measures", and "Upper Coal Measures" contain ore-bearing horizons. Carroll, Columbiana, Gallia, Hocking, Jackson, Lawrence, Licking, Mahoning, Muskingum, Perry, Scioto, Trumbull, and Vinton Counties have produced ore from these horizons; of little economic importance at present time. * * *.
>
> **Hematite** (fossil ore, dyestone).—Occurs in Clinton County, at Todds Ford, near Wilmington. Highland County, at Sinking Springs, most important deposit of this ore in State. Muskingum County, near Zanesville.

No samples were submitted from Ohio.

OKLAHOMA

Schrader, Stone, and Sanford [67] describe the occurrences of iron ore in Oklahoma as follows:

> **Brown iron ore** (limonite, brown hematite, bog-iron ore, etc.).—Johnson County, Hunton and Mill Creek. Some shipped.

No samples were submitted from Oklahoma.

OREGON

The occurrences of iron ore in Oregon have been listed by Schrader, Stone, and Sanford [68] as follows:

> **Brown iron ore** (limonite).—Baker County, has been mined for flux on Burnt River divide, South Sumpter. Clackamas County, has been mined at Oswego. Columbia County, Scappoose. Curry County, Wake-up-Riley Ridge. Jackson County, in sec. 3, T. 35 S., R. 3 W., in Gold Hill district. In black sand as follows: Baker County, Baker; Douglas County, Steamboat River; Wheeler County, Antone. * * *.
>
> **Hematite** (red iron ore).—Baker County, specular variety in argillite on Burnt River divide near Sumpter. Douglas and Lane Counties, intermingled with sulphides in Bohemia and Blue River districts; mined for gold. Jackson County, in sec. 9, T. 38 S., R. 1 E., where it occurs in a clay bank; also in Gold Hill district. In black sand at the following places: Baker County, Sparta, Sumpter district, Rye Valley, and New Bridge. Crook County, Howard. Curry County, Eckley. Douglas County, South Umpqua River, Steamboat River, Starvout, and Riddle. Grant County, Granite. Josephine County, Josephine Creek near Kerby, Waldo, Sucker Creek, and Browntown. Lane County, Cottage Grove. Linn County, Foster. Washington County, Hillsboro. * * *.
>
> **Mineral paint.**—Iron ore for making paint has been dug in Columbia County, at Scappoose. Lane County, near Creswell.

The occurrence of limonite iron ores in Oregon has been mentioned by Harder.[69]

TESTS OF OREGON PIGMENTS BY THE UNITED STATES BUREAU OF MINES

OREGON NO. 5

A sample of deep-red clay submitted by H. S. Abel, box 202, Baker, Oreg., was reported to come from a 2- to 4-foot vein on property

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[66] Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful Minerals of the United States: U.S. Geol. Survey Bull. 624, 1917, pp. 239 and 240.

[67] Work cited, p. 244.

[68] Work cited, pp. 249, 253, and 255.

[69] Harder, E. C., Manganese Ores: U.S. Geol. Survey Mineral Resources of the United States, 1908, pt. I, 1909, pp. 145-154.

owned by Mrs. Nichols, Baker, Oreg., in T. 10 S., R. 39 E., Baker County, 12 miles from Baker, the nearest town, and within 1 mile of the county road. The outcrop from which the sample was taken is about 1,800 feet long, and the bed has a possible strike of NW.-SE., with a dip of about 40° SW. Undoubtedly the overburden of basalt and other rock would require underground mining.

Laboratory tests.—Although this soft, claylike sample dispersed readily in water and could be washed, its sand content was so low that it was ground in water. When dried the fines formed a medium-hard mass of rather high shrinkage. The pulverized material required 35 drops per gram or 0.81 part by weight of linseed oil to produce a paste between henna (60135) and terra cotta (60134). When diluted with nine parts of zinc oxide the color approached salmon pink (60022). The ferric oxide content was 19.2 percent. This material was placed with class 2, salmon, burnt ochers. The light brown-red, full-strength hue was similar to that of red oxides and diluted to a color near standard burnt sienna plus some pink. The tinting strength was medium. The pigment therefore has at least limited commercial value.

OREGON NO. 6

Oregon no. 6 and the information regarding it were submitted by H. R. Foster, Columbia Chemical Co., 104 North Fifth Street, Portland, Oreg. The deposit is on the boundary line between Douglas and Josephine Counties, southern Oregon. It has been prospected by an opencut showing a face 50 feet wide and 30 feet deep. Other exposures indicate a total depth of about 180 feet. The maximum amount of overburden is 3 feet. The width of the deposit is 170 to 200 feet.

Laboratory tests.—The 7-pound sample was soft reddish-brown clay somewhat mottled with yellow-brown. Washing removed 19.8 percent of brown and buff sand, leaving a high-shrinking, tough, plastic mass of fines. Fifteen drops per gram or 0.35 part by weight of linseed oil was required to make a paste between henna (60135) and brown (60114). When diluted with zinc oxide the color changed to between peach (60157) and sunset (60088). The ferric oxide content was 13.5 percent. This material was classed with burnt ochers, but as the tinting strength was weak it will probably have only local value in the lower-grade pigments.

OREGON NO. 8

Oregon no. 8 and accompanying data were submitted by F. B. Freeland, M.D., 253 Medical Building, Portland, Oreg. The material is found in large quantities on his property in Warmsprings River Valley in central Oregon.

Laboratory tests.—The 1-pound sample consisted of ½-inch lumps to powder of reddish clay, probably originating from basalt. The acid test indicated no carbonates. The ground pulverized material required 16 drops or 0.37 part by weight of linseed oil to make a paste between henna (60135) and brown (60114). When diluted with zinc oxide the color changed to pink no. 1 (60013). The ferric oxide content was 9.6 percent. This material was grouped with the class 2, salmon, burnt ochers. The dilution test, however, indicated the weakest of tinting strengths, too low for general commercial service.

PENNSYLVANIA

MINERAL PIGMENTS OF PENNSYLVANIA [70]

By BENJAMIN L. MILLER [71]

INTRODUCTION

The mineral pigments of Pennsylvania are varied and widely distributed. They have not been utilized to their fullest extent in any section, and the products have been exhausted only in restricted localities. In some instances the output may be increased with profit; on the whole, however, production now equals demand, and further increase without new outlets would merely glut the market and result in hardships, if not actual loss.

YELLOW OCHER

Yellow ocher occurs in many places throughout the State but has been worked mainly in the East. Its distribution is virtually coextensive with the limonite iron ores, which at one time were utilized so widely but which in recent years have been largely neglected. With few exceptions they occur in limestone belts that cross the State in bands roughly northeast-southwest. Thousands of such iron mines, some large producers, have been worked in the limestone valleys in Northampton, Lehigh, Berks, Lebanon, Chester, Lancaster, York, Cumberland, Franklin, Center, Blair, and other counties; most of them, however, have been abandoned and can be located only by depressions marking former operations, which usually contain water and are being filled gradually with material washed from surrounding regions. The mines were worked mainly by opencut methods and were shallow, although some underground workings extended several hundred feet deep.

EASTON-READING DISTRICT

Geography.—The most important ocher district in Pennsylvania is a comparatively narrow belt of limestones and quartzites extending from Easton to Reading and enclosed between the gneiss ridges of South Mountain on one side and the Hudson River slates on the other. It includes the Easton, Allentown, Slatington, Boyertown, and Reading quadrangles of the United States Geological Survey and Northampton, Lehigh, and Berks Counties. The same limestone valley continues southwest of Reading; between the Schuylkill and Susquehanna Rivers it is known as the Lebanon Valley; between the Susquehanna and Potomac Rivers, the Cumberland; throughout Virginia, the Shenandoah; and in North Carolina, the Great Valley.

Most ocher mines throughout the belt are within 3 miles of a railroad, and as roads are generally good the cost of haulage to the shipping points is a small item.

Description and occurrence of deposits.—The ochers of the Easton-Reading district are closely related to the geology and structure of

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[70] This report is an abstract from Miller, Benjamin L., Mineral Pigments of Pennsylvania: Topog. and Geol. Survey of Pennsylvania Rept. 4, 1911, 101 pp. The material has been brought up to date (1930).

[71] Department of geology, Lehigh University, Bethlehem, Pa.

the region. Although they occur in rocks of several different geological series a certain regularity can be noted. The deposits are most abundant in rocks easily replaced and are consequently absent in the gneisses and slates. Of greater importance, however, is the relation between the structure of the region and the ore deposits. Most limonite and ocher deposits occur in regions where there has been intense folding or faulting. In consequence, many iron mines occur in a more or less straight line roughly parallel to the strike of the beds.

The ocher usually is closely associated with brown iron ores. It occurs either in pockets irregularly distributed throughout clays ranging in color from white to yellow, to red, or to black, or in rather definite layers, perhaps representing the strata of the original rocks that have been wholly replaced. Some ocher pockets are several feet in diameter and can be removed without taking out much clay. In other places, however, the ocher occurs in such small masses that much clay must also be removed and the mixture forms a low-grade ocher. The clay cannot be removed from the ocher by washing and settling; hence the best-grade ocher can be obtained only where it occurs in large pockets or thick layers.

The ochers and associated clays lie upon older rocks in the main and represent residual insoluble material left in disintegration of limestones or are replacements along fractured or faulted zones. All the deposits are superficial and occupy irregular basins that vary greatly in diameter and depth. In the vicinity of Fleetwood the clay and ocher were found at a depth of at least 257 feet, but in most places the underlying unaltered rocks are within 100 feet of the surface. Ridges or pinnacles of limestone sometimes rise several feet above the general level of the basin floor, and occasional steep-sided pits extend a considerable distance below.

Limonite ore, which represents a more concentrated condition of hydrated iron oxide than ocher, is present in all ocher mines, either distributed throughout the ocher and clay irregularly or arranged in rather definite layers alternating with ocher bands. The former condition is more common; considerable iron ore is removed with the ocher and accumulates about the mine until there is enough to warrant shipment to some furnace. Sometimes the limonite occurs in small masses, which can be easily ground to powder; the combined material is used in manufacturing metallic paint.

The limonite associated with the ocher occurs as nodules or geodes, either hollow or filled with clay, sand, or water, which the miners have termed "bombshells"; as hollow tubes or pipes; as a brecciated mass; or as fragments of broken nodules. In some mines small masses of chalcedony, bearing no resemblance to the chert nodules associated with the limestones, are found as secondary minerals. Residual chert from the limestone is likewise found with the ocher in many mines.

Origin of ocher.—Many writers have discussed the origin of the Pennsylvania limonite and ocher deposits; they believe that the iron came from overlying slates in which the iron existed as pyrite; from decomposition of ferrous silicate or ferrous carbonate originally present in the limestones; from pyrite originally present in the shaly strata intercalated with the limestone; etc. Undoubtedly, the source of the iron of the ocher is not confined to a single group of strata.

The rocks of every formation in the region contain some iron. In the gneiss iron exists in large quantities, primarily as magnetite but in considerable quantities as pyrite. Analyses of seven limestones from Lehigh County show 0.538 to 4.06 percent of $FeCO_3$, or an average of 1.568 percent, and 0.03 to 0.611 percent of FeS_2, or an average of 0.269 percent. The pyrite is undoubtedly associated mainly with the shaly beds, whereas the carbonate is associated with the purer limestones. Although the iron content is small in all strata of the region, enough is present to account for all ochers and brown iron ores of the region. The problem remaining is to account for alteration of the original iron components and segregation of the resulting iron minerals in their present position. Unquestionably these changes have come about during decomposition of the enclosing strata. Oxygenated waters would tend to convert the sulphide into the soluble sulphate, and in that form it was readily transported. Further oxidation would tend to convert it into the less soluble hydroxide, and as such it was precipitated about some center to produce limonite geodes or in more finely divided condition throughout the clay to form ocher. The iron carbonate and iron silicate were dissolved by waters charged with carbonic oxide or organic acids; where the solutions later flowed through limestones the iron, being less soluble than lime, was finally dropped, and lime was taken into solution instead.

Meteoric waters are responsible for concentration of the ores as they dissolved the original iron minerals and carried the iron solutions in their passage through the rocks, precipitating them along the main watercourse. It is well known that faulted and greatly fractured zones favor the passage of water; many ocher and brown iron-ore mines therefore follow the belts where the rocks have been most disturbed.

Age of ocher deposits.—The iron, which was originally distributed in small quantities throughout a great thickness of strata, began to accumulate as soon as the strata emerged from the sea in the late Paleozoic era and continues to accumulate even now. In the limestone valley several thousand feet of materials in all have been removed mainly by solution, and a considerable portion of the iron has been left with other insoluble materials that constitute the clay.

Mining methods.—The ocher is mined both by opencut methods and by shafts. The former method is employed wherever ocher lies within 10 to 15 feet of the surface, and shafts are sunk where it lies deeper. The pockety character of the ore and the uncertain market for the product do not justify elaborate equipment. In some mines little timber is used except in shafts and main drifts, and mines cave soon after operations cease. If much water is present the squeezing action of the clay requires extensive timbering even in the small stopes.

In most mines the ocher extends in a somewhat definite band. Drifts following the ore bodies are run from the shaft in either direction. If a pocket of ore extends upward, overhead stopes are opened. Drifting follows the stringers or pockets of ore; when they die out the drifts may be run in almost any direction but mainly parallel the course of the principal bodies where the ore seems to be so arranged. The ore is trammed to the shift in wheelbarrows and hoisted in buckets to the surface, where it is washed and prepared for shipment. The power necessary for hoisting, running the washing plant and grinding machinery, and operating the pumps is furnished by a small steam plant. Cornish pumps take water from the mines or near-by wells for washing the ore.

Preparation for market.—As the ore comes to the surface it is mixed with clay, nodules and fragments of limonite, and pieces of chert. The clay cannot be removed by washing, but the hard particles can. The common log washers are very effective; the ocher and clay are washed out at the lower end while the hard particles are pushed out at the upper end. Most of the iron ore is picked out by hand and thrown to one side, where it accumulates until there is enough to ship to some near-by furnace.

The ocher and clay are washed into a series of settling troughs, which are inclined slightly so that the water passes through them rather slowly. The current is further retarded by baffleboards, behind which the coarser particles settle. The coarsest sand settles first; the sediment diminishes in size in each trough until the last, where the little sand present is extremely fine. Thence it passes to settling ponds formed by digging a few feet in the surface and throwing up excavated material to form an embankment. These settling ponds are roughly rectangular and vary in size, probably averaging about 40 feet in length, 25 feet in width, and 3 to 4 feet in depth. They are frequently arranged in series so that the finest material will pass from the first pond into the second. The overflow from the last pond is carried off through a pipe. The material can be graded by turning the best grade of ocher brought to the surface into one pond and that having a large admixture of clay into another pit. When a pond is full the surplus water is allowed to evaporate. Evaporation may require a few weeks to several months, depending on the weather. When the ocher is dry enough to be shoveled readily, it is dug and hauled in wheelbarrows to the drying sheds, where it is placed on long, open shelves for final drying. In a few mines steam-drying sheds are used, but most of the ocher is air-dried. From the drying sheds the material either is hauled direct to the railroad for shipment or is ground in French buhr mills and shipped in bags or barrels.

When there are mud-dam deposits about the old iron mines the ocher is dug where the amount of sand is smallest, and washing may not be necessary. In some of these deposits ocher of almost as good quality as that carefully purified by washing can be obtained. The ocher, however, is likely to contain more clay and sand than do prepared ochers; washing may then be necessary to remove the sand. Several layers of fairly clean ocher are usually present in some extensive deposits accumulating about large mines that were worked for many years.

Development of district.—The history of the ocher industry in eastern Pennsylvania is not known with much certainty. Ocher has been dug continuously throughout the belt during the past 60 years and probably was utilized in smaller amounts since early colonial days, when the iron ores of the region were first mined.

Plant of Reichard-Coulston, Inc., one half mile south of Topton.—The ocher deposit and washery of the Reichard-Coulston Co. is one of the largest in the district. It has been operated more than 50 years during the summer and shows no indication of exhaustion. It is worked entirely by opencut methods, although at one time the ocher was removed through several shallow shafts. The maximum dimensions of the pit are about 45 feet depth, more than 300 feet length, and about

175 feet width. In some parts the ocher lies 2 to 3 feet from the surface, but in others it is overlain with 5 to 8 feet of float rock and soil.

The ocher is not of uniform character and much is too light in color to be utilized. The variously colored materials exhibit no regular arrangement. Mixed with the clay and ocher are many limonite nodules partly filled with white clay and ⅛ inch to 1 foot in diameter. In shape many are unlike the ordinary limonite geodes associated with the ochers elsewhere in that they have necks or tapering projections half as long as the main nodules. In addition to the limonite geodes there are many angular chert particles, some 8 to 10 inches in diameter. These, like the clay and ocher, are residual deposits from dissolution of the limestone. In certain places the ocher and clay are mixed with unusual aggregations of chalcedony resembling bunches of berries. These are, in the main, less than 1 inch in diameter, although a few were somewhat larger. They are unlike any siliceous nodules observed in the limestone, and their origin is problematical.

The two analyses given in table 74, furnished by the proprietors, show the character of the ocher.

TABLE 74.—*Analyses of Topton ochers, percent*

	Best quality	Second quality		Best quality	Second quality
SiO_2	55.50	58.50	Combined water	8.35	6.10
Al_2O_3	18.66	20.15			
Fe_2O_3	17.49	15.25		100.00	100.00

Only one grade of product is being made. This averages 14 to 15 percent of Fe_2O_3.

The depth of the ocher and clay has not been determined. A 145-foot well near the plant sunk to obtain water for washing the ocher failed to reach the underlying rock.

The ocher from the mine is hauled to the washing plant near by, where it first passes through a 25-foot log washer to separate the larger particles of iron ore and chert from the ocher. Thence the finer material held in suspension in the water passes through three sets of sand troughs, the first about 32 feet long with two compartments and the other two about 16 feet long with three compartments. It then goes to the eight mud dams or settling ponds, each holding 30 to more than 100 tons of dry ocher. Enough material is put in these pits to yield a depth of 2 to 3 feet of ocher after drying. It requires 2 or 2½ months for the product to dry enough to be dug. Thence it is taken to the six drying sheds, 50 to 75 feet in length and 15 to 20 feet in width. One shed has steam coils beneath the floor to assist drying, while a small part of another shed next to the boiler house is enclosed on all sides and fitted with steam coils. This holds about 15 tons and is used in winter when air-drying is impracticable.

The ocher from this plant is hauled to Topton and shipped to the proprietors' paint mills at Bethlehem, where it is ground in an air mill and sold as raw ocher or mixed with oil to make paint. The yearly output of this plant varies greatly, as enough can be dug and floated in one season to supply the demand for several seasons; the plant is therefore idle much of the time. The company markets around 150 tons annually. The price is about $30 a ton in carload lots and somewhat more in smaller quantities. The product is used in paint, oilcloth, mortar, cement, and stucco.

Plant of C. K. Williams & Co. 1¼ miles east of Fleetwood.—This plant is the most important in the State as judged by length and continuity of operation and grade of product. Several shafts have been sunk at different times, and the ocher has been removed from a large area. Squeezing of the clay through which the shaft and drifts are run makes it more practicable to abandon certain shafts and sink or drive others closer to the deposits being worked. No surveys have been made; consequently, old filled drifts are encountered from time to time. Only one mine is now in operation, but two or more have been worked simultaneously.

This mine is on the steep slope of South Mountain about three eighths mile from a siding of the Philadelphia & Reading Railroad, where the finished ocher is loaded into cars for shipment.

The shaft is about 100 feet deep, with a pump beneath, into which all mine water is drained and pumped to the surface at intervals. Work has been done on two levels, one at about 100 feet and the other at 100 feet.

Drifts follow pockets and stringers of ocher. These are mined out in stopes or breasts and then carried until other deposits are found. The drifts or gangways are 6 to 7 feet high and 5 feet wide and timbered to resist squeezing of the clay. Lagging of sawed slabs is laid close on the tops and sides, and the bottom is floored with plank for passage of wheelbarrows. Openings are provided for dumping the ocher from the stopes to the hoisting level, whence it is wheeled to the shaft and raised. The stopes are driven where pockets are found, and if the size of the pockets and the quality of the material demand it they are timbered with square-sets.

The ocher either occurs as small masses in pockets in the clay or interstratified with it. It is separated by hand from clay in the mine; the clay is used to fill old workings. Impurities in the ocher are particles of quartzite, cherty limestone, flakes of shaly limestone, and fragments and nodules of limonite. The large pieces of limonite are picked out on the surface and saved until there is enough for shipment. In recent years disposal of this iron ore has been difficult because local furnaces were closed and the ore was siliceous. Cavities lined with quartz crystals are common in the iron ore. No bedrock has been encountered in the mine workings, but a well drilled down the hoisting shaft struck loose sandstone boulders at 275 feet.

The ocher and iron ore occur in pockets, the ore predominating in the upper levels and the ocher in the lower, with clay between. The deposit seems to be in the form of a horseshoe extending along the hill, with its greatest dimension parallel to the hill. The bands of iron ore, clay, and ocher appear to run horizontally. The underlying rock is quartzite, which outcrops along the ridge with a dip of 75° toward the bottom of the hill.

The ocher from this mine is of three grades, as follows:

1. "Gold dust" or no. 1, the purest variety.
2. "Gravel ocher", good ocher, containing particles of limonite which must be washed out.
3. Clay and ocher, the poorest variety, containing pieces of chert up to 2 feet in diameter. The clay is red, yellow, white, and purplish and has no value.

Ocher is raised from the mine by an engine hoist and dumped into a log washer, from which it passes to 28 floating troughs 14 to 16 feet long and 13 inches square in cross section. The fine sand is removed in the first 12 or 13 troughs, and the final separation is accomplished in the 15 smaller ones; the mixture is then run through a long trough to one of the 4 settling ponds, where it is left for partial drying before transfer to one of the 4 drying sheds. After thorough drying it is ground in French buhr mills as final treatment for the market.

In general it takes 1 month to fill the settling ponds and 3 weeks more for the material to dry to the consistency of a stiff mush so that it can be shoveled. It has to be left 1 month in the sheds before it is dry enough to grind. The material is finished at the company mill, Easton, Pa., which is designed to handle an output of 2,000 to 2,500 tons a year. A grinder with a capacity of 10 tons a day is used. Steam drying is not thought to be the best method because of the danger of dehydrating and changing the color of ocher by contact with steam pipes. Two grades are made regularly, the best, termed "gold dust", and another, called "C.L." A third of intermediate strength is sometimes produced. The iron oxide content of Fleetwood ocher is 15 to 30 percent.

The land is usually leased for 15 to 20 years, 1 year or 6 months being allowed for exploration before the lease is executed. A royalty is paid to the owner either at a nominal rate or at a fixed price per ton, according to the amount of ocher taken out.

C. K. Williams & Co., northeast part of Reading.—For a number of years this company has been operating an ocher mine near Tulpehocken Creek in the northwest part of Reading.

The ocher from this region contains less limonite iron ore than most places but does contain considerable chert. Some of the best ocher of the district has been mined here; part of it, ranging from 68 to 72 percent of ferric oxide (Fe_2O_3), is really a sienna. On the other hand, some runs as low as 35 percent of ferric oxide.

Much prospecting has been done in that section in the last year or so, without satisfactory results.

PRECIPITATED OCHER FROM MINE WATERS

In recent years a new product, which has received favor with the paint manufacturers, has been obtained in Pennsylvania. It is the precipitated hydrated iron oxide found in swampy places into which heavily charged ferruginous waters from the bituminous-coal mines have drained. The material has collected largely in those places where considerable vegetation has decayed, although it is found in stagnant water almost everywhere through the bituminous mining district.

Most of this material has been obtained near Dubois, Punxsutawney, and Ebensburg, although other localities are being examined and it is probable that other deposits of economic value will be found.

A few deposits as much as 4 feet thick have yielded up to 1,500 tons. Men wade in the soft oozy material, remove logs and tree branches, and then shovel the slimy yellow substance into wheelbarrows to transport it to trucks. Sometimes trucks can be driven into the swamps and the material loaded direct.

The material contains a large amount of water and considerable vegetable debris as no attempt is made to remove the fine woody matter. On burning, a bright- to dark-red product is produced.

Kaplan and Reger of Morgantown, W.Va., have patented a process by which they claim they can precipitate the iron of mine waters on a commercial basis to obtain the same kind of product produced naturally in swamps.

OTHER OCHER DEPOSITS

Other ocher deposits in Pennsylvania, mainly idle at present, are:

1. A.K.S. Sampson, Easton, ¾ mile south of Easton on north flank of South Mountain.
2. Victor Mining Co., 140 Maiden Lane, New York City; mine ¾ mile southwest of Wescosville on the farm of Hiram Hiskey.
3. Abandoned mine 1½ miles northwest of Alburtis.
4. Bear Bros. plant 1½ miles northwest of Breinigsville.
5. Mud-dam deposit 1 mile northeast of Trexlertown, on farm of Jerry Gramme.
6. Mud-dam deposit 1½ miles northeast of Trexlertown, on farm of William J. Smith.
7. Mud-dam deposit 1½ miles northwest of Hancock; worked in 1930.
8. Ocher mine of Dr. Wilson P. Long ½ mile southwest of Hancock.
9. Mud-dam deposit ½ mile southwest of Hancock owned by the Thomas Iron Co.
10. Ocher plant ½ mile south of Blandon on property of E. B. Wade.
11. Ocher prospects 1½ miles southeast of Blandon on farms of Lewis Keller and John Hoover.
12. Ocher plant ½ mile east of Seisholtzville operated by John D. Reitnauer, Alburtis, R.F.D. 2.
13. Abandoned ocher mine ½ mile southwest of Stouchsburg, Berks County, on the farm of Hiester Filbert of Robesonia.
14. Farm of Schuchert ½ mile from Old Zionsville.
15. Ocher plant 1¾ miles west of Saylorsburg, Monroe County.
16. Mylin iron-ore mine in southeast corner of Pequea Township, Lancaster County.
17. E. Halderman & Co. iron-ore mine 3¾ miles northeast of Hanover.

UMBER

Much ocher of the Pennsylvania limestone valleys contains small amounts of manganese oxide, and almost every analysis of limonite iron ore shows its presence. It seems strange that few localities are known where the percentage of manganese in ochers is great enough for the mixture to be called umber. The author knows only four localities containing umber deposits large enough to justify working. Three have been operated at intervals for many years, whereas the other has only been prospected.

Reichard-Coulston, Inc., in recent years has obtained some fair-quality umber from the farm of W. F. Witte, near the eastern edge of the Allentown quadrangle about 2 miles northeast of Springtown. The material is taken from an open pit, which was opened for mining limonite iron ore and proved too lean to be profitable. Occasional small masses of good-quality iron ore were encountered. A large quantity of iron ore was mined by opencuts and shafts in the region a short distance to the west.

Umber and ocher were found in the iron mines; and although it is said that some was dug and burned in kilns near by, little attention was given to them owing to lack of a market, so the industry was abandoned.

The umber in the pit lies in a bed exposed to a depth of about 8 feet. It is overlain by about 20 feet of hillside wash and residual clay. The umber is more uniform than in most deposits and contains little other foreign matter than occasional small masses of limonite.

The umber owes its origin to replacement of siliceous sandstones and quartzites near the contact of the overlying limestones. Pieces of the unreplaced rock are present in the umber.

A partial analysis, which is probably correct although the analyst is unknown, follows:

Analysis of umber northeast of Springtown, percent

Fe_2O_3	40	SiO_2	25
MnO_2	5	Al_2O_3	10

Another analysis shows 49 percent of Fe_2O_3, and some specimens contain more MnO_2.

A second deposit lies on the south slope of Quaker Hill or Camels Hump about 2½ miles north of Bethlehem, Northampton County. Though now abandoned the deposit was worked in a small way by the C. K. Williams & Co. and others for 45 years. About 6 feet of umber under 10 feet of soil and colored clay were removed from the bottom of a small open pit. The umber and associated materials represent decomposition and replacement products of Hardyston quartzite, which extends along the south flank of the hill as determined by the float rock.

A third deposit was formerly worked on the south side of Buckingham Mountain 5 miles east of Doylestown, Bucks County. The deposit is probably not very large; it occurs along a fault by which the Cambrian quartzite and limestones have been brought to the surface.

A fourth deposit has been prospected 1 mile west of Bethel, Berks County, on the farm of W. C. Kline, of Myerstown.

SIENNA

Except for the ocher mine of C. K. Williams & Co. northwest of Reading there is only one locality in Pennsylvania where sienna has been mined.

Sienna mine on Neversink Mountain, Reading.—For a number of years sienna was obtained on the north slope and about 100 feet from the crest of Neversink Mountain directly south of the east part of Reading. Neversink Mountain and its counterpart, Mount Penn, are composed of Hardyston quartzite which, being resistant to atmospheric agencies, has been reduced more slowly than adjacent limestones and so forms steep hills or mountains rising 600 to 800 feet above where Reading stands. Although the rock has worn away slowly much is greatly decomposed and contains many sand pits. Part of it, particularly beds in which arkose is a prominent constituent, is so decomposed that it can be crushed easily in the hand and all of it readily in a rock crusher. While one of these pits was being worked a layer of sienna interbedded with rotten quartzitic sandstone was struck, from which a small amount of excellent material was obtained. The band was too thin and irregular to be worked profitably, and the mine was abandoned.

The sienna is rich yellow with somewhat darker thin streaks and is remarkably free from impurities. The following percentage analysis was given by C. K. Williams & Co.:

Fe_2O_3	69.0	Combined water and undetermined	14.0
SiO_2	24.0		
Al_2O_3	3.0		100.0

The ore has the same dip as the enclosing beds of rotten quartzite and the slope of the mountain, 25° to 30° N. It represents replacement of the quartz and arkose of certain beds and shows the stratification lines of the original rock. These lines show even more distinctly in the rich-yellow, fine-grained sienna than in the unaltered coarser quartzite. The replacement process has been somewhat irregular, as the ore is 5 feet thick in places and thins rapidly to a few inches or disappears within 10 to 15 feet. The strata of the quartzite, on the other hand, are remarkably regular, showing that the sienna does not represent a single stratum of the original rock. The ore bodies thicken and thin in the direction of the dip as well as along the strike of the quartzite. Certain layers, however, seem to have been replaced more completely than others, and when ore is found the drifting is carried along the same strata even though there is no ore in certain places. Two bands or series of beds carrying the sienna have been found, and it is not improbable that more may be located.

Because of the small bodies of ore and the uncertainty of their continuation mining was done in a rather primitive manner—practically without equipment. A tunnel was run into the mountain about 35 feet to the place where the ore was found. The drift was then turned along the strike about 20 feet, partly in ore. At the end of this drift a pocket of ore was found. The ore was taken from the mine in wheelbarrows and placed on a sheet-iron platform over a wood fire. When partly dry it was placed in a covered storage shed, whence it was hauled to the railroad at Reading for shipment.

It is regrettable that a large deposit of this material has not been found as it is the highest-grade pigment located in Pennsylvania.

CARBONATE OF IRON PAINT ORES OF LEHIGH GAP

The paint ores of Lehigh Gap outcrop in a narrow band along the north side of Stony Ridge, a rugged ridge of resistant Oriskany sandstones broken in a few places by streams. The ores have been worked successfully in a belt extending almost entirely across the southern end of Carbon County from Germans to Little Gap.

These are of special interest because they have been mined continuously, longer than any other paint ores of the State (since their discovery in 1856), and the value of the output exceeds that of any other Pennsylvania paint-ore district. In chemical composition also they are unique, as no similar ores are known elsewhere. The product is known in the trades as "Prince's metallic paint" and "Prince's Double Label mineral brown" and has especial value for painting metallic structures.

History of development.—In 1856 Robert Prince found an outcropping rock containing considerable iron a little northeast of Hazard and near the crest of Stony Ridge, one of the few places in the region where the bed appears at the surface. Proximity to the resistant ridge-making Oriskany sandstone causes the bed to be almost always concealed at its outcrop by the accumulation of talus. Prince at once began to work the deposit; the ore was ground at a mill on Big Creek and the finished product hauled to Weissport, where it was shipped at a selling price of $120 per ton. Occurrence of the ore in a definite continuous bed led others to search for it, so that in a short time many other competitors were operating in the region. Mines soon extended along the entire southern end of Carbon County and a short distance into Schuylkill County. Shafts were sunk on the outcrop and tunnels driven into the ridge from either side; so extensive were the workings that the ore bed can now be traced by the almost continuous line of sink holes and abandoned shafts. For many years various companies operated mines in the region, but most of them were forced to discontinue because of the poor character of the ore in certain places. For several years the industry has been represented by only one company, the Prince Manufacturing Co., successor to the original discoverer. This company has recently absorbed the Prince Metallic Paint Co., successor to the firm of Rutherford & Barclay, and the operations at Little Gap, last worked by William D. Freyman. The company controls the industry through the options which it holds on other properties than those being worked. The Prince Manufacturing Co., with offices in Bowmanstown, operates mines northeast of Hazard and Little Gap and kilns and a roasting and grinding mill at Bowmanstown. There are also kilns at the mines, but these have not been used recently. The ore is hauled by truck to Bowmanstown for calcining and grinding.

Description of paint ore.—The paint ore outcrops in one line from a point 1 mile west of Germans to Bowmanstown in three bands—two faults caused repetition of the bed—from there to a point opposite Lehigh Gap and in a single band eastward to Little Gap. The formation that includes the paint rock has a much greater extent than the latter, but the peculiar lithologic characteristics that render the rock valuable for paint are wanting except in this limited area. There has been much prospecting west of Germans and east of Little Gap, with little success. The best ore seems to occur east of the Lehigh River between Hazard and Little Gap, and the most extensive workings have been carried on near Hazard and near Millport.

Lithologic character.—The ore resembles impure blue limestone without distinct bedding or joint planes; were it not for the high specific gravity it would scarcely be thought to have any value. It is dark blue when fresh but on exposure to the air soon reddens, because of oxidation of iron originally present as carbonate. Specimens of ore, red throughout, are frequently found about old workings; all the iron in these pieces has been oxidized to the ferric state. The ore is termed "sunburned ore." Oxidation likewise weakens the structure so that the pieces of ore can be broken readily. In many places there is no sharp line of separation between the paint ore and the overlying so-called "cement rock", and the miners distinguish them chiefly by the greater weight of the ore. In other places the ore breaks in a different manner than cement rock, and miners can distinguish them in this way. Much of the ore contains considerable pyrite; specimens of such ore are very tough and require considerable effort to reduce them to the size desired for burning. The specific gravity of the ore is 3.2 to 4.

The chemical composition of the ore, in percent, as reported by A. S. McCreath,[72] follows:

Metallic iron	34.600	Phosphorus	0.018
Metallic manganese	.929	Silica	16.210
Alumina	5.492	Loss on roasting	24.350
Lime	3.510		
Magnesia	1.081		86,864
Sulphur	.674		

(In the raw ore the elements exist for the most part as carbonates.)

The ore bed is of variable thickness, but averages about 18 inches throughout the district. The maximum thickness observed was 2 feet 8 inches, but the bed has been reported thicker. Since its deposition in the Devonian Sea the paint-ore bed has undergone many changes by which its original position has been greatly altered. It now forms part of the Appalachian Mountains; these are the result of uplifting accompanied by folding and faulting that occurred at the close of the Paleozoic era. The structure of the ore bed is thus very irregular and disturbed by movement.

Origin of paint ore.—The origin of paint ore has not been definitely determined. Two theories are proposed to account for it. According to one, the ore was originally deposited in the ocean in essentially the same form in which it is found today; that is, the iron has been present in the bed since its deposition. Fine brown or red mud with a high iron content was laid down on the bottom of the ocean with calcareous matter from solution or animal remains. The resulting deposit was a bed of muddy, calcareous rock rich in iron oxide. Deposition of the Marcellus-Hamilton carbonaceous shales over this layer would change the iron to the ferrous condition. Possibly, too, the iron in solution at once replaced part of the calcium of the calcium carbonate, and the deposit as first formed was a rock containing mud, calcium carbonate, and iron carbonate. The pyrite in the ore is also believed to be due to the presence of the organic matter in the carbonaceous shales.

The other theory is that the ore bed represents merely part of the cement bed wherein iron carried by descending waters from the overlying strata has replaced part of the calcium in the original calcareous deposit. Possibly the carbonaceous shales provided iron for replacement by metasomatism, by which iron was substituted for calcium without destroying fossils or rock structure. The bed of clay underlying the ore body would effectively stop downward percolation of iron-bearing waters and so favor replacement of the beds just above. Deposition and replacement always take place more readily from stagnant waters than from freely moving streams.

Determining the origin of the ore is highly important, for the extent of the ore body depends on it. According to the original deposition theory the ore body should show no diminution in thickness or richness with depth, as it has no connection with existing conditions. On the other hand, if the replacement theory is correct the ore should decrease in value with depth, as metasomatic replacement from descending waters does not occur much below the permanent level of the

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[72] Hill, F. A., Report on the Metallic Paint Ore Along the Lehigh River: Second Geol. Survey of Pennsylvania Ann. Rept., 1886, pt. IV, 1887, p. 1404.

ground waters. These data conflict, and the true explanation of the formation must be left to a time when more reliable information can be obtained. Although many workings along the outcrop have been abandoned the ore has not been exhausted, as practically all the workings have been shallow and much ore above the water level in Lehigh River remains.

Mining methods.—Only two mines are now mining in the carbonate paint ore. The Prince Manufacturing Co. is operating a tunnel near Hazard and another at Little Gap. One of its mines near Millport will be described even though now idle.

The ore bed here outcrops well back in the Oriskany Hill and dips steeply 60° to 70° due north. It has been worked 2,000 feet along the strike; a timbered air hole marks the present western limit. One thousand feet east of this the bed was first pierced by a tunnel from the hillside 999 feet due north. The bottom of the shaft is 600 feet east of the point at which the tunnel strikes the bed, and the workings continue 400 feet farther east of this point. A shaft was put down in the hanging wall and struck the bed at 159 feet, the same level as that at which the tunnel enters it. The shaft is 5 feet square and timbered with 6-inch cribbing, inside which are nailed 1-inch boards, forming a complete lining.

The drifts along the strike are 7 feet high and 5½ feet wide at the bottom and 5 feet at the top. They are driven along the ore, which here is 2 feet thick, and are timbered their entire length. Only one post is used in the sets, as the cement-rock hanging wall is firm enough to support one end of the cap in a hitch cut in the rock. The sets, made of 9-inch timber, are placed 3 feet apart and closely lagged.

A pillar is left to protect the shaft, and the stoping is commenced beyond the pillar. The drift is driven 30 to 40 feet at a time; then a section of this length is stoped to the surface or to the overburden of earth and clay. Overhead stoping with filling is the method used. The stope is inclined in advancing so that the top corner farthest from the shaft is kept about 20 feet ahead of the face of the drift. The ore can thus be rolled down from the working face to the drift. Six-inch props are placed at intervals to support the roof while the ore is being removed. The stopes are 4 to 6 feet wide—2 feet of ore and the rest clay and cement rock. The ore is carefully sorted out and rolled down the stope. The clay and cement rock are used as filling. At intervals air holes are driven from the top of the stopes to the surface. From these air is carried to the working places by a small timbered and lagged monkey gangway, which runs along the top of the worked-out and filled-in stopes. As the workings advance new air holes are driven and old ones abandoned.

The ore is blasted down with dynamite, the holes being drilled by hand. After it is sorted and rolled down to the drift it is loaded into boxes holding about half a ton. Each box is suspended from the hoisting ropes by four chains hooked into rings fastened to the corners of the box. The hoisting is done by a horse hoist. After being hoisted the ore is stored in sheds ready for the mill. This mine is rather wet, but natural drainage through the tunnel disposes of all water. One 4-man shift working in a stope can produce 10 tons a day.

In the Hazard tunnel, which is 1,300 feet long, the ore bed where it is being worked dips only about 20°, the most gentle dip inclination the author has observed throughout the district. The ore is worked up the dip about 500 feet in 8-foot slices. The waste rock is thrown back in the worked-out space. A vertical shaft about 100 feet deep, formerly used to hoist ore, connects with the workings and furnishes good circulation of air. Considerable water is encountered, but this flows out through the tunnel which is below the operations.

In the mine at Little Gap the ore bed is practically vertical, and the ore is stoped above the tunnel level to a height of 135 feet. The tunnel follows the ore from its natural outcrop in the end of the hill.

Preparation of paint ore for market.—The treatment of the ore is simple, as only two processes are involved—calcining and grinding to a fine powder when it is ready to be mixed with oil to form paint.

The ore is hauled in trucks from the mines to the mill at Bowmanstown, where it is stored in sheds until used. As it comes from the mine it is mainly in lumps 10 to 14 inches in diameter; these are broken with sledges into smaller pieces before burning so that calcination may extend through the entire mass. The maximum diameter of the fragments is about 6 inches. The ore is then trammed to the kilns, which are generally built on the side of a hill with the ore bins at a higher level so that the ore can be carried over a trestle to the charging door at the top of the kiln without being elevated. The kilns were formerly of stone, but now the best are of brick, with sheet-steel sheathing 25 feet high and 10 feet in diameter. The fire boxes are on either side of the kiln and increase the width at the base to 18 feet. Wood is used as fuel, and the ore is heated cherry red. It remains in the kiln about 24 hours, 10 tons being withdrawn every 12 hours and an equal amount of raw ore added at the top. The object of calcination is elimination of the sulphur of the pyrite and conversion of the iron to the oxide. Raw iron is mainly combined with carbon dioxide to form siderite; part of it, however, is united with sulphur as pyrite. In the burning process the ore changes from blue to dark reddish brown and becomes much less tenacious. The moisture is also driven off during burning. The loss in the process is 20 to 25 percent. Finally the ore is ground in mills near the kilns. At present the burned product is pulverized so that 98 to 99 percent passes through a 325-mesh screen.

Composition of finished product.—The composition of paint made from this material is shown in table 75. The Prince Metallic Paint Co. furnished the analysis for column (1) and the Prince Manufacturing Co. that for column (2) These are old analyses. Column (3) shows the analysis now contained in the advertising literature of the Prince Manufacturing Co.

TABLE 75.—*Prepared paint ores of the Prince Metallic Paint Co., percent*

	(1)	(2)	(3)		(1)	(2)	(3)
Fe_2O_3	41.0–47.0	43.70	50.00	S	0.5– 1.5	--------	-------
SiO_2	32.0–37.0	38.65	34.75	CO_2	1.5– 2.5	--------	-------
Al_2O_3	9.0–11.0	5.79	8.13	H_2O	.6– .9	--------	-------
CaO	.1– 3.0	1.80	2.44	Moisture at 105°	-------------	0.30	-------
MgO	1.7– 3.5	2.04	1.39	Ignition loss above 105°	-------------	2.54	-------
MnO_2	.35– 1.8	1.85	1.40	Undetermined	-------------	3.33	-------
P_2O_5	.14– .17	--------	--------				
						100.00	

Properties and uses.—The manufacturers claim that the paint as marketed has some properties of a Portland cement, as the original rock is a variety of cement rock. They state that 7 pounds of paint mixed with 1 pound of boiled linseed oil will cover 500 square feet. The claims for great durability under the most severe conditions seem to be well substantiated. Most of the paint from this region is used for painting structural steel, bridges, tanks, ships, cars, and tin roofs. More is used in painting freight cars than for any one other use. The material is also used as filler in oilcloth and linoleum.

Production and statistics.—The annual output of the district was around 5,000 tons in 1910; about 50 men were employed in the mines and mills. The output from 1856 to 1910 totaled roughly 100,000 tons.

Bibliography.—Much has been written on the metallic-paint deposits of the Lehigh Gap district. Many of these articles contain data pertaining to the occurrence, mining, and properties of the pigment minerals.[73]

BLACK SHALES USED FOR PIGMENTS

Black shales, ground and sold as mineral black, are used extensively in paint manufacture.

> Mineral black is a pigment made by grinding a black form of slate. It contains a comparatively low percentage of carbon and consequently has low tinting value. It finds use as an inert pigment in compounded paints, especially for machine fillers. The pigment has a flocculent appearance, the particles showing a strong tendency to mass.[74]

Black shales are distributed widely throughout Pennsylvania, occurring in every Paleozoic period and in a great many formations. In many places the material has been dug for paint purposes, and in some slate regions the refuse about the quarries has been shipped to paint factories. A limited use has been found for the culm heaps about the anthracite coal mines and the disintegrated surface coal near the outcrop. Most of the black shale tends to settle out of the oil, but this is not a serious objection. Many who have used paint made from black shales have vouched for its durability. Although some of the shale is used in making paint for buildings most of it is utilized in the manufacture of black filler for ironwork. Because of the large number of deposits of black shale suitable for this work it is certain that the supply is infinitely greater than the limited demand.

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[73] Chance, H. Martyn, Special Survey of the Lehigh Water Gap, in 1875: 2d Pennsylvania Geol. Survey G 6, 1882, pp. 349-363.

White, I. C., The Geology of Pike and Monroe Counties: 2d Pennsylvania Geol. Survey G 6, 1882, pp. 1-333.

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Miller, Benjamin L., The Mineral Pigments of Pennsylvania: Pennsylvania Topog. and Geol. Survey Rept. 4, 1911, pp. 48-88.

[74] Gardner, H. A., The Properties and Structure of Certain Paint Pigments: Paint Mfrs. Assoc. of the United States, Sci. Sec., Bull. 29, p. 35.

Location of deposits.—Black shales have been mined by the Keystone Paint & Filler Co., Muncy, Lycoming County, and the Penn Keystone Co. in the west end of Nippenose Valley. The mill of the latter company is about 1 mile southwest of Antes Fort in a gap where a stream cuts Bald Eagle Mountain. In the Keystone Paint & Filler Co. quarry the dead-black shale is interbedded with black argillaceous limestones, which are discarded. Analyses are given in table 76.

TABLE 76.—*Analyses of black-shale pigment materials, percent*

	[1] (1)	[1] (2)	[2] (3)	[3] (4)
SiO_2	57.53	55.25	59.24	56.97
Al_2O_3	16.72	14.60	17.10	26.05
Fe_2O_3	4.52	3.85	7.26	
FeS_2	3.76	9.15		
$CaCO_3$	4.12		1.70 (CaO)	4.38 (CaO)
MgO	1.38		1.22	2.69
Na_2O	1.06		.96	2.31
K_2O	2.12		3.34	
Water	3.19	16.15	[4] 9.86	[4] 7.14
Organic matter (C)	5.60			
	100.00			

[1] Keystone black filler. Analysis furnished by Harrison Bros. & Co.
[2] Finished product from the Penn Keystone Co., Williamsport. Analysis furnished by the company.
[3] Old Bangor slate from quarry at Bangor. Analysis furnished by J. S. Moyer.
[4] Volatile matter and combined water.

In recent years an increasing amount of disintegrated and partly decomposed anthracite coal has been used in the paint industry. In many of the stripping operations now extensively carried on in the Pennsylvania anthracite region considerable weathered coal, which has disintegrated to a powder and is intensely black in color, has accumulated. This is pulverized by several concerns and sent to paint manufacturers, who use it in part as a substitute for carbon black and bone black.

YELLOW SHALES USED FOR PIGMENTS

Yellow shales occur in many places and at several geological horizons, particularly in the Martinsburg and Mauch Chunk formations. In a number of places these shales have been utilized in the manufacture of paint and when ground fine and mixed with oil are very serviceable. Their principal use, however, is as a filler for oilcloth, linoleum, and phonograph records. They are considerably lighter in color than the ochers and contain a much lower percentage of hydrous iron oxide, seldom more than 5 percent. Yellow shales used for paint are often called ochers, but this term applied to them is plainly not justified.

Location of yellow shales.—Near Moosehead Station, Luzerne County, yellow shales have been worked continuously since 1867. The Luzerne Ocher Manufacturing Co., with offices at White Haven, operates a mine in which the deposit of yellow shale is 12 feet thick. The shale does not break into thin layers as do most shales, but comes out in irregular blocks or masses more like consolidated or dried clay. Table 77 gives analyses.

The material is mined, crushed to finer than 2-inch size, dried in a rotary drier, ground in an impact pulverizer, and separated by air. The material is packed in bags for shipment. The output of this plant has been as much as 6,000 tons a year, although it is now somewhat less.

Table 77.—*Analyses of yellow-shale pigment materials of Pennsylvania, percent*

	[1] (1)	[2] (2)	[3] (3)
Silica	64.24	57.36	63.25
Alumina	22.40	27.44	20.61
Iron oxide	4.80	1.62 FeO 2.94 Fe_2O_3	4.41 .88 TiO_2
Combined water	5.70	1.93 $CaSO_4$	.06 MnO_2 .47 CaO
Undetermined	2.86	.66 $MgSO_4$ 4.50 organic matter .85 water	.48 MgO .09 SO_3 3.21 K_2O and Na_2O 6.54 loss on ignition
	100.00	97.30	

[1] Analysis furnished by S. S. Staples, of the Luzerne Ocher Manufacturing Co.

[2] Analysis by Hugh Hamilton; quoted from Winslow, Arthur, The Lehigh River Cross Section Measured, Mapped, and Described in Detail: 2d Pennsylvania Geol. Survey Ann. Rept. for 1886, pt. IV, 1887, p. 1346.

[3] Analysis made in chemical laboratory of Pennsylvania State College.

RED SHALES USED FOR PIGMENTS

Red shales have been employed in the manufacture of paint in many places in the State, although at present (1930) no plant is known to be in operation. Operations are not limited by the distribution and amount but by the market. Red shales occur in many geological formations but are especially well represented in the Martinsburg (Hudson River), Catskill, and Mauch Chunk formations of the Paleozoic era and the Brunswick shales of the Triassic period.

The red coloring matter of these shales is ferric oxide, which coats the individual grains and was undoubtedly present when the shales were deposited. In some places the iron content has been changed somewhat since deposition by precipitation of more iron oxide, whereas in other places some iron has been removed by subsequent leaching. However, as shales are relatively impervious to water shale strata do not form good media for the passage of water and are accordingly less likely to undergo changes in composition than more porous rocks.

Location of deposits and operations.—For a number of years the J. Wilbur Co., Providence, R.I., operated two open pits near Greenwald, Berks County, in 75 to 250 feet of fine-grain, brick-red shale. Iron and alumina oxides totaled 14.55 percent.

Other pits have been worked about one half mile south of Albany, Berks County; near Hudsondale, Carbon County; near East Charleston, Tioga County; and near Pulaski, Lawrence County. Red shales are known to occur in Wyoming, Somerset, Armstrong, and Venango Counties.

The Pulaski Umber Co. of Pulaski operates a mine and mill to produce a red pigment called "Reno umber filler." The red shale is crushed to ½-inch size, dried, pulverized, and packed. The company furnished the following analysis of the shale:

Analysis of Reno Bros. Paint Co. "Reno French umber filler," percent

Silica	57.26	Sulphuric anhydride	0.02
Ferric oxide	9.28	Phosphoric acid	.10
Alumina	21.34	Combined water	6.10
Lime	.25		
Magnesia	.16		98.74
Titanic acid	.94	Fineness, through 200-mesh	99.85
Alkalies	3.29	Fineness, through 325-mesh	99.17
Manganese	.00	Specific gravity	2.77

The foregoing analysis shows plainly that the product is not an umber; the reason for so designating it is not known. The material from the Pulaski Umber Co. was sold as Reno filler and was used as a filler for many kinds of articles. It was also used to fill small pores and pits on metal and wooden products to make a smooth surface on which other paint was later applied, as a base in many prepared fillers, and frequently mixed with white lead. Most of it was sold to steel and iron manufacturers, particularly locomotive, safe, and structural-steel makers.

The same company also mines a gray mineral marketed under the trade name "Alsi". The analysis and data were furnished by the company; the percentage analysis follows:

Silica	56.80	Magnesia	1.18
Alumina	38.00	Carbon	.68
Ferric oxide	3.30		

This mineral is ground so that over 99 percent will pass a 325-mesh sieve. The finished product is used in the manufacture of structural and railway paints, oil primers and surfacers, lacquer primers and surfacers, molder compositions, coloring for cement and plaster, and grease. The price in car lots is $20 per ton.

PIGMENT FILLERS

There is no sharp line of separation between pigments and fillers, as in many manufactured articles a certain substance is used for both purposes. The following materials produced in Pennsylvania are more properly termed "fillers", although they are with reason likewise termed "pigments".

The Penn Keystone Co. quarries a partly weathered dark shale about 1½ miles south of Oriole in the Nippenose Valley; it is sold under the name "rotten rock". It is crushed, pulverized to different degrees of fineness, and shipped to manufacturers of phonograph records, furniture, automobiles, and brass articles. The ground product is gray. There has been a good demand for the material, and some is exported. Its percentage analysis, as furnished by the company, follows:

Rotten stone

Silica (SiO_2)	60.65	Lime and magnesia ($CaO.MgO$)	2.92
Alkalies ($K_2O.Na_2O$)	8.62		
Alumina (Al_2O_3)	17.68		100.00
Ferric oxide (Fe_2O_3)	9.04	Specific gravity at 15° C. (60° F.)	2.62
Hygroscopic moisture	1.09		

The percentage of silica given does not represent free silica in the form of quartz or sand but silica combined in the form of silicates, chiefly with alumina to form aluminum silicate, the chief component of clay.

The same company grinds a light-yellow shale quarried near Antes Fort, which is marketed under the trade name of "Velvet." This is sold to the paint trade. Percentage analyses of Velvet, mineral black, and Keystone filler, furnished by the Penn Keystone Co., follow:

Velvet filler

Silica	59.72	Magnesium oxide	1.32
Iron and alum oxides	31.43	Loss on ignition	6.32
Calcium oxide	.30	Specific gravity	2.706

Mineral black

Moisture	3.48	Aluminum oxide	4.44
Carbon	84.72	Lime	Trace.
Silica	5.95	Magnesia	Do.
Iron oxide	1.41	Specific gravity	1.5701

Keystone filler

Volatile matter and combined water	2.00	Iron oxide	7.26
		Alumina	17.10
Silica	59.24	Carbon	14.30

Near Virginville the Berks Mineral Products Co. is mining a dark-gray siliceous slate of the Martinsburg formation; part of it is pulverized to pass a 200-mesh screen and the rest to pass a 325-mesh screen. The gray product is used widely in the manufacture of linoleum, oilcloth, phonograph records, paints, rubber, roof cements, and molded plastic work.

The following percentage analysis was furnished by the company:

Silica	61.80	Magnesium oxide	5.07
Alumina	12.48	Alkalies	4.42
Iron oxide	3.72	Loss on ignition	7.30
Titanium oxide	.40	Sulphuric anhydride	.51
Calcium oxide	3.77		

IRON ORES USED IN PAINTS

The iron ores composed of the ferric oxides limonite and hematite have been used in many places in Pennsylvania and adjoining States by manufacturers of metallic paint and mortar colors. In recent years no iron-ore mines, other than those described as ocher mines, have been operated for paint within the State.

The Clinton or fossil ores occur in the Clinton formation of the Silurian period and are distributed through counties of the central part of the State. At present the Clinton ores of Pennsylvania are not being worked, although Pennsylvania paint manufacturers are using considerable New York Clinton iron ores. The Clinton hematite ore affords a superior base for the manufacture of metallic paint and mortar colors. For these purposes ores with relatively high iron content are used, as they are usually softer, more uniform, and more deeply colored. Iron ore has been mined for paint in Gregg Township, Union County; near Gibson's Rock on Rock Hill, Carroll Township, Perry County; in the hills 1 mile south of Mansfield, Tioga County; in Berks County; and near Sand Hill, Monroe County.

TESTS OF PENNSYLVANIA PIGMENTS BY THE UNITED STATES BUREAU OF MINES

PENNSYLVANIA NO. 1

Pennsylvania no. 1 was a 100-pound sample from the Topton mine of the Reichard-Coulston Co., Inc., 95 Madison Avenue, New York City.

Laboratory tests.—The sample was yellow-brown, damp, claylike material ranging from yellow, gray-buff clay to hard rocklike lumps 3 inches or less in diameter. Washing removed 32.1 percent of gray sand and coarse brown fragments. The fines were dried, pulverized, and mixed with 15 drops per gram or 0.37 part by weight of linseed oil to make a paste between maple sugar (60080) and gold (60164). When diluted with zinc oxide the color changed to near sunset (60088). The ferric oxide content was 7.1 percent. The pigment was placed in class 2, yellow, ochers.

PENNSYLVANIA NO. 2

Pennsylvania no. 2 was a 100-pound sienna sample mined by C. K. Williams & Co., Easton, Pa., from the Younssing mine at Reading.

Laboratory tests.—The sample was a soft, damp mixture of black, brown, and some gray plastic, fine-grained material, which blunged with difficulty. The lighter-colored material mixed more readily, but the plastic brown and black portion was greasy and difficult to disperse. A residue of 9.3 percent was removed, but this waste contained some material of good color. The suspension of fines in water did not settle with the usual hydrochloric acid treatment. Mixture with 20 drops per gram or 0.46 part by weight of linseed oil produced an olive-wood (60082) paste, which was very difficult to work and spread on the glass slide. When diluted with zinc oxide the color changed to chamois (60179).

A second portion was ground in a ball mill without separation. This sample likewise did not produce a smooth paste and required 24 drops per gram or 0.56 part by weight of linseed oil to make a paste between autumn (60083) and bronze (60165). When diluted with zinc oxide the color changed to between chamois (60179) and tan (60089). The iron oxide content of the fine material from the washing test was 25.8 percent, whereas that of the milled product from the complete sample was 68.1 percent. This material was placed in class 2, yellow, ochers.

PENNSYLVANIA NO. 3

A 100-pound original ocher sample was sent from the Fleetwood mine of C. K. Williams & Co.

Laboratory tests.—The sample was damp, yellow-brown, claylike material similar to Pennsylvania no. 1; it likewise contained large lumps of hard rock but had a fairly uniform, dark ocher color. Washing removed 47.6 percent of brown residue. The fines were dried and pulverized. They required 19 drops per gram or 0.44 part by weight of linseed oil to make a topaz (60112) paste. When diluted with zinc oxide the color was sunset (60088). The ferric oxide content was 27.0 percent. This material was grouped with light-grade Pennsylvania or class 2, yellow, ochers. It, however, was one of the best duplications from this district of French (class 1) hues. The dilution test indicated moderate tinting strength with a variation toward pink.

Another portion of the sample was ground in water in the ball mill, dried, pulverized, and mixed with 16 drops per gram or 0.37 part by weight of linseed oil to make a paste between terrapin (60091) and topaz (60112). When diluted with zinc oxide the color changed to dark sunset (60088). This sample was placed with dark-grade Pennsylvania or class 2, yellow, ochers. The dilution test indicated moderate tinting strength, and the let-down color varied toward pink-gray. Grinding this material in the ball mill in place of the usual washing darkened the color but did not change it to sienna or other type of pigment, although the ferric oxide content rose to 43.8 percent.

PENNSYLVANIA NO. 4

Pennsylvania no. 4 was a 4-pound sample of "limonite deposit along bituminous coal-mine streams", from the Reichard-Coulston Co., Inc. (See p. 148 for a description.)

Laboratory tests.—The sample was soft, claylike material containing roots and woody fibers. No carbonates were indicated. Washing removed 31.8 percent of dark sand and woody fiber. The fines when dried gave a hard mass of high shrinkage, requiring 25 drops per gram or 0.58 part by weight of linseed oil to make a mummy (60081) paste. When diluted with nine parts of zinc oxide the color changed to champagne (60097). The ferric oxide content was 68.2 percent. This material was grouped with very dark-grade Georgia or class 2*b*, siennas. The full-strength hue varied from the standard toward red-brown. The dilution test indicated good tinting strength. The laboratory test indicated commercial value if a large quantity of uniform material can be produced.

PHILIPPINE ISLANDS

PHILIPPINE ISLANDS NO. 1

The only sample from the Philippine Islands and data regarding it were submitted by the owner, B. D. Dillow, civil engineer, P.O. box 66, Tabaco, Albay, P.I. The deposit is reported to cover about 20 acres in Tiwi municipality, Province of Albay. It is 200 meters from the nearest wagon road, and 12 km from the shipping point, the port of Tabaco. The material occurs on low, fairly level land about 500 meters from the beach on one side and 20 km from an extinct volcano on the other. A few feet below the surface this area is heated by steam and mud geysers, which occur at frequent intervals. The ocher averages about 8 feet in thickness and the overburden 2 feet, ranging from a thin cover to 4 feet. Exploratory borings have been made at 50-meter intervals. Dillow estimates that 100,000 cubic meters of ocher occur in this deposit and that the material can be stripped, mined by opencuts, and hauled by motor trucks to the ship for $12.50 per metric ton, including the cost of containers.

Laboratory tests.—After being ground in water in a ball mill the dried, pulverized fines were mixed with 20 drops per gram or 0.46 part by weight of linseed oil to make a gold-brown (60113) paste. When diluted with nine parts of zinc oxide the color changed to sunset (60088). The ferric oxide content was 50 percent. This material was grouped with class 1*a*, pink, siennas, as it was stronger and had a different hue from the present commercial orange-yellow siennas. The full-strength color was light red-brown, and the diluted color peach-tan. The tinting strength was good. If mining and economic conditions are satisfactory it should have commercial value.

RHODE ISLAND

Bog-iron ore has been reported 3 miles west of Foster Center near the State line in Providence County.[75]

No samples were submitted for testing.

SOUTH CAROLINA

According to Dr. Stephen Tabor, State geologist, no ocher deposits are being mined in South Carolina, although several prospects have been investigated. The sample from near Abbeville indicated that good-quality ochers occur in this region.

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[75] Schrader, F. C., Stone R. W., and Sanford, Samuel, Useful Minerals of the United States: U.S. Geol. Survey Bull. 624, 1917, p. 269.

Schrader, Stone, and Sanford [76] describe the following occurrence of hematite in South Carolina:

Hematite (specular iron ore).—Occurs in highly metamorphosed Archean and later rocks. Cherokee County, in zone crossing Broad River at mouth of Doolittle Creek and thence along west side of Peoples Creek. Deposits have been worked to small extent but not of immediate importance.

SOUTH CAROLINA NO. 1

T. Frank McCord, 508 National Loan & Exchange Bank Building, Greenwood, S.C., submitted a sample from his property, about 2¼ miles east of Abbeville just off Calhoun highway in Smithville Township, Abbeville County, about 2 miles from the station on the Southern Railway. As reported by McCord, outcrops in gullies and stream beds indicate that the ocher deposit covers a 375-acre tract. The outcrop from which sample no. 1 was taken is about 30 feet wide and 15 feet deep, in a hillside covered with timber and underbrush. No development work has been done. The cost of transportation to the railroad is estimated by McCord as $3 to $5 a ton.

Laboratory tests.—The sample consisted of lightweight, irregularly colored chunks 3 to 4 inches in diameter. Although the lumps were soft they did not disintegrate in water easily, and the sample was ground in a ball mill in water. After being dried and pulverized the sample was mixed with 19 drops per gram or 0.44 part by weight of linseed oil to make a good-working paste of gold-brown (60113) plus bronze (60165). When diluted with nine parts of zinc oxide the color was near sunset (60088) and close to chamois (60179). This material was classed with the medium-grade Pennsylvania or class 2, orange-yellow, ochers, slightly grayed. The dilution test indicated medium tinting strength of cream hue. The ferric oxide content was 17.9 percent. This ocher had enough color strength for commercial work, and the test indicated value if enough uniform material could be produced at low cost.

SOUTH DAKOTA

The occurrence of iron ore in South Dakota has been summarized by Schrader, Stone, and Sanford [77] as follows:

Hematite (red iron ore).—Custer County, occurs at Iron Mountain. Pennington County, northwest of Hayward mine, 4 miles south of Keystone, contains gold and silver; abundant on Box Elder Creek, and in slates and quartzites near Rapid City and at and near Hot Mound, 10 miles northwest; occurs at Iron Mountain; oölitic hematite occurs in the Deadwood formation, at the top of the Cambrian. * * *.

Limonite (brown hematite).—Occurs with gold quartz veins in Black Hills, with other iron ores in Iron Mountain on Pennington-Custer County line, carries gold and silver; near Rochford, secondary deposits in swamps and ponds along the creeks, and called "bog ore" and "yellow ocher" ore; mined for mineral paint; similar deposits occur near Nahant.

No samples were received from South Dakota.

TENNESSEE

BROWN IRON ORES OF TENNESSEE DRAINAGE AREA [78]

Second to the Appalachian region so far as present developments are concerned, but probably far outranking it in unworked reserve tonnages, is the region lying in northwestern Alabama, middle Tennessee, and western Kentucky, along the Tennessee River drainage, and in areas drained by its main tributaries. * * *

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[76] Work cited, p. 272.

[77] Work cited, pp. 277 and 278.

[78] Eckel, E. C., Iron Ores. Their Occurrence, Valuation, and Control: McGraw-Hill Book Co., New York, 1914, pp. 234–235. See also Burchard, E. F., The Brown Iron Ores of West-Middle Tennessee: U.S. Geol. Survey Bull. 795-D, 1927, pp. 53–112.

The ores differ in geologic association from those of the Appalachian Valley. They are associated with limestones * * * of lower Carboniferous age, in place of the Cambrian and Silurian limestones which are associated with the Appalachian ores. * * * In the Appalachian region the rocks have been greatly folded and tilted, so that both ores and associated rocks rarely lie in even approximately horizontal attitudes. In the Tennessee drainage area, on the other hand, the folding and tilting have been very slight; the rocks dip at very low angles; and the brown-ore deposits mantle over them in comparatively regular form. * * * There is thus an area of perhaps 2,000 square miles, over which brown-ore deposits are scattered more or less thickly. Of this total area close geologic study will probably rule out nine tenths as not being likely to contain any large deposits, but this leaves several hundred square miles of very promising territory, within which deposits of serious size are likely to occur, and within which a very large tonnage of workable ore has already been developed.

The Tennessee Basin ores are similar in composition to the average of the Appalachian district, not as poor as the ores of the Virginia Oriskany district nor as rich as the best ores of Virginia and Alabama.

TENNESSEE RED OR CLINTON HEMATITES [79]

The main belt of the Clinton ore outcrop extends 170 miles northeast across Tennessee from Chattanooga to Cumberland Gap, where it enters Virginia. Although not continuous the total length of the Clinton outcrops in Tennessee is nearly 300 miles; of this total about 115 miles are reported to contain an ore bed more than 2 feet thick. The Chamberlain seam is said to be the thickest—5 to 7 feet. The composition given by Burchard is: Iron, 25 to 45 percent; lime, 8 to 20 percent; silica, 4 to 15 percent; alumina, 4 to 10 percent; phosphorus, 0.25 to 0.75 percent; and sulphur, trace to 1 percent.

Schrader, Stone, and Sanford have outlined the iron-ore occurrences of Tennessee as follows:[80]

Hematite.—Occurs in Bledsoe, Bradley, Campbell, Claiborne, Cocke, Grainger, Hamilton, Hancock, Henderson, James, Loudon, Marion, McMinn, Monroe, Rhea, Roane, Sequatchie, and Sullivan Counties. Mined in Carter County, Stony Creek Valley, McMinn County, east of Athens.

Brown iron ore.—Wide-spread and extensively mined in east Tennessee.

Brown hematite.—Eastern iron-ore region across the State from Virginia to Georgia, in Blount, Carter, Cocke, Greene, Johnson, Monroe, Polk, Sevier, Sullivan, and Washington Counties. The ores occur in matrix of clay, sand, chert, and debris of disintegrated rocks, mostly in Knox dolomite. Blount and Monroe Counties, almost inaccessible. Carter County, Dove River Cove banks. Cocke County, Whitehall, Pecks Mountain, and elsewhere. Greene County, several banks of manganiferous ore near Unaka Furnace. Johnson County, Crockett's, Sharp's, and other banks, south foot of Holston Mountain, Laurel Creek Valley, and Butler Furnace banks. McMinn County, Tellico Plains, several deposits. Polk County, in gossan at Ducktown copper mines. Sevier County, Sullivan County, at Crockett bank and other places in eastern part of county. Washington County, deposits in Bumpass Cove and Greasy Cove.

Limonite.—Wide-spread in middle Tennessee and is produced in the region west of the Central Basin. Occurs in Benton, Decatur, Dickson, Hardin, Hickman, Houston, Humphreys, Lawrence, Lewis, Montgomery, Perry, Stewart, and Wayne Counties; mines at Allens Creek, Ferro, Iron City, Pinkney, Riverside, and West Point.

TENNESSEE NO. 1

Tennessee no. 1 was sent through the courtesy of Dr. Walter F. Pond, State geologist, from the Johnson mine of the Tennessee Products Co., Hickman County.

Laboratory tests.—The material as received consisted of 20 pounds of 1- to 2-inch lumps of hard limonite ore. The material was ground in water, dried, and

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[79] Abstract from Eckel, E. C., work cited, pp. 227-228.

[80] Work cited, pp. 281, 284.

mixed with linseed oil to make a brown (60114) paste. When diluted with zinc oxide the color changed to tan (60089) plus gray. The iron oxide content was 76.7 percent. This material was classed with the class 1*a*, pink, siennas. The dilution tests indicated good tinting strength, well worth consideration as pigment material. The color did not duplicate any now on the market.

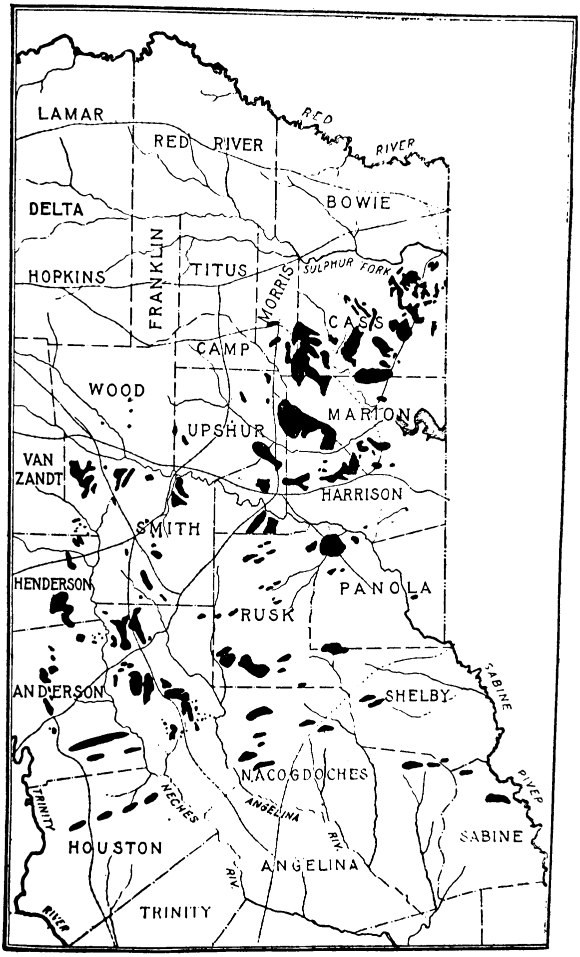

FIGURE 28.—Map of Texas brown-ore district, according to Kennedy (Eckel).

TEXAS

Kennedy [81] has mapped brown iron-ore districts aggregating more than 1,000 square miles in 20 counties in northeastern Texas—Camp, Cass, Marion, Morris, Upshur, Wood, Harrison, Van Zandt, Gregg, Panola, Smith, Rusk, Cherokee, Henderson, Anderson, Houston,

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[81] Kennedy, W., Reports on the Iron-Ore District of Eastern Texas: Texas Geol. Survey 2d Ann. Rept., 1891, pp. 7-326.

Nacogdoches, Shelby, Sabine, and San Augustine. The total reserves are estimated to range from 500,000,000 to 1,000,000,000 tons. Eckel states:[82]

> The possibility of commercial utilization depends upon factors other than total tonnage. The ores occur in approximately horizontal beds, associated with clays, sands, and greensands of Tertiary age. (See fig. 28.) The ore bodies are conformable to the associated beds and often are enclosed in them, but * * * were formed somewhat later.

ORE FORMATION

Although of good grade the ores occur in thin beds ranging from 1 to 10 feet in thickness and averaging 2 to 3 feet; the beds are near the surface on the tops of plateaus and separated by sharp little ravines. (See fig. 29.) The ore occurs as relatively large nodules or in platy layers, which can be easily freed from the accompanying sand, except when the sand is entrapped in the nodules or lumps of ore. Kennedy gives the following average composition of 131 samples from all parts of this area: Metallic iron, 46.63 percent; silica, 14.47 percent; alumina, 8.17 percent; sulphur, 0.083 percent; and phosphorus, 0.172 percent. Eckel states that the ores "can be mined cheaply and easily at any given point, and the whole problem is one of assembling a tonnage from a series of scattered operations."

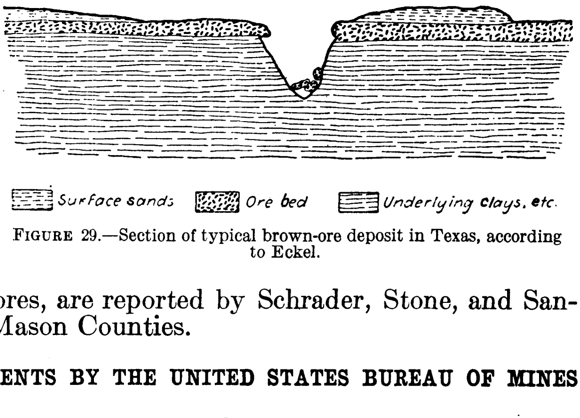

FIGURE 29.—Section of typical brown-ore deposit in Texas, according to Eckel.

Hematites, associated with magnetite ores, are reported by Schrader, Stone, and Sanford [83] in Llano and Mason Counties.

TESTS OF TEXAS PIGMENTS BY THE UNITED STATES BUREAU OF MINES

TEXAS NO. 2

Museum sample no. 47 from Knight's Bluff, Marion County, Tex., was submitted by E. H. Sellards, associate director, bureau of economic geology, University of Texas, Austin.

Laboratory tests.—The 180-gram sample as received was a bright-yellow ocher lump veined with dark-brown hard limonite, with an occasional red spot. The acid test indicated no carbonates. The sample was ground in water, and the resulting fines on drying formed a moderately hard mass of fair shrinkage. Seventeen drops per gram or 0.39 part by weight of linseed oil was required to make a light red-brown paste, which when diluted with nine parts of zinc oxide changed to strong peach-tan varying toward orange. The dilution test indicated excellent tinting strength. The ferric oxide content was 40.9 percent. Although the pigment color did not match any commercial pigment colors it was grouped with class 1*a*, orange-yellow, siennas, and because of its pleasing hue should have commercial value if enough material of this character can be found. (Compare with the yellow-brown limonite sample, New York no. 6.)

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[82] Eckel, E. C., Iron Ores. Their Occurrence, Valuation, and Control: McGraw-Hill Book Co., New York, 1914, pp. 236–239. Iron Ores of Northeastern Texas: U.S. Geol. Survey Bull. 260, 1905, p. 348. Burchard, E. F., Iron Ore in Cass, Marion, Morris, and Cherokee Counties, Tex.: U.S. Geol. Survey Bull. 620 (*e*), 1915, pp. 69–109. Kennedy, W., Iron Ores of East Texas: Trans. Am. Inst. Min. Eng., vol. 24, 1894, pp. 258–288.

[83] Work cited, p. 291.

TEXAS NO. 3

Texas no. 3, also submitted by Sellards, was sample no. 51 from Port Caddo, Marion County.

Laboratory tests.—The 55-gram sample as received was a hard, dark red-brown chunk with a red coating on one side and a limonite brown skin on the other. After being ground it formed a moderate-shrinking mass of fair hardness. Thirteen drops per gram or 0.30 part by weight of linseed oil was required to produce a light red-brown paste, which diluted to strong, standard class 2, burnt sienna, plus old rose. The tinting strength was good, and the iron oxide content 79.6 percent. This material should have commercial value in the burnt-sienna class

TEXAS NO. 4

Texas no. 4, museum sample no. 261, also submitted by Sellards, consisted of 12 grams of light brown-red hard ore, which gave no acid reaction.

Laboratory tests.—After being ground in water the material formed a moderate-shrinking mass of fair hardness when dried. Nineteen drops per gram or 0.44 part by weight of linseed oil was required to produce a light red-brown paste, which diluted to class 2, salmon, burnt sienna. The tinting strength was medium and the iron oxide content 25.7 percent. The sample apparently has possible commercial value.

TEXAS NOS. 5, 6, 7, AND 8

Texas nos. 5, 6, 7, and 8 were also sent by Sellards and marked, respectively, 1596, 1597, 1598, and 1599, Cass County.

Laboratory tests.—All consisted of 100 grams or less of light- and dark-brown crushed fragments, which changed to red on fine grinding in water; the pulverized samples on drying formed a low-shrinking, soft mass. No lime carbonates were indicated by acid test. Fourteen drops per gram or 0.32 part by weight of linseed oil was required to make a dark chocolate-brown paste, which when diluted with nine parts by weight of zinc oxide changed to standard class 2, violet, mineral brown. The tinting strength was better than that of commercial browns. The test indicated that these materials have the oil-absorption, tinting-strength, and color requirements of commercial pigments and are not handicapped by lime carbonate. The distance from the eastern market is the greatest drawback in marketing, and demands for this hue may not be large.

UTAH

IRON ORES

The iron-ore occurrences in Utah have been listed by Schrader Stone, and Sanford [84] as follows:

Brown iron ore (limonite).—Beaver County, important ore mineral in Cave mine, Mineral Range. Box Elder County, large body at Copper Mountain mine, Lucin district. Iron County, occurs near Modena, containing silver, lead and gold. Extensive deposits in Iron, Juab, Morgan, and Uinta Counties; used as flux in lead smelting. Piute County, iron mines in Antelope Range. * * *.

Hematite (red iron ore).—Iron and Washington Counties, immense quantities in Iron Mountain district, has been mined at Iron City. Summit County, near North Fork of Provo River. Wasatch County, large deposits at the head of Duchesne River, in the Uinta Range, mined for flux. (See fig. 30.)

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[84] Work cited, pp. 299, 303.

The literature [85] contains a number of references to Utah iron ores. An advertising circular distributed by the department of mining and metallurgical research, University of Utah, states:

> In the past, red pigment material has been mined in the northwestern part of Piute County and yellow ocher has been mined to some extent near Gunnison, Sanpete County, by the Utah Wall-Tint Co., of Salt Lake City. Deposits not at present being worked have been reported in the western part of Cache County near Clarkston and another near Ophir in Tooele County.

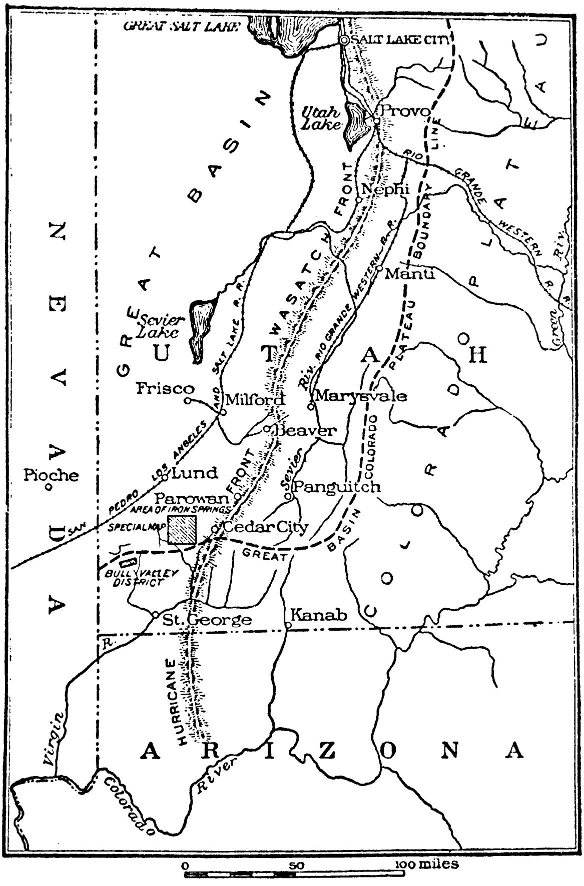

FIGURE 30.—Map of Iron Springs district, Utah, according to Leith and Harder (Eckel).

Through the courtesy and cooperation of D. A. Lyon, director, department of mining and metallurgical research, University of Utah, 34 samples of possible pigment materials were received for testing.

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[85] Boutwell, J. M., Iron Ores in the Uintah Mountains: U.S. Geol. Survey Bull. 225, 1904, pp. 221-228.
Jennings, E. P., Origin of the Magnetic Iron Ores of Iron County, Utah: Trans. Am. Inst. Min. Eng., vol. 35, 1904, pp. 338-342.
Leith, C. K., Iron Ores in Southern Utah: U.S. Geol. Survey Bull. 225, 1904, pp. 229-237.
Leith, C. K., and Harder, E. C., The Iron Ores of the Iron Springs District, Southern Utah: U.S. Geol. Survey Bull. 338, 1908, 102 pp.
Lerch, F., The Iron-Ore Deposits in Southern Utah: Iron Trade Rev., May 19, 1904, pp. 49-50.
Putnam, B. T., Utah Iron Ores: Repts. 10th Census, vol. 15, 1886, pp. 469-505.

TESTS OF UTAH PIGMENTS BY THE UNITED STATES BUREAU OF MINES

UTAH NO. 1

Sample no. 1 and the data thereon were submitted by Frank Judd, St. George, Utah. The material is reported to lie 2 miles from a good highway and about 50 miles from the nearest railway at Cedar City. The deposit is estimated to cover 10 to 15 acres and to be 40 feet thick, as indicated by watercourses. The ocher has been used in calcimine on the walls of buildings in St. George and shows good color after 40 years.

Laboratory tests.—The 1-pound sample as received consisted of yellow ocherous clay containing hard siennalike particles. The washing test removed 45.5 percent of yellow-brown material. A second sample was therefore ground in water in the ball mill; it produced a high-shrinking, hard, brittle mass which when pulverized required 15 drops per gram or 0.35 part by weight of linseed oil to make a paste between pablo (60090) and gold (60164). When diluted with nine parts of zinc oxide the color changed to between polar bear (60004) and leghorn (60005). The ferric oxide content was 12.2 percent. This material was grouped with light-grade Pennsylvania or class 2, orange-yellow, ochers, slightly grayed. The dilution test indicated a tinting strength entirely too weak for commercial purposes. The secondary tint was pink.

UTAH NO. 2

Sample no. 2 and its description were furnished by the owner, David McMullen, Leeds, Utah. The deposit is in T. 41 S., R. 13 W., S.L.M., Washington County, in the Harrisonburg mining district; it is three fourths of a mile from United States Highway No. 91 and from Leeds. Cedar City, the nearest shipping point, is 38 miles from Leeds. The outcrop exposes a mineral seam about 3 feet wide and 20 feet long, with an overburden of 5 to 6 feet. Little work has been done on this deposit.

Laboratory tests.—The 3-pound sample was reddish-brown hard shale with a few black, magnetitelike spots. It was fairly uniform in color and too hard for washing. The sample was ground in water; it produced a high-shrinking hard residue, which when pulverized required 13 drops per gram or 0.30 part by weight of linseed oil to make a paste between tobacco (60143) and henna (60135). When diluted with zinc oxide the color changed to Grecian rose (60175). The ferric oxide content was 35.7 percent. This material was grouped with class 1, red-brown, burnt siennas. The dilution test indicated medium tinting strength, equal to standard commercial burnt siennas, with a variation toward violet-gray. If economic and marketing conditions can be made satisfactory, this material has commercial value.

UTAH NO. 3

Utah no. 3 and its description were submitted by Afton St. George, Tooele, Utah. The deposit is reported to be on a good road 20 miles south of Tooele Mountain and 5 miles from the railway. The outcrop is 4 miles long and indicates a 4-foot vein with 45° dip.

Laboratory tests.—The sample as received was a mixture of reddish clay and white calcite in crystalline material ranging from 4-inch lumps to dust. Washing removed 67.8 percent of calcite and other residue, but the remainder still contained a high amount of carbonates. The dried, pulverized fines required 12 drops per gram or 0.28 part by weight of linseed oil to produce a henna (60135) paste. When diluted with zinc oxide the color changed to between tea rose (60021) and Grecian rose (60175). The ferric oxide content was 26 percent. The pigment was classed as weak class 2, salmon, burnt sienna; however, the dilution test indicated such weak tinting strength that its commercial value for general purposes is doubtful.

UTAH NO. 4

Sample no. 4 and data thereon were submitted by Thomas Burt, 565 South First West, Salt Lake City. The deposit is within 100 yards of a highway about 10 miles north of Cedar City and about 10 miles from the railway. The material occurs in a 19-inch seam and was traced for about 150 yards along the sides of a shallow canyon.

Laboratory tests.—The sample consisted of three 3- to 4-inch lumps of red-brown, shalelike material too hard for washing. It was ground in water, and the pulverized fines required 15 drops per gram or 0.35 part by weight of linseed oil to produce a brown (60114) (plus red) paste. When diluted with nine parts of zinc oxide the color changed to light Grecian rose (60175). The ferric oxide content was 16.7 percent. This material was grouped with class 1, old rose, mineral browns. The tinting strength was medium or equal to that of commercial browns, although it varied from their hue toward old rose. The color, however, was attractive enough for further investigation as to mining and marketing.

UTAH NO. 5

Utah no. 5 and information thereon were submitted by George Marshall, Jr., Minersville, Utah. He reports a large quantity 14 miles from the railway and from the highway.

Laboratory tests.—The sample as received consisted of two 4-inch flat lumps of reddish-brown shale too hard for washing. These were ground in water in a ball mill and the dried, pulverized fines mixed with 17 drops per gram or 0.39 part by weight of linseed oil to produce a reddish-brown (60114) paste. When diluted with nine parts of zinc oxide it changed to light Grecian rose (60175). The ferric oxide content was 12.6 percent. This material was grouped with class 1, old rose, mineral browns. The tinting strength was medium or equal to that of commercial browns, from which the let-down color varied toward old rose. Although this material did not match present commercial browns, it was attractive enough for further investigation as to mining and marketing.

UTAH NO. 9

Wayne Clark, Cullen Hotel, Salt Lake City, submitted Utah no. 9, Clark sample no. 1, from a deposit in Beaver County on a good highway about 12 miles from the railway. The outcrop exposes ocher at least 1,000 feet.

Laboratory tests.—The sample as received was deep brown-red, soft, lightweight material, which floated on water and was hard to wet and disperse. Washing removed 53 percent of lightweight, red-brown, coarse sand containing white and stained calcite. The fines dried to a hard mass with moderate shrinkage. When pulverized they required 33 drops per gram or 0.77 part by weight of linseed oil to produce a mahogany (60136) paste. When diluted with zinc oxide it changed to brown Grecian rose (60175). The ferric oxide content was 62.5 percent. This material was grouped with class 1, red-brown, burnt siennas. Although the iron content was very high, the dilution test indicated weak tinting strength. The let-down tint was close to standard in hue but not quite so strong. It might be improved by different preparation. It has at least local commercial value if economic and marketing conditions are satisfactory.

UTAH NO. 10

Wayne Clark also submitted Utah no. 10, Clark sample no. 2, from a deposit on a good highway in Sevier County about 40 miles from the Denver & Rio Grande Railroad. The reported thickness is about 20 feet.

Laboratory tests.—The sample as received was deep-red claylike material ranging from 2-inch lumps to powder. Washing removed 22.4 percent of red and white sand, leaving a high-shrinking, hard, brittle mass. The pulverized material required 21 drops per gram or 0.49 part by weight of linseed oil to make a mahogany (60136) paste. When diluted with nine parts by weight of zinc oxide the color changed to Grecian rose (60175). The ferric oxide content was 52.4 percent. This material was grouped with class 2, salmon, burnt siennas. The light red-brown, full-strength color was near the red oxides. The dilution test indicated medium tinting strength equal to commercial pigments plus a red tint. These tests indicated commercial value if economic and marketing conditions are satisfactory.

UTAH NO. 11

Utah no. 11 and data thereon were submitted by one of the owners, J. H. Jensen, 49 South Utah Street, Richfield, Utah. The deposit lies in T. 18 S., R. 4 W., Millard County. The claim is 6 miles from the main highway, 19 miles north of Holden, 25 miles southeast of Delta, and 12 miles from the Salt Lake & Los Angeles Railroad. Jensen estimates that the material can be mined and loaded on cars at McCormick station for $5 a ton. It occurs in quartzite.

Laboratory tests.—The 2-pound sample was hard, yellow-brown ocher-colored vesicular or porous limonite ore containing softer claylike portions. No carbonates were indicated by the acid reaction. When ground in water the sample formed a low-shrinking mass of medium hardness. The dried and pulverized fines were mixed with 17 drops per gram or 0.39 part by weight of linseed oil to produce a gold-brown (60113) to topaz (60112) paste. When diluted with nine parts by weight of zinc oxide it changed to between dark sunset (60088) and light pablo (60090). The ferric oxide content was 50 percent. This material was grouped with class 1, orange-yellow, siennas. The full-strength color varied from that of dark-grade Pennsylvania yellow ocher toward red-brown. The dilution test indicated excellent tinting strength toward a brown hue, stronger than any American or French yellow ocher. The pigment was more like 28 percent ferric oxide artificial ochers. Although it did not duplicate existing commercial ochers it had a pleasing color, good-working physical properties, and good tinting strength and should therefore have market value.

UTAH NO. 13

Utah no. 13 and data thereon were supplied by one of the owners, Harry Christianson, box 5, Spanish Fork, R.F.D. 1, Utah. The deposit is reported to be a 7-foot seam in Utah County close to Utah Lake, southeast of Curek and about 4 miles from the Denver & Rio Grande Railroad. The outcrop indicates a 4- to 5-foot vein with a light overburden.

Laboratory tests.—This ¾-pound sample was a dark-red powder containing light lumps. Some carbonate was indicated by the acid reaction. The material was ground in water; and the dried, pulverized fines were mixed with 19 drops per gram or 0.44 part by weight of linseed oil to produce a paste between brown (60114) and henna (60135). When diluted with nine parts by weight of zinc oxide the color changed to between Grecian rose (60175) and bois de rose (60176). The ferric oxide content was 61 percent. This material was grouped with class 2, salmon, burnt siennas. The tinting strength was medium or equal to that of commercial burnt siennas, and the hue varied from the standard toward red. These tests indicated commercial value if the lime content is not objectionable.

UTAH NO. 14

B. A. McBride, 4081 South West Temple Street, Salt Lake City, submitted Utah no. 14 from a deposit in Tooele County, 3 miles from the railroad.

Laboratory tests.—The ¼-pound sample consisted of dark-red, lightweight compact but comparatively soft rock and some yellow-brown limonite particles. The acid test indicated no carbonates. The sample was ground in water and when dry formed a medium- to low-shrinking mass of fair hardness. The pulverized material required 25 drops per gram or 0.58 part by weight of linseed oil to make a henna (60135) paste. When diluted with nine parts of zinc oxide the color changed to bois de rose (60176). The ferric oxide content was 69.6 percent. This material was grouped with class 2, salmon, burnt siennas. The dilution test indicated excellent tinting strength, stronger than the commercial standard. The let-down tint varied from the standard toward red. If economic conditions are satisfactory this material should have commercial value.

UTAH NO. 16A

Mrs. Ellen Winder, Cleveland, Utah, submitted Utah no. 16A from a deposit in Emery County.

Laboratory tests.—The small sample was soft, yellow-brown nodular clay which could be washed or ground. The acid test indicated no carbonate. The sample was ground in water and formed a moderate-shrinking mass of fair hardness. The pulverized fines were mixed with 24 drops per gram or 0.56 part by weight of linseed oil to produce a gold-brown (60113) paste. When diluted with nine parts of zinc oxide the color changed to sunset (60088). The ferric oxide content was 41.4 percent. This material had a different hue from commercial yellow ochers, and classification was difficult. The full-strength hue was very dark red-brown. The dilution test indicated good tinting strength of brown-cream, stronger than any natural American or French yellow ocher. The pigment was more like 28 percent iron oxide artificial ochers. This color could undoubtedly be used for certain purposes but could not be substituted for present commercial ochers. It was grouped with class 1, orange-yellow, siennas.

UTAH NO. 16B

Sample no. 16B and data thereon were also submitted by Mrs. Ellen Winder.

Laboratory tests.—The sample comprised a few ounces of brownish-black, lightweight, organic material which gave no indication of carbonates. The sample was ground in water and gave a high-shrinking hard mass, which when pulverized required 36 drops or 0.84 part by weight of linseed oil to make a black smoke (60036) paste. When diluted with nine parts of zinc oxide the color changed to beaver (60101). The ferric oxide content was 20.8 percent. Although this material was placed with the umbers and the tinting strength exceeded that of commercial pigments of this class it did not match those of this study in hue. The graphite-black, full-strength color diluted to strong beaver-brown with a green secondary color, unlike any commercial umbers. The oil requirements were high, and the color was unusual. A new commercial color series would have to be developed to permit its use; therefore general application is doubtful.

UTAH NO. 17

W. S. Wright, 173 North Fourth West, Payson, Utah, submitted Utah no. 17 from a deposit in south Juab County. Although the size of the deposit has not been determined the red color can be traced for about 1 mile.

Laboratory tests.—The 2-pound sample was a yellowish-red mixture of hard and soft particles which contained some carbonate. A sample was ground in water and dried to a hard mass of medium shrinkage. Twenty drops per gram or 0.46 part by weight of linseed oil was required to make a henna (60135) paste. When diluted with nine parts of zinc oxide it changed to tea rose (60021). The ferric oxide content was only 6.6 percent, and the dilution test indicated weak tinting strength, sufficient only for local use in cements and plasters. The pigment was grouped with class 2, salmon, burnt ochers.

UTAH NO. 19

R. A. Campbell, 193 West Second South, Tooele, Utah, submitted Utah no. 19 (Campbell no. 1, yellow) from a deposit in the Grantsville mining district on the northwest slope of the Stansburg Range, 15 miles southwest of Grantsville. (See Utah no. 6.) The yellow 18- to 30-inch vein occurs in a blue limestone formation and dips 65° northwest on a strike of N. 70 E. The outcrop can be traced several hundred feet. The extent of the deposit is uncertain, as no development work has been done.

Laboratory tests.—The 1-pound sample was yellowish-brown material ranging from 3-inch lumps to fines. It was fairly hard, compact rock containing some carbonate. The sample was ground in water and dried to a hard, high-shrinking mass, which showed a brown scum. The pulverized fines required 19 drops per gram or 0.44 part by weight of linseed oil to produce a paste between gold-brown (60113) and maple sugar (60080). When diluted with nine parts of zinc oxide the color changed to maize (60006). The ferric oxide content was 23.2 percent. This material was placed with class 2, orange-yellow, ochers, slightly grayed, but should be in a class by itself. It has good commercial possibilities if economic and mining conditions are satisfactory. The value of this pigment lies not in the magnitude of the iron oxide content but in the peculiar brightness or clearness of the yellow. The full-strength color was like that of dark-grade Pennsylvania varying toward red-brown. When diluted it was deeper yellow than any commercial, natural, or artificial ocher and second only to Nevada no. 26 in the strength of yellow chroma. It could be used in small quantities for increasing the tinting power of eastern ochers if the cost of delivery to the East were not too high.

UTAH NO. 20

Utah no. 20 (Campbell no. 1, red) and data thereon were submitted by Campbell. The location is the same as that of Utah no. 19. The red seam is reported to be 2 to 4 feet wide.

Laboratory tests.—The ½-pound sample was red clay ranging from 4-inch lumps to powder and gave a carbonate reaction with acid. When ground in water it formed a high-shrinking, hard mass on drying. The pulverized fines required 20 drops per gram or 0.46 part by weight of linseed oil to produce a henna (60135) paste. When diluted with nine parts of zinc oxide it changed to salmon pink (60022). The ferric oxide content was 21.3 percent. This material was grouped with class 2, salmon, burnt ochers. The dilution test indicated medium tinting strength, equal to that of commercial burnt siennas. These tests indicated a commercial material if the lime content is not objectionable.

UTAH NO. 21

John T. Winn, 141 West Second South Street, Lehi, Utah, submitted Utah no. 21. The material covers a large area on a hillside in Rush Valley, Tooele County, about 6 miles from Foss railroad station.

Laboratory tests.—The 4-ounce sample consisted of deep-red, crushed, hard fragments with an indication of carbonate. It was ground in water to give a mass of moderate hardness and shrinkage. The pulverized fines required 15 drops per gram or 0.35 part by weight of linseed oil to make a henna (60135) paste. When diluted with nine parts of zinc oxide the color changed to Grecian rose (60175). The ferric oxide content was 30.3 percent. This material was grouped with class 2, salmon, burnt siennas. The tinting strength was medium or equal to that of commercial pigments. The tint varied in hue from the standard toward red. If mining and marketing conditions are satisfactory and the lime content is not objectionable, the material should have commercial value.

UTAH NO. 25

Utah no. 25 and data thereon were submitted by the owner, Paul Kimball, 413 Ness Building, Salt Lake City. The sample was collected from near Green River, 8 miles from the main line of the Denver & Rio Grande Railroad. Kimball estimated the cost f.o.b. cars at $1.50 to $2.50 per ton. Little or no development work has been done on this deposit, but the tonnage is estimated to be very large.

Laboratory tests.—The small sample was partly ground, dark-red hematite ore. No carbonate was detected. The ore was ground in water, and the dried, pulverized fines were mixed with 15 drops per gram or 0.35 part by weight of linseed oil to make a paste between monkey skin (60123) and dark blossom (60171). When diluted with nine parts of zinc oxide this changed to light Grecian rose (60175). The ferric oxide content was 30.7 percent. This material was grouped with class 1, old rose, mineral browns. The tinting strength was very good. The let-down color varied from the standard toward old rose. Although it did not match commercial hues it was attractive enough for commercial use and should be investigated further.

UTAH NO. 26

R. Albern Allen, Kingston, Utah, located the deposit from which Utah no. 26 was sampled in sec. 6, T. 29 S., R. 2 W., S.L.M., about 2 miles from a good highway and 24 miles from the railroad. The pigment material occurs as several seams of red ore ranging from 1 to 4 feet in thickness with occasional pockets of yellow (Utah no. 27). The prospect has been cut only on the surface and shows a width of about 80 feet.

Laboratory tests.—The 5-pound sample consisted of reddish-brown, hard, tough, claylike lumps, 3 inches and finer. Part of it was ground in water, and the dried, pulverized fines were mixed with 21 drops per gram or 0.49 part by weight of linseed oil to make a henna (60135) paste. When diluted with nine parts by weight of zinc oxide it changed to light Grecian rose (60175). The ferric oxide content was 21.1 percent. This material was grouped with class 2, salmon, burnt ochers, although it was close to weak red oxides because of the bright brown-red original color. The tinting strength was too weak for general commercial service, but it might find local use in mortars, etc.

UTAH NO. 27

Utah no. 27 and data thereon were also submitted by Allen. (See no. 26.)

Laboratory tests.—The 5-pound sample was a yellow-brown, claylike mass, which gave the carbonate of lime test with acid and consisted of 4-inch lumps to dust. After the sample was ground in water, dried, and pulverized the fines were mixed with 23 drops per gram or 0.53 part by weight of linseed oil to make a topaz (60112) paste. When diluted with nine parts of zinc oxide the color changed to a mixture of sunset (60088) and leghorn (60005). The ferric oxide content was 8.2 percent. This material was grouped with light-grade Pennsylvania or class 2, orange-yellow, ochers, slightly grayed, but was close to light-grade French. The dilution test indicated weak tinting strength of cream hue. The commercial value of this material is doubtful, especially in the general market.

UTAH NO. 28

Utah no. 28 and data thereon were supplied by David McMullin, Leeds, Utah. (See Utah no. 2.)

Laboratory tests.—The 1½-pound sample consisted of 2- to 4-inch sienna-colored, rocklike lumps of limonite and quartz pebbles. The mass was hard enough to require grinding but had the usual vesicular structure of this type of limonite. No carbonates were found with the acid test. Part was ground in water, dried, and pulverized. The fines required 13 drops per gram or 0.30 part by weight of linseed oil to make a gold-brown (60113) paste. When diluted with nine parts of zinc oxide it changed to pale pink (60026). The iron oxide content was 26.7 percent. This material was listed with class 1, red-brown, burnt siennas. Although the iron oxide content was satisfactory the dilution test indicated only weak tinting strength, below that of present commercial burnt siennas. It therefore has only doubtful general commercial value.

UTAH NO. 29

McMullin also furnished Utah sample no. 29. (See Utah no. 28.)

Laboratory tests.—The sample was partly ground, sienna-colored material. A slight indication of carbonates was found with hydrochloric acid. After being ground the sample required 13 drops per gram or 0.30 part by weight of linseed oil to produce a paste between gold-brown (60113) and terrapin (60091). When diluted with nine parts of zinc oxide the color changed to flesh (60025). The ferric oxide content was 18.6 percent. Although this material was grouped with class 1, red-brown, burnt ochers, its tinting strength was very weak; its commercial value is therefore doubtful.

UTAH NO. 30

Utah no. 30 and data thereon were submitted by the owner, J. A. Elmer, Moab, Utah, from a deposit in sec. 24, T. 24 S., R. 18 E., Grand County, about 24 miles from Thompsons on the Rio Grande Railroad. Not much is known about the deposit save that it apparently contains a large amount of red ore and has no overburden.

Laboratory tests.—The sample consisted of 2- to 4-inch lumps of purplish red-brown sandstonelike ore. No carbonates were found with acid. The mass was hard and needed grinding. When pulverized it required 13 drops per gram or 0.30 part by weight of linseed oil to produce a brown (60114) paste. When diluted with nine parts of zinc oxide the color changed to pink no. 2 (60014). The ferric oxide content was only 7.2 percent. This material was grouped with class 1, blossom, mineral browns. The tinting strength, however, was weak; the material can therefore have but local use as a cheap pigment.

UTAH NO. 31A

Utah no. 31A and data thereon were submitted by J. A. Elmer, Moab, Utah. The deposit is in eastern Grand County and reported to be large.

Laboratory tests.—The sample was hard, rocklike, red-brown material which showed some indication of carbonates. The pulverized mass required 14 drops per gram or 0.32 part by weight of linseed oil to produce a henna (60135) paste. When diluted with nine parts of zinc oxide the color changed to light Grecian rose (60175). The ferric oxide content was 21 percent. This material was placed with class 2, salmon, burnt ochers. The tinting strength was medium, and the tests indicate local commercial value if economic conditions are satisfactory.

UTAH NO. 32

Utah no. 32 and data thereon were supplied by L. J. Anderson, 1755 South Fifth East Street, Salt Lake City, through the Intermountain Experiment Station, United States Bureau of Mines. The deposit is reported to be large and is 10 miles from Leamington, Salt Lake Route.

Laboratory tests.—The half-pound sample of hard, brown-red lumps 3 inches to 1 inch in size had uniform color and gave no indication of carbonates. It was ground in water, dried, and made into a paste near mahogany (60136). When diluted with zinc oxide it changed to pale pink (60026). The ferric oxide content was 8.5 percent. The dilution test indicated a tinting strength too low for commercial service save locally as a mortar or cement pigment.

VERMONT

LOCATION AND GEOLOGIC RELATIONS OF MINERAL PIGMENTS IN VERMONT

By Frederick A. Burt [86]

The productive part of the Vermont ocher belt extends along the western base of the Green Mountains through Addison, Rutland, and Bennington Counties. (See fig. 31, *A*.) Deposits are known to occur at many places in these counties, but development has been attempted only at Bennington and Shaftsbury in southern Bennington County and Brandon in northern Rutland County. Ocher mining is one of the oldest mineral industries of the State, beginning as early as 1820 and continuing through 1916; since that date no production has been reported in mineral-resources statistics.

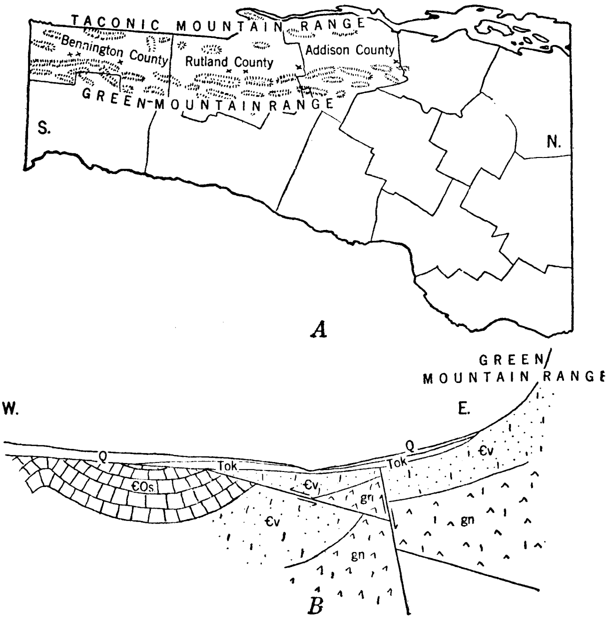

FIGURE 31.—*A*, Outline map of Vermont showing location of three counties in which deposits of ocher and allied substances occur; ocher deposits of possible commercial value are indicated by crosses. *B*, Generalized cross section of Vermont ocher area: Q, Pleistocene and recent deposits; Tok, ocher, kaolin, quartz sand, and iron-manganese ore; Ꞓos, Cambro-Ordovician dolomite, limestone, and marble; Ꞓv, lower Cambrian quartzite and schist; gn, pre-Cambrian gneisses.

The ocher is part of a series of unconsolidated deposits consisting of kaolin, ocher, quartz sand, iron and manganese ores, and lignite. On the basis of the fossils within the lignite and of the stratigraphic position of the deposits and their relations to the erosional features of the area they have been determined as Tertiary (mainly Miocene) in age.

The stratigraphic section of the ocher-bearing area is given in table 78.

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[86] Geology department, Agricultural and Mechanical College of Texas.

The materials of the Brandon formation lie unconformably on the gneisses, schists, quartzite, and limestone close to the base of the Green Mountains. (See fig. 31, *B*.) In this position they were protected from glacial erosion by the high barrier of the Taconic Range to the west, which with the Green Mountains formed the deep, canoe-shaped Vermont Valley in which glacial erosion was sluggish.

TABLE 78.—*Stratigraphic section of the ocher-bearing area of Vermont*

Period	Formation	Thickness	Character
		Feet	
Pleistocene	Surficial	0–50	Drift, alluvium, and soil.
Tertiary	Brandon	0–175	Kaolin, ocher, sands, ores, and lignite.
Ordovician	Berkshire	0–5, 000	Graphitic and pyritic quartz schist.
Cambro-Ordovician	Stockbridge	1, 200±	Crystalline limestone, dolomite, and marble.
Cambrian	Vermont	1, 600±	Quartzite and quartz schist with feldspathic and argillaceous beds.
Pre-Cambrian	Stamford, Woodford, and White gneisses.		Quartz, feldspar, biotite, and hornblende gneisses.

There is no regularity of relationship between the various types of the Brandon deposits. The kaolins, sands, ores, and ochers occur as alternating beds, as pockets within one another, and as stringers extending vertically, diagonally, or horizontally through each other. These deposits are clearly the result of the Tertiary alteration in situ of portions of the pre-Cambrian gneisses and the Vermont formation.[87]

The principal minerals of the ocher are quartz, kaolinite, feldspar in various stages of decomposition, turgite, limonite, and göthite. Accessory minerals include muscovite, sericite, vein quartz, magnetite, psilomelane, pyrolusite, and braunite. Many other minerals occur in minute quantities.

Petrographically the ocher ranges from fat to sandy kaolin impregnated with iron oxides and, in some beds, with considerable manganese oxide.

The deposits near Brandon extend from east of the village northward along both sides of the highway from Brandon to Lake Dunmore. These ocher beds were famous 50 years ago, but are not now worked, and ocher is available only from well cores. Intermingled beds, pockets and shoots of ocher, kaolin, quartz sand, and manganese ore form a deposit known to cover an area of 1 to 2 square miles and ranging from 10 to to 175 feet in thickness. The deposits lie partly on the Vermont and partly on the Stockbridge formation and are covered by a 10- to 30-foot overburden of glacial drift.

A large deposit of ocher is known to lie between the Rutland Railroad and the foot of the mountain range east of South Wallingford. The ocher is now entirely covered, but about 1917 it was open to observation in the shafts of a company opening up manganese prospects. Jones[88] states that the ocherous material consists of red ocher with a kaolin base and umber, the manganese minerals in the latter showing very little decomposition. Records of the old

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[87] For further description of the geologic relations, genesis, and age of these deposits, a discussion of their problems, and references to the earlier literature see Burt, Frederick A., The Origin of the Bennington Kaolin: 16th Biennial Rept., Vermont State Geologist for 1927–28, pp. 65–84; The Geology of the Vermont Ocher Deposits. The latter paper will appear in the 17th Biennial Rept., Vermont State Geologist, and will carry a complete bibliography of publications touching ochers of the State.

[88] Jones, R. W., The Manganese Deposits of South Wallingford, Vt.: Eng. and Min. Jour., vol. 105, 1918, p. 779.

South Wallingford Manganese Mining Co., which operated a shaft during the middle of the past century, show that a large mass of ocher and kaolin lies between the Stockbridge limestone and the main manganese body.

The Bennington-Shaftsbury deposits extend from northeast Bennington northward along Furnace Brook and the western side of its drainage basin into Shaftsbury. Parts of these deposits were worked for many years. The ocher vein is horizontal, and no stratification is evident. On the east the ocher adjoins the kaolin deposits now being extensively mined under lease by the Merrimac Chemical Co. The deposits lie on limestone, quartzite, and nodular iron ore cut by a few low-grade manganese veins. The overburden ranges from 2 to 15 feet in thickness and is composed of glacial drift.

As ocher mining at Bennington and Brandon has been abandoned, specimens can now be obtained only from weathered surface exposures or from well cores. The samples on which the laboratory work of this paper is based were therefore not very satisfactory, as they were either weathered or very small; but data on them are offered as the best now obtainable.

ECONOMIC FACTORS

Future development of Vermont ocher is limited by two conditions. First, the largest, and probably the highest-grade deposits are scattered along a line of considerable length, thus necessarily decentralizing the industry. The most favorable areas for prospecting are probably near Brandon, South Wallingford, and Bennington. The gap between the first two towns is 30 miles by direct rail and between the last two, 44 miles. Much ocher occurs in these gaps, but the chances of these intermediate deposits proving of commercial value is less, judged by the evidences of geologic structures and available well records, than near the three towns mentioned.

Second, the extent of the ocher pockets and beds is limited, and the character of the ocher as between two beds or pockets in close proximity to one another varies greatly. Data on the extent and character of the ocher underlying any particular area can be obtained only by thorough drilling, spacing the test wells very closely.

On the other hand, large quantities of ocher are known to be present along the foot of the Green Mountains in the three counties mentioned. Good highways reach to within a few hundred yards of all areas worthy of investigation. Railroad lines are in no place more than 3 or 4 miles by highway from prospecting territory, and towns with excellent labor conditions are near all known deposits. Throughout the whole territory likely to be underlain with ocher, streams are abundant and large enough to provide the necessary water for washing and preparing the material for market.

Of the Brandon residual materials kaolin is by far the most abundant in commercial qualities and quantities. In many places along the base of the Green Mountains kaolin can be mined profitably. Sands of abrasive, glass, and foundry type are often associated with the kaolin and ocher. It is possible that ocher cannot be mined profitably except as a byproduct or coproduct with kaolin, unless at Bennington where the beds have greater continuity than elsewhere. A kaolin-ocher mining company prepared to market the associated sands would have still greater opportunity for success.

The occurrence of red iron ore in Vermont has been summarized by Schrader, Stone, and Sanford [89] as follows:

> **Hematite.**—Chittenden County, Milton, near Lake Champlain; formerly worked to slight extent. Windsor County, small deposit at Weathersfield.

TESTS OF VERMONT PIGMENTS BY THE UNITED STATES BUREAU OF MINES

VERMONT NO. 1

Vermont no. 1 was collected by Frederick A. Burt from the property of Elmer Rockwood 1 mile northeast of Bennington. The specimen was taken from the ground about 6 feet below the top of the bed. Rockwood said it was typical of material he has been mining for many years.

Laboratory tests.—The small hand specimen as received was soft, sandlike ocher of good color. It dispersed readily in water; washing removed 45.6 percent of light-buff sand, leaving a fine ocher, which required 14 drops per gram or 0.32 part by weight of linseed oil to make a poor-working bronzed olive-wood (60082) paste. When diluted with nine parts of zinc oxide the color was near chamois (60179). The ferric oxide content was 7.60 percent. This material was listed with medium-grade Pennsylvania or class 2, orange-yellow, ochers, slightly grayed. The dilution test indicated medium tinting strength, with a variation from the standard toward gray. It has possible commercial value if economic conditions are satisfactory.

VERMONT NO. 2

Vermont no. 2 was collected by Frederick A. Burt from the quarry of the Rutland Fire Clay Co. 3 miles southeast of the city of Rutland. The quarry is operated for the overlying fire clay; no ocher is marketed. The specimen was taken from the bottom of the quarry, where it had been exposed to weathering for about 2 months. Evidence from borings indicates that a large mass of this material underlies the quarry area. The ocher varies greatly in color and texture and is found in seams and pockets, which range from a few inches to 3 feet in thickness and from 100 square feet to nearly an acre in area. The seams are separated by red, white, and yellow sands or by white and yellow clays. Considerable undecomposed rock material is mingled with the deposits.

Laboratory tests.—The 1-pound sample as received was soft, light-brown clay, which dispersed readily in water; washing gave 8.3 percent residue. When the fines were dried and pulverized 24 drops per gram or 0.56 part by weight of linseed oil was required to make a fair-working dark-topaz (60112) paste. When diluted with nine parts of zinc oxide the color was light chamois (61079). The ferric oxide content was only 4.8 percent, and the color strength was therefore weak. This material was classed with medium-grade Pennsylvania or class 2, orange-yellow, ochers, slightly grayed. The full-strength color varied from the standard toward red-brown. As operators are having trouble in marketing similar Pennsylvania-type ochers with about 5 percent iron oxide content, it is doubtful whether this material could be marketed outside its own district.

VERMONT NO. 3A

Vermont no. 3A, submitted by I. W. Horn of Brandon, was unwashed ocher from the core of a well 300 feet south of the old lignite mine on the Horn & Crockett kaolin properties 2 miles northeast of Brandon on the highway from Brandon to Middlebury via Lake Dunmore. The sample was collected 100 feet below the surface.

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[89] Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful Minerals of the United States: U.S. Geol. Survey Bull. 624, 1917, p. 311.

Laboratory tests.—The 20-gram sample was too small for the washing test and was ground as received. It contained some quartz-sand grit and needed washing to obtain the best results. When ground with 17 drops per gram of linseed oil it formed a poor-spreading paste of topaz (60112) toward pablo (60090). When diluted with nine parts of zinc oxide the color was polar bear (60004). The low ferric oxide content, 1.75 percent, and the low color strength would eliminate this specimen from commercial ochers. However, the color strength could have been improved by washing.

VERMONT NO. 3B

Sample 3B, also submitted by I. W. Horn, was a plastic red pigment from the core of a well 47 feet below the surface on the Horn & Crockett kaolin properties. (See no. 3A.) Well logs indicate a large quantity of this material.

Laboratory tests.—The specimen received at the laboratory was too small for washing, and after a few grams were used for color tests not enough was left for chemical analysis. Fifteen drops per gram or 0.35 part by weight of linseed oil was required to make a good-working mahogany (60136) paste. When diluted with nine parts of zinc oxide the color was grayed old rose (60172). This material was grouped with class 1, old rose, mineral browns; the tinting strength was very good compared with some commercial browns on the market. If mining and marketing problems can be solved satisfactorily the material should have commercial value.

VERMONT NO. 3C

Vermont no. 3C, submitted by I. W. Horn, was a crudely washed umber sample from the core of a well on the Horn & Crockett property. (See no. 2A.)

Laboratory tests.—The specimen was too small for the washing test. Eighteen drops per gram or 0.42 part by weight of linseed oil was required to make a good-working brown (60114) paste. When diluted with nine parts of zinc oxide the color was a mixture of silver (60050) and tan (60089). The ferric oxide content was 9.3 percent. The pigment was classed as an umber of medium tinting strength. As this material had more of a putty (60169) hue the let-down color differed from the standard umber colors used in this study. Its general commercial value is therefore doubtful.

VIRGINIA

As no detailed study of Virginia ochers has been made, available information is meager. Ocher has been reported from 13 counties in the Coastal Plain, Piedmont, and valley provinces. It may occur in other counties, but the Virginia Geological Survey has no record of its occurrence elsewhere in the State. The data at hand indicate that the American Pigment Corporation, of Bedford, Va., is the only company producing natural mineral pigments in Virginia. Prepared samples of ocher, metallic brown, raw sienna, and burnt umber were received from this company, and test data have been included under their respective commercial classes in part III. Ocher was formerly mined, usually on a small scale, in Augusta, Bedford, Chesterfield, Loudoun, Page, and Rockingham Counties. The maximum reported production was a few thousand tons in 1913 by the Virginia Ocher Corporation, at Stanley, Page County.[90]

According to Dr. Thomas Watson, former State geologist, writing April 19, 1923:

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[90] Information for this section of the Virginia report was furnished by Dr. Arthur Bevan, State geologist of Virginia, and J. J. Scott, Jr., manager of the American Pigment Corporation.

Ocher has been produced at the following localities in Virginia:

In the extreme eastern part of Chesterfield County, near Bermuda Hundred on Appomattox River; in Little Catoctin Mountain near Leesburg, Loudoun County; near Bedford City, Bedford County; in the vicinity of Marksville, Page County; near Keezletown, Rockingham County; along the west base of southwest Massanutten Mountain; and along Naked Creek in Page and Rockbridge Counties, about 5 miles southeast of Shenandoah Station on the Norfolk & Western Railway.

Probably equally as good ocher deposits are found distributed over parts of the valley and Piedmont provinces and, to some extent, the Coastal Plain province. which have not been worked. Deposits of ocher which seem promising, but not yet developed, are found in Campbell and Bedford Counties; near Bon Air in Chesterfield County; near Fairfield, Rockbridge County; near Waynesboro, Augusta County; and near Roaring Run, Craig County.

VIRGINIA RED OR CLINTON HEMATITES [91]

A few deposits of red hematite have been found to be of commercial value, and mining development has taken place on a small scale only. Beds near Cumberland Gap were once worked for the furnaces at Middlesboro, Ky., but have been idle for many years. Another red ore was formerly mined south of Lowmoor Station on the Chesapeake & Ohio Railroad. (See fig. 32.)

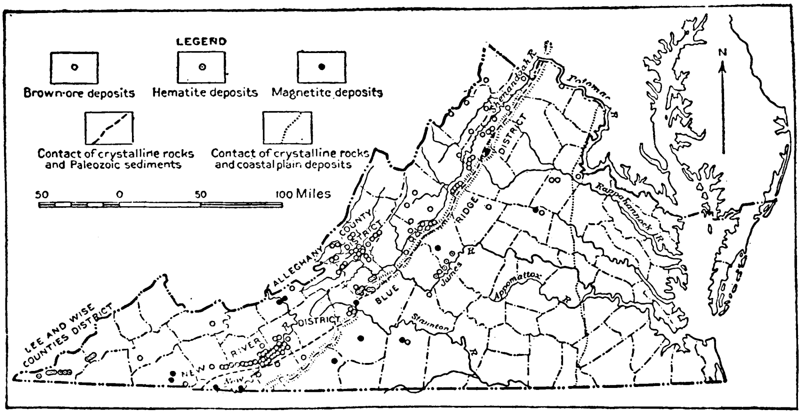

FIGURE 32.—Map showing iron-ore deposits in Virginia, according to Harder (Ries).

Schrader, Stone, and Sanford[92] have summarized the occurrence of the hematite in Virginia as follows:

Hematite (specular).—Occurs in workable quantity along Blue Ridge in Bedford, Botetourt, and Roanoke Counties. Bedford County, Ironville and Dewey mines, near Montvale. Botetourt County, Arcadia and Wood mines about 4 miles southeast of Buchanan, Lemon, Grubb-Specular, and Edith mines, about 3 miles northwest of Blue Ridge Springs. Roanoke County, Griffin-Specular mine, 5 miles south of Roanoke. Smyth County, in the Blue Ridge near Marion. Washington County, in the Blue Ridge near Abingdon.

Hematite (fossil ore).—Occurs in workable quantity in Alleghany, Lee, and Wise Counties. Alleghany County, has been mined on southeast slope of Horse Mountain, 3 miles southeast of Lowmoor, and in bluff northeast of Jackson River at Iron Gate. Lee County, southwest of Pennington Gap along Poor Valley

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[91] Eckel, E. C., Iron Ores. Their Occurrence, Valuation, and Control: McGraw-Hill Book Co., New York, 1914, p. 228; The Oriskany and Clinton Ores of Virginia: U.S. Geol. Survey Bull. 285, 1906, pp. 183–189.

Moore, P. N., Report on Iron Ores in the Vicinity of Cumberland Gap: Kentucky Geol. Survey, vol. 4, 1878, pp. 241–254.

[92] Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful Minerals of the United States: U.S. Geol. Survey Bull. 624, 1917, p. 319.

Ridges, includes Pennington, Lavine, Ben Hur, Truro, Noes Siding, Grabill, Boones Path, and Ewing mines. Wise County, south of Big Stone Gap, on Wallen Ridge, and in Powell Valley; fossil ore is mined at Yeary, Irondale, Keystone, and Oreton mines.

OTHER IRON-ORE DEPOSITS

Virginia—in the past, at least—has been recognized as the main producer of residual limonite.[93] One belt of historic and former commercial importance is the "great gossan lead" found mainly in southwestern Virginia and traceable for more than 20 miles; its metallic iron [94] content averages 40 to 41 percent. (See fig. 33.)

The occurrence of limonite or mountain brown ores in Virginia has been summarized by Schrader, Stone, and Sanford [95] as follows:

Mountain brown ore.—Occurs in two belts, one extending along west slope of Blue Ridge from Front Royal, Warren County, to 10 miles south of Roanoke, Roanoke County. The other belt extends along the east side of the New River-Cripple Creek district, Pulaski County, and along and near to the Wythe-Carroll County boundary. Associated with Cambrian quartzite. Principal group of mines: Page County, at Shenandoah. Rockingham County, Grottoes. Rockbridge County, Vesuvius and Buena Vista. Roanoke County, Roanoke. Brown ore also mined near Pittsville, Pittsylvania County. Gossan ore of the sulphide deposits of crystalline area formed the basis of the first iron industry in the South.

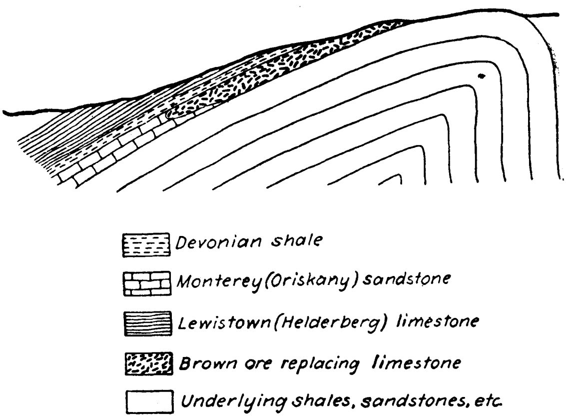

FIGURE 33.—Cross section of typical ore deposits in Oriskany district, Virginia, according to Eckel.

TESTS OF VIRGINIA PIGMENTS BY THE UNITED STATES BUREAU OF MINES

Seven samples were submitted for testing.

VIRGINIA NO. 2

Virginia no. 2 and the data thereon were submitted by the owner, Paul M. Tyler, 1817 Thirty-seventh Street, Washington, D.C. The deposit is near Stanley, Page County, Va., and this material came from the "main cut" of Eureka manganese mine.

Laboratory tests.—The 5-pound sample was compact, soft, light grayish-brown material showing no sand. Washing removed less than 1 percent sand of the same color. The pulverized, dried fines required 16 drops per gram or 0.37 part by weight of linseed oil to produce a paste between terrapin (60091) and gold-brown (60113). When diluted with nine parts of zinc oxide this changed to sunset (60088). The ferric oxide content was 5.1 percent. This material was classed with medium-grade Pennsylvania or class 2, orange-yellow, ochers, slightly

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[93] Ries, H., Economic Geology: John Wiley & Sons, Inc., New York, 4th ed., 1916, p. 554.

[94] Ries, H., work cited, p. 550.
Harder, E. C., Iron Ores of the Appalachian Region in Virginia: U.S. Geol. Survey Bull. 380, 1909, pp. 215-254.

[95] Work cited, p. 321.

grayed. The full-strength color varied from the standard toward red-brown. The dilution test, however, as well as the percentage of iron oxide, indicated tinting strength too weak for general commercial value. The let-down color varied toward pink.

VIRGINIA NO. 4

As a fourth sample Tyler submitted a 5-pound sample representing run-of-mine material from the drying sheds of another company at Stanley, not now operating. After being dried the material was selected and ground principally for cold-water paints. Tyler estimated that if material represented by this sample could be sold at $8 a ton, the property and mill probably could be operated successfully.

Laboratory tests.—The sample was soft, shalelike, yellowish-brown material showing streaks of red, gray, and brown, although the color was fairly uniform. Washing removed 12.2 percent of coarse, light-brown sand, leaving a soft, low-shrinking mass which required 17 drops per gram or 0.39 part by weight of linseed oil to produce a paste between pablo (60090) and topaz (60112). When diluted with nine parts of zinc oxide the color changed to sunset (60088). The ferric oxide content was 9.1 percent. A second portion of the sample was ground in water. It required 21 drops per gram or 0.49 part by weight of linseed oil to make a topaz (60112) paste. When diluted with zinc oxide the color changed to sunset (60088). The ferric oxide content was 8.8 percent. This material was classed with light-grade Pennsylvania or class 2, orange-yellow, ochers, slightly grayed. The dilution test indicated medium tinting strength of cream hue and possible commercial value. Grinding the entire sample in the ball mill did not change the hue appreciably but shifted the color value to medium-grade yellow ocher.

VIRGINIA NO. 5

Virginia no. 5 and data thereon were submitted by the owner, A. J. Goyne, care of W. L. Burgess, R.F.D. 2, Chester, Va., as his no. 1 sample. It represents a 2-foot vein under a 5- to 6-foot ocher seam. Goyne reported that about 250 acres contained ocher seams represented by nos. 5, 6, and 7. The deposit is about 100 feet from a main highway and 1¼ miles from the railroad.

Laboratory tests.—The sample was a light-yellow 6-inch lump containing pinkish-brown claylike material with little sand. No carbonates were indicated. After being ground the pulverized mass required 17 drops per gram or 0.39 part by weight of linseed oil to make a pablo (60090) paste. When diluted with nine parts of zinc oxide the color changed to between chamois (60179) and sunset (60088). The ferric oxide content was 9.7 percent. This material was grouped with medium-grade Pennsylvania or class 2, orange-yellow, ochers, slightly grayed. The dilution test indicated low tinting strength with a variation in hue toward pink. Because of its low strength and iron oxide content its commercial value is doubtful.

WASHINGTON

Washington iron ores[96] are magnetites, hematites, limonites, and hematite-magnetite mixtures. The principal known iron-ore deposits are in Skagit, King, Kittitas,[97] Stevens, and Mason Counties. Bog ores are found in several places in Whatcom, Clallam, Spokane, Whitman, Thurston, and Jefferson Counties.

The ores in Snoqualmie Pass are the only true magnetites; those in the Clealum and Hamilton districts and part of those in Stevens County are mixtures of hematite and magnetite. The ores in Jefferson County and the rest of those in Stevens County are limonite or

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[96] Whittier, W. H., An Investigation of the Iron-ore Resources of the Northwest: Univ. of Washington Bur. of Ind. Research Bull. 2, 1917, pp. 22–34.

[97] Smith, G. O., and Willis, B., The Clealum Iron Ores, Washington: Trans. Am. Inst. Min. Eng., vol. 30, 1910, pp. 356–366.

bog ores. The iron ore in Mason County is largely hematite, but most of it has little commercial value. Some strong lodestone ore occurs in the Clealum district. Limonite has been reported in the gold and silver mines of the Monte Cristo district, Snohomish County, and in prospects near Deep Creek Lake southeast of Northport. Stevens County.

The principal ochers and mineral pigments of Washington are described in Bureau of Mines Bulletin 304.[98] A yellow ocher found near Deer Park, Stevens County, about 34 miles north of Spokane, was the best of this type found in Washington. Although the color is not identical with that of French ocher it has a similar bright-yellow appearance and will stand an even better dilution test than the French. It requires 16 percent more oil and is handicapped by high mining and transportation costs.

However, as the market for pigments grows in the North Pacific Coast and Northwestern States these natural pigments should be able to compete in local trade. Already there is a market for crude mortar, stucco-plaster, terrazzo, and cement colors in large, low-price lots where the freight rate from the West or South is a large item in the final selling price. A single company operating in eastern Washington could produce ocher yellows, sienna browns, and "paint-pot" reds by simple purification and grinding methods and could by calcination to low temperatures add brighter reds, darker browns, and blacks to their color series. The opportunities in natural pigments are not so attractive in western Washington, because the color range is limited to impure red-brown and black.

The following samples have been submitted from Washington for testing since Bulletin 304 was issued.

TESTS OF WASHINGTON PIGMENTS BY THE UNITED STATES BUREAU OF MINES

WASHINGTON NO. 1

Washington no. 1 and data thereon were submitted by M. W. Schlosser (president, Pacific Clay Co., Sunnyside, Wash.) from a property in secs. 26 and 35, T. 12 N., R. 23 W., Yakima County, 14 miles from the railroad; a good wagon road passes through the deposit. The red material is about 40 feet thick with no overburden and could be mined very cheaply.

Laboratory tests.—The sample consisted of 2-inch lumps of plastic, light-red, lightweight, speckled clay. Although the dried mass broke easily to small fragments in water it did not disperse readily to the finest particles; the sample was therefore ground in water in the pebble mill. On drying, the ground material formed a hard, claylike, high-shrinking mass. Thirty-three drops per gram or 0.77 part by weight of linseed oil was required to make a terra cotta (60134) paste. When diluted with nine parts of zinc oxide the color was light pink (60026). The ferric oxide content was only 2.6 percent, and the tinting strength was too low to have commercial value, except for local use in cheap mortars, in competition with burnt ochers of much greater coloring power.

WASHINGTON NO. 3

A sample of ocher was submitted by George A. Mowatt and A. L. Spray, box 295, Chewelah, Wash. The material from which the

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[98] Wilson, Hewitt, Ochers and Mineral Pigments of the Pacific Northwest; Occurrence, Possible Methods of Preparation, and Testing of Ocher, Siennas, and Colored Clays: Bull. 304, Bureau of Mines, 1929, 74 pp.

sample was taken occurs near Chewelah, 4 miles from a railway. Mowatt reported a 70-foot deposit of the red and yellow.

Laboratory tests.—The small sample dispersed readily in water; washing removed 19 percent of buff sand. The fines required 17 drops per gram or 0.40 part by weight of linseed oil to make a poor-spreading topaz (60112) paste of low plasticity. When diluted with nine parts of zinc oxide the color was flesh (60025). The ferric oxide content was only 2.5 percent. The full-strength color was similar to medium-grade Pennsylvania or class 2, orange-yellow, ochers, slightly grayed, varying toward red. The dilution test and chemical analysis indicated tinting strength too weak for general commercial use. Because of its distance from present sources of ochers it may have local value.

WASHINGTON NO. 4

Washington no. 4, a red sample, was also submitted by Mowatt and Spray. The material from which the sample was taken occurs as a bed lying between two ocher seams. The property is near Chewelah, 4 miles from a railroad. (See Washington no. 3.)

Laboratory tests.—This small sample was soft, weak red-brown, claylike material, which did not disperse readily in water and was ground in water in the ball mill. When dried it gave a mass of medium hardness and shrinkage. The pulverized material required 24 drops per gram or 0.56 part by weight of linseed oil to make a paste between henna (60135) and mahogany (60136). When diluted with zinc oxide the color approached blossom (60171). The ferric oxide content was 26.4 percent. This material was grouped with class 1, blossom, mineral browns. The tinting strength was too weak for general use and varied from the standard hue toward blossom. As it is so far from eastern supplies it may have only local value.

WASHINGTON NO. 6

Washington no. 6 was a sample of iron ore, D-100, received partly ground from the Manufacturers Mineral Co., 1107 West Idaho Street, Seattle, Wash. The material came from the property of Michael Kulzer, east of Chewelah.

Laboratory tests.—The sample was reground in water to pass a 300-mesh sieve and dried; the fines were mixed with 12 drops per gram or 0.28 part by weight of linseed oil to make a paste between brown (60114) and mahogany (60136). When diluted with nine parts of zinc oxide the color changed to between monkey skin (60123) and crocus (60186). The ferric oxide content was 79.4 percent. This material was classed with class 2, violet, mineral browns. The tinting strength was slightly greater than that of the standard browns, and the hue was similar. It therefore has possible value as commercial pigment if marketing conditions are satisfactory.

WEST VIRGINIA

The occurrence of iron ore in West Virginia is summarized by Schrader, Stone, and Sanford [99] as follows:

Brown iron ore (brown hematite, limonite).—Berkeley County, south of Martinsburg, pits were opened and ore shipped. Grant County, Greenland Gap, has been mined. Greenbrier County, prospects near Anthony Creek Gap. Hampshire County, near Capon Springs, on ridges north of Capon Springs. Hardy County, ore bank 4 miles above Harpers Ferry, has been mined. Mineral County has been mined near Keyser. Monroe County, considerable quantity in Zenith area, in flint and lime at Crimson Spring; prospects on Peters Mountain elsewhere, has been mined at Crimson Spring. Morgan County, Sandy Ridge. Pendleton County, at many places along North Fork Mountain; prospects on sides of Little Mountain, 2 miles east of Franklin. Pocahontas County, prospects on Beaver Lick Mountain. Raleigh County, has been mined near Beckley. * * *.

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[99] Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful Minerals of the United States: U.S. Geol. Survey Bull. 624, 1917, pp. 333, 335.

Hematite (red iron ore).—Grant County, prospects in southeastern part, South Fork Mountain. Hardy County, has been mined near Wardensville and Perry. Mineral County, has been mined 1 mile southeast of Keyser. Monongalia County, location of several early furnaces which used local ore.

Hematite (fossil ore).—Grant County, vicinity of Greenland Gap, parallel seams 5 feet thick, has been mined. Greenbrier County, Anthonys Creek and Howard Creek, prospected, both fossil and black ore. Hardy County, middle and also on north mountain ranges, large bodies developed. Mercer County, north slope of East River Mountain, Bluestone River, on Black Oak and Flat Top Mountains, prospected. Monroe County, South Fork Mountains, prospected. * * *.

Ocher.—Cabell County, on Guyandotte River. Hardy County, South Branch Valley. Jefferson County, Lost River, near Harpers Ferry and near Shepherdstown. Lewis County, yellow ocher near Weston. Pendleton County, Clines Crossroads. Wayne County, near Ceredo; not mined.

An iron mine at Orebank [1] is on the Potomac River, 4 miles north of Harpers Ferry; it is reached by a railroad switch from Engle Station via the Bakerton limestone quarries. This ore is described as mixed with red clay, which forms the surface cover of the Cambrian limestone of that region. Doctor Grimsley, geologist for the Baltimore & Ohio Railway, believes that the deposit of this material is large and of sufficient quality to pay for its development.

Iron carbonates in bedded deposits are found in the Carboniferous rocks of western Pennsylvania, northern West Virginia, eastern Ohio, and northeastern Kentucky. These ores were formerly the basis of an important iron-mining industry, but little is obtained now except in southeastern Ohio.[2]

No samples of mineral pigments were received from West Virginia.

WISCONSIN

Schrader, Stone, and Sanford [3] have summarized the occurrence of mineral pigments and iron ores of Wisconsin as follows:

Brown iron ore (brown hematite, limonite).—Florence County, accompanies hard hematite ore at Commonwealth and Florence mines. Grant, Iowa, and Lafayette Counties, in minor quantities in ore-bearing crevices and in pockets of rock of the lead and zinc region. Pierce County, mined and smelted at Spring Valley. Sauk County, Ironton, Westfield, and elsewhere.

Hematite (red hematite).—*Iron Ridge.*—"Clinton" or "fossil" ore, near Mayville, Dodge County, in beds of irregular outline and lenticular cross section.

Menominee range.—Western extension is worked extensively at Commonwealth and Florence mines, in T. 40 N., R. 18 E., in Florence County. Beds of great thickness in Huronian rocks. Hard red ore accompanied by some limonite.

Penokee-Gogebic range.—Large deposits, upon which a number of mines are working in eastern side of Iron County. The deposits occur in pitching troughs formed by the intersection of "greenstone" dikes and the footwall quartzite. Ore is mostly a soft red or brownish-red hematite with a little hard, steely, specular hematite.

Baraboo range.—Deposits of red hematite ore in Huronian iron-bearing rocks in Sauk County; several mines being developed. * * *.

Mineral paints.—Dodge County at Iron Ridge. * * *.

Ocher.—Juneau County, brown ocher has been mined. Waupaca County, red and yellow ocher at Clintonville.

Sienna and umber.—Iowa County, at Mineral Point, not worked.

For a description of the iron ranges of Wisconsin, Michigan, and Minnesota, see Michigan, page 117.

Two samples were received and tested.

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[1] Grimsley, Jefferson, Berkeley and Morgan County Report of the West Virginia Geological Survey: West Virginia Geol. Survey, 1908, pp. 584-586.

[2] Harder, E. C., Iron Ores, Pig Iron, and Steel: U. S. Geol. Survey Mineral Resources of the United States, 1908, pt. I, 1909, p. 92.

[3] Work cited, pp. 337-341.

WISCONSIN NO. 1

Wisconsin no. 1 and the data regarding it were submitted by Abe Mathews, Jr., general superintendent, Pickands, Mather & Co., Ironwood, Mich. This sample and no. 2 represent the two principal grades of ore in the Cary mine at Hurley, Wis., a few miles from Ironwood, Mich. The deposit is owned in fee by the Northern Chief Iron Co. and is operating under lease to the Odanah Iron Co. The material occurs in pockets in the Plymouth member, Ironwood formation, middle Huronian series, which at this mine is a simple monocline dipping at 65° NW. The ore pockets were formed by underground waters leaching the silica from the chert of the Ironwood formation and leaving the iron material as an insoluble residue. The principal minerals in the ore are hematite and chert and the principal impurities, pyrolusite and manganite. Wisconsin no. 1 represents a more highly manganiferous material than no. 2. The quantities estimated to be available are: 186,000 tons of material similar to no. 1 running 58.5 percent of iron and 3.9 percent of manganese (dry); and 207,000 tons of material similar to no. 2 running 62 percent of iron and 1 percent of manganese. The thickness of the deposits is 10 to 100 feet, depending on the location, and averages 25 feet. The area underlain by the deposits is quite small because of the steep dip and is entirely within the limits of the NW¼ sec. 26, T. 46 N., R. 2 E., and the SE¼NE¼ and the NE¼SE¼, sec. 27, of the same township.

The deposit has been worked some 45 years by underground mining at gradually increasing depths. The lowest level is now 1,880 feet below the surface. The bulk of the production has gone to Lake Erie ports for its iron content, but some has been sold for pigment for more than 30 years. The total pigment production since 1924 has been 3,750 tons; the material was similar to Wisconsin no. 1 and was sold as mined to the Ricketson Mineral Paint Works, Milwaukee, Wis.

Laboratory tests.—The 5-pound sample consisted of reddish-black, heavy, 2-inch or finer lumps, which were too hard to wash. A portion of the sample was ground in water in a ball mill, and the dried fines required 10 drops per gram or 0.23 part by weight of linseed oil to make an iridescent grayish tobacco (60143) paste. When diluted with nine parts of zinc oxide the color changed to dark monkey skin (60123). The ferric oxide content was 77.8 percent. This material was placed with class 2, violet, mineral browns, although it was browner and blacker than commercial browns. The tinting strength was excellent, varying from the standard toward brown-black. It is already in commercial service.

WISCONSIN NO. 2

Wisconsin no. 2 and data regarding it were submitted by the Pickands, Mather & Co. Its occurrence is discussed under Wisconsin no. 1.

Laboratory tests.—The sample consisted of dark-red, heavy, 2-inch lumps and finer material. Part of it was ground in water, and the resulting fines required 10 drops per gram or 0.23 part by weight of linseed oil to produce an iridescent marron-glace (60146) paste. When diluted with zinc oxide the color changed to Grecian rose (60175). The ferric oxide content was 94.4 percent. This material was grouped with class 1, old rose, mineral browns. The tinting strength was good and varied from the standard hue toward old rose. It is already in commercial service.

WYOMING

The occurrence of iron ores in Wyoming has been summarized by Schrader, Stone, and Sanford [4] as follows:

> **Brown iron ore (limonite).**—Albany County, occurs at Jelm mines. Converse County, near Douglas. Fremont County, on Little Popo Agie Creek; not mined. * * *.
>
> **Hematite (red iron ore).**—Carbon County, extensive deposit north of Rawlins was mined for flux; also on south side of Seminole Mountains, 35 miles north of Rawlins, and at Jelm mines. Platte and Goshen Counties, chief ore of Hartville iron range; mined at Sunrise, Lone Jack, and Good Fortune mines. * * *.
>
> **Mineral paint.**—Carbon County, made from soft iron ore at Rawlins. Suitable material at Hartville and other iron localities.

The literature [5] contains other references to the iron ores of Wyoming.

Iron ore (hematite) is the most important economic product of the Hartville (eastern Wyoming) region.[6] It is found in the rocks of the Whalen group within a rather limited area on the west side of Whalen Canyon, beginning about 1 mile south of Frederick and extending southwesterly a little more than 4 miles. Its western limit is Hartsville and its southern limit about 1½ miles south of Sunrise. The iron ore occurs both in the limestones and schists, being developed mainly along and not far from the contact between them. It appears to be scattered in irregular pockets in the limestone and in the schist, as long lenses of variable size from a fraction of a foot to 100 feet or more in width. The ore comprises two varieties of hematite, one soft and one hard. The former is generally a schistose, fine-grained, light-red ore which soils the fingers easily and is known as "paint ore." The harder variety is dark bluish gray, from which it receives the name "blue ore."

The Colorado Fuel & Iron Co. developed an opencut at Sunrise. (See fig. 34.) The looser surface material can be handled as it lies, but the harder ore beneath requires blasting. The ore is taken out with a steam shovel, which loads it directly into the cars that carry it to Pueblo, Colo., for smelting. The ore averaged about 62 percent of metallic iron and 2½ percent of silica, with a maximum iron content of about 66 percent.

WYOMING NO. 1

The sample tested was sent by the Colorado Fuel & Iron Co. from an experimental washing plant at Pueblo. It was the fine sludge product from the Dorr thickener and was removed in concentrating iron ore for smelting.

Laboratory tests.—The 50-pound sample of sludge was red-brown powder, which dispersed readily in water and gave a 17.9 percent residue of coarse particles, 9.5 percent of which would, however, pass a 300-mesh sieve. When mixed with 17 drops per gram or 0.39 part by weight of linseed oil a reddish oak-wood (60142) paste of good spreading properties was produced. When diluted with 10 parts of zinc oxide the color was close to old rose (60172). The ferric oxide content was 62.71 percent. The color strength was therefore very good. The hue was unusual. When the pigment was dispersed in water there was a glowing irides-

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[4] Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful Minerals of the United States: U.S. Geol. Survey Bull. 624, 1917, pp. 342, 345, 346.

[5] Ball, S. H., The Hartville Iron-Ore Range, Wyoming: U.S. Geol. Survey Bull. 315 (*d*), 1907, pp. 190–205; Titaniferous Iron-Ore of Iron Mountain, Wyoming: U.S. Geol. Survey Bull. 315 (*d*), 1907, pp. 206–212.
Chance, H. M., The Iron Mines of Hartville, Wyo.: Trans. Am. Inst. Min. Eng., vol. 30, 1901, pp. 987–1003.

[6] Smith, W. S. T., Hartville, Wyo.: U.S. Geol. Survey Folio 91, 1903. Additional data can be obtained from U.S. Geol. Survey Bull. 315 (*d*).

cent effect of colloidal particles during movement which reflected the light rays at different angles. Although the color approached burnt sienna, this material should probably be classed as red oxide, as its diluted hues were similar to those of oxides.

A number of calcination tests were made, with the following results.

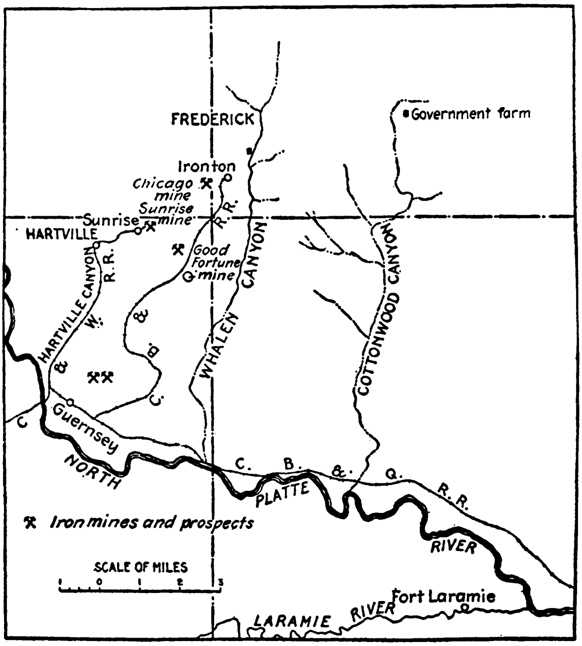

FIGURE 34.—Map of Hartville district, Wyoming, according to Ball (Eckel).

Pigment in linseed oil

[Original color, between oak wood (60142) and mahogany (60136)]

Calcination temperature, ° C.	*Color*
500	Mahogany (60136).
750	Between mahogany (60136) and garnet (60071).
1,000	Do.
1,100	Near garnet (60071).
1,200	Do.
1,250	(Reduced.) Near eggplant (60139) with a slight brown (60114) tone.

Pigment mixed with 10 parts of zinc oxide and linseed oil

[Original color, old rose (60172)]

500	Darker than old rose (60172).
750	Do.
1,000	Near Grecian rose (60175).
1,100	Do.
1,200	Near orchid (60085).
1,250	(Reduced.) Near Saxe blue (60125).

INDEX

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