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EOCENE: Bridger Eb; Wasatch Ew

CRETACEOUS: Laramie Kl; Montana Km; Colorado Kc; Dakota Kd

JURA-TRIAS: Upper Ju; Lower Jl

CARBONIFEROUS C; SILURIAN S; CAMBRIAN € ; ARCHEAN gn; BRECCIAS B; ERUPTIVE E

⚒ Coal mines. × Coal prospects.

GEOLOGY OF NORTHWESTERN WYOMING.

o Oil. ------ Route of reconnaissance.

Scale of Miles.

10 0 10 20 30 40

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J. W. POWELL, DIRECTOR

A

GEOLOGICAL RECONNOISSANCE

IN

NORTHWEST WYOMING

BY

GEORGE HOMANS ELDRIDGE

WASHINGTON

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DEPARTMENT OF THE INTERIOR,
U. S. GEOLOGICAL SURVEY,
DIVISION OF GEOLOGY AND PALEONTOLOGY,
Washington, D. C., March 6, 1894.

SIR: I have the honor to transmit herewith my report of a reconnoissance in northwest Wyoming, made during the summer of 1893, and authorized by you under date of July 1, 1893.

Very respectfully,

GEO. H. ELDRIDGE,
Geologist.

Hon. J. W. POWELL,
Director, U. S. Geological Survey.

PREFACE.

The reconnoissance which forms the basis of the following report was authorized with special reference to the coal resources of the Big Horn basin in northwest Wyoming. Incidentally regions adjoining were to be included, and such examinations as time permitted were to be made for oil, building stones, and other economic materials. The route of reconnoissance was, therefore, controlled by these conditions, and many areas could be examined only in a most general way. The southeastern portion of the area mapped was beyond reach, and for this the reports of the Territorial geologists and the maps of the early Hayden Survey were freely consulted.

Formation lines, except in the southeastern area, are drawn upon the map solid or broken, according as the respective portions have been approximately determined by direct observation or still remain uncertain; in the southeast the solid portions have been traced from the early maps and descriptions, while uncertainty is indicated by a broken line.

As a base for the geology the map of the U. S. General Land Office, edition 1892, has been employed, but it leaves much to be desired respecting accuracy, particularly as regards stream courses. No other maps of the region, however, exist, excepting the Hayden sheets in the southern part.

A GEOLOGIC RECONNOISSANCE IN NORTHWEST WYOMING, WITH SPECIAL REFERENCE TO ITS ECONOMIC RESOURCES.

By George H. Eldridge.

GEOGRAPHIC POSITION.

The area of Wyoming covered in this reconnoissance lies between meridians 106° 30′ and 109° 30′ W. and parallels 42° 45′ and 45° N.— about 150 by 150 miles, or 22,500 square miles. The examination, however, extended about 15 miles across the Montana-Wyoming line, making a total area of 24,750 square miles. (Pl. I.)

Four important towns lie within this region: Sheridan and Buffalo in the northeastern portion; Red Lodge, in Montana, in the northwestern; and Lander in the southern. Besides these, are two army posts: Fort McKinney and Fort Washakie, the former 3 miles west of Buffalo, the latter 16 miles northwest of Lander. Sheridan and Red Lodge have railroad communication with the East and West, the former by the Burlington route, the latter by the Northern Pacific Railroad.

In the southern part of the region is the reservation of the Shoshone and Arapaho Indians, in area 60 by 66 miles, or 3,960 square miles.

TOPOGRAPHY.

The topographic features of the region are two structural valleys, the Big Horn and Wind River basins, each nearly inclosed by high mountain ranges: the former basin, however, is separated from the country to the north by only a gentle rise; the latter from the valley of the Platte by a low divide of complex structure. The Wind River passes by a deep gorge in the Owl-Rattlesnake Range into the Big Horn basin, where it becomes the Big Horn River, flowing thence to the Yellowstone valley through one of the most rugged and impassable canyons of the West.

INCLOSING RANGES.

The Rocky Mountains.—The Rocky Mountains border the region on the west and southwest. Their eastern slopes are deeply cut by four large streams, Clarks Fork, Stinking Water, Grey Bull, and Wind

River. The general mass is divided into three subordinate ranges, Absaroka, Shoshone and Wind River.

The Absaroka Range extends from the Stinking Water, 50 or 60 miles south of the Montana-Wyoming line, northward to the Yellowstone River. It occupies the eastern portion of the Yellowstone Park Reserve and constitutes in part the watershed of the Yellowstone River, Clarks Fork, and the Stinking Water, but does not enter into the formation of the continental divide. The configuration of the range in the interior and more elevated portions is that of a lofty mass of castellated peaks and ridges and cliff-bound canyons, carved out of horizontal beds of breccias and conglomerates, while at lower altitudes and adjacent to the prairies the topography is characteristic of an Archean core, fringed by sedimentary formations dipping usually between 45° and 90° E. or NE. Occasionally, secondary parallel ridges skirt the base of the main range, the result of minor folding.

The Shoshone Range lies between the Stinking Water and Wind River valleys. It enters only slightly into the formation of the continental divide, but sends from it to the northeast and southeast two rugged and almost impassable ridges, that to the southeast being the more important. The spur to the northeast has the subordinate name of Meeteetse Mountain. Like the more elevated part of the Absaroka Range, this is a confused mass of castellated peaks and ridges in the breccias and conglomerates which extend southward from it; this configuration is maintained to the mountain front. A broad belt of low foothills succeeds, composed in the main of the remnants of early folds, parallel in trend with the range front and belonging to the transition zone between prairie and mountain structure.

The Wind River Range is one of the highest and most rugged segments of the Rocky Mountains. It has a general northwest trend, and extends from the Tukwatika[1] Pass to a point a little southeast of Lander, constituting for nearly its entire length the continental divide. The topographic aspect of the range is that of a great anticlinal fold with an exposed core of Archean rocks and a bordering zone of sedimentaries of more of less steep dip, reaching an altitude of 1,000 and 2,000 feet above the mountain base. The range is deeply cut by mountain streams, and across their canyon mouths may be observed in many instances the terminal moraines which mark the extent of early glaciers.

The Big Horn Range.—This is a lofty anticline about 100 miles east of the Rocky Mountains. The trend varies from N. 10° E. at the southern end to northwest at the northern, near the Montana-Wyoming line. The general altitude is between 7,000 and 8,000 feet, or 3,000 to 4,000 feet above the prairies to the east. Elevations between 8,000 and 9,000 feet, however, are frequently encountered, and the principal point,

[1] Tukwatika or Tukwarika, "Mountain Sheep Eaters." This, according to Dr. Hoffman, of the U. S. Bureau of Ethnology, is the name of a band of Shoshone Indians. It has long been applied to the pass in question, but on existing maps is spelled "Twogwotege," a form not as acceptable as that adopted in the text.

Cloud Peak, reaches a height of about 13,500 feet. In topography the range is an instance of a broad, flat, anticlinal arch presenting an Archean core within sedimentary formations which dip more or less steeply from the center. The summit of the range is from 10 to 25 miles wide. The higher peaks, of crystalline rocks, occur midway its length, while beyond these the surface is undulating or studded with low buttes and ridges, the uneroded remnants of Paleozoic quartzites, limestones and shales. The drainage of the summit is peculiar in the long north and south courses pursued by the streams before they break through the rim to fall rapidly to the prairies below; this is due to the frequency of minor folds and faults running with the range, by which the early channels were directed. The scenic features of the Big Horn Mountains are remarkably beautiful. On the summit broad grassy parks exist in picturesque contrast with extended masses of heavy timber; and on the slopes of the range are wild canyons with swift-flowing torrents, broken at the rim of the upturned sedimentaries by cascades over hard Archean granites, the whole in the midst of boldest crags which tower high on the mountain face.

The divide between the Big Horn basin and the valley of the Yellowstone.—This is in the main low and developed largely by what may be termed the accidents of erosion, although primarily determined by a gentle anticline. At the eastern end the divide passes into the Pryor Mountains; at the western, into a projecting spur of the Absaroka Range. The trend is irregular, particularly in the middle section, where folding has been slight and erosion the chief factor in development. Five or six miles from the western end is the sharp double peak of Heart Mountain, an isolated hill rising from 1,000 to 1,200 feet above the general prairie level, and constituting a landmark visible from all parts of the basin and its rim.

The Pryor Range, at the eastern end of the divide, attains an elevation between 7,000 and 8,000 feet. Structurally it is the northwestern extension of the Big Horn Mountains, from which it is separated by the Big Horn Canyon and the valley in its immediate vicinity. The range is twinned by a northwest to southeast strike fault, the gentler slopes of both ridges being to the west. The northeast ridge is the greater, and a little distance from its northwestern end is cut by the gorge of Pryor's Fork. The southwest ridge terminates at the head of Sage Creek, a tributary of the Stinking Water rising opposite Pryor's Fork. The Pryor Range disappears at the north and west by a gradual sinking of its axis, but a large area of the country is maintained at a considerable elevation above the prairies along the Yellowstone.

The Owl and Rattlesnake Mountains.—These form the southern side of the Big Horn basin and separate it from the Wind River valley beyond. They extend from the Shoshone Range to the southern end of the Big Horn Mountains, the general trend of the chain being N. 50° to 60° W. The Owl Mountains lie to the west of the Wind River Canyon, the Rattlesnake Mountains to the east.

The Owl Mountains have the appearance at their crest of a series of ridges diagonally placed with reference to the general trend of the range and rising from 400 to 500 feet above intervening depressions. This appearance is brought about by a series of anticlinal folds—possibly with an occasional fault—of which the trend is approximately northwest or slightly diagonal to that of the range as a whole. This structure is locally continued to both north and south slopes of the range, producing a series of subordinate ridges in a position en échelon with reference to one another. The altitude of the range is probably between 6,000 and 7,000 feet, or 2,000 to 3,000 feet above the general level of the valleys on either side. The southern slope is the more precipitous, the northern being gentle and deeply cut by canyons—a condition also existing on the southwestern or gentler slope of the Pryor Mountains.

The Rattlesnake Range unites the Owl and Big Horn Mountains. It is an anticline, with a precipitous slope to the south, the northern being gentle and considerably cut by erosion. Upon the latter slope the several members of the Cretaceous extend well up toward the summit rim.

The divide between the drainage of the Wind and Platte rivers.—This is low and is in part structural and in part the accident of erosion.

BASINS.

The Big Horn basin.—The topographic features of this area are mainly those of the well known "Bad Lands" of the West. The outcropping strata are clays and sandstones, the former predominating. Gray is the prevailing color, but white, purple, pink and black, in bands, also occur. The surface is a plain, relieved by buttes and ridges and by the broad bottoms of the larger streams and their tributary gullies. The configuration is the result of erosion, or of erosion combined with structure, the latter being the case in the numerous anticlinal ridges, from 1 to 30 miles in length, which occur within a belt of 5 to 15 miles along the inclosing ranges. Valleys now occupy the longitudinal axes of many of these folds and sharp incisions cross them. In the interior of the basin the ridges are more the result of erosion alone, and, with the buttes, occur without system; here, too, both ridges and buttes may consist wholly of clay, when they are sharp crested or pointed, or they may be capped by sandstone, becoming tabled. The height of the elevations is between 100 and 500 feet above the general bench levels, the stream bottoms being from 50 to 200 feet below. The general altitude of the basin is about 4,000 feet. Areas of great fertility exist about the periphery of the basin in the portions of the valleys occupied by the clays of the Montana Cretaceous. These tracts are often several miles in width and length, and in certain localities they are repeated two or three times from structural causes, increasing materially the total area available for agriculture.

The topographic features of the Big Horn basin extend across the divide to the Clarks Fork valley.

The Wind River basin.—The area from Torrey's Fork east is, with the exception of the bottoms of the main streams and a narrow zone along the base of the inclosing ranges, a barren waste of sand, clay and grit, relieved in configuration only by an occasional butte or the shallow depressions of its dry stream courses. Nearly all of its water is carried well toward the southern side, the Wind River Range affording almost the only supply. This edge of the basin has many fine streams and broad valleys, presenting large tracts of valuable agricultural land. Crow Heart and Pavillion buttes are the prominent landmarks of the basin. Thirty to forty miles above the former the valley begins to narrow, the topography of the Wind River Range prevailing to the head on the south, while on the north the Shoshone Range presents its bold cliffs and deep gorges carved in horizontal beds of breccia.

GENERAL GEOLOGY.

FORMATIONS.

The Archean.—The Archean consists of granites, gneisses and schists of various types. It forms the cores of the Big Horn, Wind River, Absaroka and Owl-Rattlesnake Ranges. The area of exposure varies in the different ranges, depending upon the conformation of the folds, the amount of reduplication, the degree of erosion, and the cover of late Tertiary conglomerates and breccias of eruptive material. On the summit of the Big Horn Range the Archean forms the bottoms of many beautiful parks, and towards the central portion of the range enters into the structure of the higher peaks. In the latter case it is cut by eruptive bodies of considerable importance. In the Wind River and Absaroka Ranges the area of Archean is very extensive, while in the Shoshone Mountains it is reduced to a minimum, if, indeed, there is a single exposure. The condition in the Shoshone Range is brought about by heavy deposits of eruptive breccias and conglomerates, which not only cap the highest peaks but extend in long ridges quite to the front of the range and prairie border. In the Owl-Rattlesnake Range, in addition to the main exposure, an independent outcrop of Archean occurs further to the west, induced by erosion of a sharp anticlinal fold or denudation along a possible fault line, in direction somewhat diagonal with the general trend of the range.

The Cambrian.—This consists of a series of shale, sandstone, grit, conglomerate and limestone, the shale and sandstone locally having the general composition and hardness of quartzite, and also containing a variable, though always small, amount of lime. The material at the base of the formation is usually coarse, constituting the chief conglomerate of the series; in many instances it is apparently derived from

the neighboring Archean, but not infrequently there is found the white quartzite and quartz conglomerate so common in the Colorado areas of Cambrian, the source of which is possibly somewhat more distant. The color of the arenaceous or quartzitic members varies from darker brown to gray, white, or, locally, red or green, but the first predominates.

The shales, which are greenish gray or brown, constitute by far the larger part of the formation, the sandstones and grits being distributed from base to summit of the series, in beds 2 to 20 feet thick, in the Big Horn Range an especially prominent zone occurring about midway.

The limestones are impure and occur in thin beds at a few horizons only. The entire series contains disseminated grains of the green silicate of iron (glauconite) which is now recognized as characteristic of the Cambrian throughout the Rocky Mountain region.

The thickness of the formation varies from a few feet—with possibly entire absence in one or two localities—to about 900 feet, the region of minimum development being the Owl Mountains, that of maximum the canyon of Clarks Fork. On the eastern slopes of the Big Horn Range, in the canyon of Big Goose Creek, the estimated thickness is from 400 to 600 feet, which is maintained over the greater portion of this range.

The fossils of the Cambrian within the region examined are doubtless far more numerous than casual search revealed, but aside from a few trilobites no attempt at collection was made.

The Cambrian exposures are confined to the mountains. The formation occupies considerable areas of the summits of the Owl and Big Horn ranges, while in the Absaroka and Wind River Mountains it is confined to the lower slopes. On the summit of the Big Horn Range it forms numerous low buttes which rest upon the Archean floor and are usually capped by the lowermost strata of the Silurian.

The Silurian.—Overlying the Cambrian, the upper limit of which is somewhat arbitrarily taken at the top of the shales, are several hundred feet of limestone and quartzite in which it is difficult to trace a definite line of division but approximately the lower half of which is of Silurian age, and the upper half, Subcarboniferous. The Silurian series presents three varieties of rock: a peculiar, laminated, pebble-bearing limestone at the base, and light colored cherty limestones and white quartzites, overlying to the summit.

The basal limestone is from 50 to 100 feet thick. Some of its layers abound in lenticular pebbles, also of limestone, in size minute up to 1 or 2 inches in maximum diameter. The colors are green, greenish gray, purple or purplish brown. The layers devoid of pebbles are crystalline in texture and delicately laminated, the color changing with the laminations; their hardness also varies, causing the rock to weather in delicate corrugations. The matrix of the pebbly layers is similar to the above. The texture of the pebbles is homogeneous, the

grain very fine; the prevailing color is green without, gray within. The pebbles lie both with the lamination planes and across them. Pebbles and matrix are of equal hardness, the rock fracturing across both alike. The presence of this series is general in the mountains bordering the Big Horn basin.

The nature of these pebble-limestones seems to be that of an intra-formational conglomerate, the pebbles having been formed shortly after deposition of the original material by the breaking up of the bed, and settling in their new positions in the midst of fine calcareous matter brought down at the same time.

The chert-bearing limestones form the mass of the Silurian series. They occur in heavy beds of 50 to 100 feet and are white to light gray, mottled purple or brown. Locally they contain a varying amount of quartzose matter, by reason of which they not infrequently graduate into true quartzite, and vice versa. Limestones of this appearance and nature characterize the Silurian throughout the Rocky Mountain region.

The Silurian quartzites are usually pure white and of considerable uniformity of texture. In the region examined they are distributed throughout the chert-bearing limestone in beds from 1 to 30 feet thick, but in several localities in the Rocky Mountains concentration into one or two heavy beds has been observed.

The thickness of the Silurian over the field examined varies. In the Big Horn Mountains it is estimated at about 600 feet; on Clarks Fork at 1,000 feet; in the Owl-Rattlesnake Range there is marked diminution with, possibly, even total disappearance at one or two localities; in the Wind River Mountains a thickness of 1,000 feet is again attained.

Characteristic fossils were obtained from a layer within 75 feet of the probable top of the formation.

The area of Silurian in the Big Horn Mountains is little less than that of the Cambrian; the lower members of the formation, having escaped erosion, cap many of the buttes on the summit, while there is a general rim of both quartzites and limestones about the whole periphery of the crest. In the Absaroka Range the formation is chiefly confined to the lower slopes, extending to higher altitudes only to the south of Clarks Fork, and in the vicinity of the Stinking Water, where additional area of exposure has been acquired by the presence of minor folds parallel with that of the general uplift. In the Wind River Range the conditions of outcrop and exposure are relatively the same as in the Absaroka. In the Owl-Rattlesnake Mountains the Silurian area is not extensive except in the immediate vicinity of the Wind River Canyon, where erosion has been carried to a degree that has left it the superficial rock over much of the crest. In the Pryor Mountains the delineation of the Silurian was undetermined, but it doubtless appears in the canyon of the Big Horn River, and possibly just west of the fault line in the valley separating the two ridges of which the range is composed.

The Carboniferous.—This embraces both divisions usually found in the West—the Subcarboniferous and the Coal-measures.

The Subcarboniferous includes the upper half of the great Paleozoic series of limestones and quartzites of which the lower half has been described as Silurian. Not more than 50 feet above the horizon regarded as the probable base of the formation characteristic fossils are found, while the upper limits are equally well defined by a sharp change in sedimentation. The thickness of the series varies between 300 and 1,000 feet, the maximum being attained in the Absaroka and Wind River Ranges, the minimum and average occurring in the Owl-Rattlesnake Mountains and in the Big Horn Range respectively.

The mass of the Subcarboniferous is limestone, divided into two or three varieties. In the region of the Big Horn Mountains there are two: the upper, the typical, massive "blue limestone" of the Rocky Mountains; the lower, a bedded, white, quartzite-bearing limestone, resembling that of the upper portion of the Silurian. In the region of Clarks Fork Canyon in the Absaroka Range, the quartzite is at a minimum and the limestone, which is of a more decided gray than usual, occurs in two or three broad bands separated by 50 to 100 feet of thin bedded limestone of reddish hue. The whole series is locally more or less ferruginous, while the blue limestone proper is also frequently cavernous. The beds occur in either one or two pronounced benches or with the Silurian form an unbroken cliff from base to summit.

The distribution of the Subcarboniferous includes the slopes of most of the great ranges bordering the Wind River and Big Horn basins, and, within the latter basin, the central terrane of the Sheep Mountain anticline—a long, low ridge near the eastern side of the basin—and the crest of Heart Mountain, near the western end of the divide between Clarks Fork and the Stinking Water.

The Coal-measures of the Carboniferous are the most variable of the formations within the present field. The series is most complete along Big Goose Creek in the Big Horn Mountains where the following beds are present: at the summit, 60 to 80 feet of white sandstone, in two benches, a red layer of 5 or 10 feet between; for 130 feet below this, thin beds of limestone, quartzite and shale, all more or less noncontinuous and shading into each other; beneath this, 20 feet of limestone in thin layers, some of which are white and very pure, others brown and more or less quartzose; shales with narrow quartzites and limestone now succeed for 60 feet; finally, the lowest bed consists of 40 feet of deep red sandstone with a few very thin beds of limestone interlaminated. The last rests directly on the Subcarboniferous.

Of the foregoing series the most important bed, both from general occurrence and the determinative value attached to it, is the heavy sandstone or quartzite at the top. This forms the outer rim of the Paleozoic measures in all the lofty ranges about the Big Horn and Wind River basins, except the Shoshone. The remainder of the series between this and the blue limestone is not only very variable, but, as in the section at Clarks Fork Canyon, locally disappears. At many

points, however, and in the Big Horn Range especially, the prominent red sandstones at the base are present, and afford a ready means for identification of stratigraphic horizons. In the Wind River Range the quartzite is present, but the general constitution of the Coal-measures differs from that elsewhere in having a greater proportion of shale.

The distribution of the Coal-measures follows that of the Subcarboniferous.

The Trias.[1]—This is represented wholly by the well known "Red Beds" of the Rocky Mountains—heavy bedded, bright red sandstones and conglomerates, the former often of fine, even texture and uniform color, the whole consisting of quartzose and other Archean-derived material and being somewhat ferruginous. The upper 50 to 75 feet are usually more thinly bedded and carry a few narrow bands of limestone, constituting a transitional zone, to the overlying Jura. The thickness of the Trias varies approximately between 300 and 1,000 feet.

The folding and erosion that have taken place in the localities of the subordinate anticlines which parallel the main ranges have exposed much greater and more numerous areas of the Red Beds than would have been shown under circumstances of greater regularity. As a consequence, therefore, the Trias not only skirts the base of the more lofty ranges in zones of greater or less width according to the degree of dip, but occupies considerable areas in the basins themselves. Prominent among these areas in the Big Horn basin are the Sheep Mountain and Five Spring ridges on the east, the southern extension of the Rattlesnake Ridge—a spur of the Absarokas—on the west, and the region along the northern base of the Owl-Rattlesnake Range, in which both minor folds and gentle dips on the mountain slope itself have added materially to the breadth of outcrop. Other localities in the basin where the area of Red Beds is thus considerably increased are the southwestern base of the Pryor Mountains, and the western base of the Big Horn Range both in the vicinity of the Big Horn Canyon and between No Wood Creek and the main range. In the Wind River basin, in the vicinity of Fort Washakie and the town of Lander, are two very prominent anticlines parallel with the Wind River Range at a distance of 12 to 15 miles from its base, and on the southern spurs of the Owl Mountains adjoining the Shoshone Range, in the northwestern portion of the Shoshone Reservation, are several other folds en échelon with one another where extensive exposures of Red Beds exist.

The Jura.[1]—This, so far as the evidence obtained indicates, is, within the region under examination, wholly of marine origin. The thickness is between 400 and 600 feet, which is approximately maintained over the entire area of exposure. Shales constitute the mass of the formation in which from base to summit occur thin beds of sandstone and fossiliferous limestone of types characteristic of the Jura in the Rocky Mountain region. Gray is the predominating color of the

[1] In the text Jura corresponds to Upper Jura-Trias of map; Trias, to Lower Jura-Trias.

shales, but throughout the formation red, purple, yellow, slate and pink, in greater or less intensity, may be observed. At a number of localities a considerable amount of siliceous matter appears, in occurrence suggesting the action of hot waters.

The sandstones are of slight importance. They are chiefly gray with a slightly greenish tint. The lower beds, however, are red, shaly, and transitional from the Trias, while near the summit are two of greater thickness, which, but for their tint and the overlying typical Jura shales, might be confounded with the Dakota.

The limestones are nearly all fossiliferous, and of the drab color peculiar to the Jura in the west. In thickness they vary from a few inches to 15 feet. Three or four in the lower 100 feet and one or two in the upper third of the formation are especially prominent.

The distribution of the Jura is approximately that of theTrias, the one succeeding the other in all localities.

The Dakota.—As elsewhere in the Northwest, this is essentially a formation of quartzose sandstone with a few minor layers of shale or clay which locally become somewhat carbonaceous or, perhaps, take on the nature of a fire-clay. The sandstone is gray, but usually tinged yellow, red or brown from the presence of iron. At the base of the formation is a layer of conglomerate in which pebbles and matrix are more or less silicified, a feature also characteristic of the formation in other parts of the West. Plant remains occur.

The thickness of the Dakota varies, but is generally less than 100 feet. In the region of Five Spring Creek, at the western base of the Big Horn Range, the formation is entirely absent, the black shales of the Benton resting directly upon the variegated clays of the Jura. This is, however, a local occurrence, and within 3 or 4 miles of the base of the range the formation reappears, first in a clearly recognizable layer hardly 6 inches in thickness, then gradually increasing westward until a general thickness of 50 feet is attained. The phenomenon is apparently one of nondeposition.

The Colorado.—The component members of the Colorado—the Benton and Niobrara formations—are grouped under one color on the map, their line of division being too indistinct to permit separation.

The Benton is a body of leaden gray and black shales carrying a few thin bands of limestone and numerous small, lenticular ironstones. The formation maintains the general features that characterize it throughout the West. Its thickness is between 300 and 600 feet.

The Niobrara consists largely of light gray shales, but it also carries some impure, shaly limestones, a characteristic sandstone locally developed, and an equally remarkable conglomerate in which the pebbles are of black chert—in one or two places mingled with more or less eruptive débris. The thickness varies from 300 to 800 feet.

The shales constitute a broad, light colored zone between the darker clays of the Benton and Pierre. In general they are soft, friable and earthy, but there are layers more especially associated with the local

sandstones and conglomerates, which are of extremely close grain and of fine even texture, indurated in a marked degree, and which, though gray on fresh fracture, weather a characteristic milky white. They occur in bands from 1 to 3 feet thick.

The limestones are not of a pronounced character, but rather are calcareous layers of the shale, which are held together with greater tenacity than portions containing less lime. These layers are rarely over a foot or two thick, are very earthy and are usually of a fine texture. They contain numerous molluscan casts, poorly preserved.

The sandstones are white, stained yellow or brown from the presence of iron, and they carry an occasional ferruginous concretion from 1 to 3 feet in maximum diameter. They are especially well developed along the front of the Absaroka Range in the vicinity of Clarks Fork, here attaining a thickness with the associated conglomerates of 50 feet. There are apparently two horizons of these sandstones—one 200 feet above the base of the formation, another at the summit. The sandstones are either massive or divided into layers 1 to 6 feet thick.

The conglomerates have a matrix of sand, but the pebbles are chiefly black chert, averaging half an inch in diameter, in some places sparsely scattered through the rock, in others constituting almost its entire mass. Mingled with the chert pebbles are others of eruptive material; these are especially abundant in the vicinity of Clarks Fork. The pebbles of the Niobrara conglomerates, particularly those of black chert, are characteristic of the formation for the region examined and afford ready identification of the geologic horizon.

The sandstones of the Niobrara in the Clarks Fork region are leaf-bearing, affording the only instance within the United States in which this formation has been found to contain plant remains.

The Niobrara occurs not only in the regular succession of beds along the base of the several mountain ranges but includes numerous areas in the basins proper, where it occupies the center or rim of most of the subordinate anticlines about their peripheries. Notable among these anticlines are several along the west base of the Big Horn Range; others very extensive north of the Owl Mountains, having a N. 60° W. trend; a number in the region between Wood River and Stinking Water, of a general north-northwest direction; portions of the general divide between the Big Horn basin and the Yellowstone valley; and, in the Wind River valley, several along the Wind River Range, and others extending in a southeasterly direction from the Owl Mountains.

The Montana.—This embraces the Pierre and Fox Hills formations, which, by reason of their gradual passage one into the other, it has been impossible to separately delineate upon the map.

The Pierre is composed entirely of dark, leaden gray clays, which carry numerous concretions of limestone, averaging 2 to 3 feet in diameter. These concretions are often veined with calcite seams, and easily break into angular fragments; they are fossiliferous, affording many typical Pierre forms.

The Pierre outcrops over a much greater area than any of the older formations. This is due to the low degree of dip beyond the immediate base of the mountains, to the many gentle anticlines mentioned, and to the general level of erosion attained at the present day. In the Wind River valley broad areas of Pierre exist both on its northern and southern sides. In the Big Horn basin the Pierre occupies a broad belt along the base of the inclosing ranges, locally, however, as along the base of the Absaroka Range, contracted by reason of its steeper dip. East of the Big Horn Range the formation again occurs at a comparatively gentle dip, 10° to 20°; here, opposite the Laramie, its area of exposure is from 3 to 5 miles wide, while to the south of this formation it is reported over a much more extended stretch of prairie. The thickness of the Pierre is probably between 1,000 and 2,000 feet, but no actual determination was made.

The Fox Hills was not definitely recognized in the present field of exploration. Towards the top of the clays which constitute the Montana series the material locally becomes a little sandy, but no heavy beds of sandstones, such as mark its summit in many western localities, appear, and no fossils characteristic of the horizon were obtained.

The Laramie.—This is a series of alternating sandstones and clays, with seams of lignite or coal at various horizons from base to summit.

The clays as a rule predominate. They are gray, and often bear plant remains or carbonized particles of wood sufficiently abundant to stain layers of them a brownish hue, or to impart to thin beds a more or less lignitic character. They frequently carry concretionary bodies of indurated sandstone, and in a single locality—one mile below the town of Red Lodge, on Rocky Fork, in Montana—limestone concretions from 1 to 6 feet across, containing leaf and wood impressions. The latter concretions resemble those of the Pierre in texture and fracture, but are yellowish gray and are associated with lignite-bearing beds.

The sandstones are almost wholly composed of quartz grains, of medium size. The normal color is gray to white, but a variable amount of iron locally imparts a brownish tint. The beds vary in thickness from 1 to 50 feet, those of 20 to 30 feet being of common occurrence. They are of considerable persistence, particularly those of the lower 150 to 200 feet. As a rule the lower beds form prominent outcrops, whether their position is vertical or but slightly inclined. Leaf impressions are common.

The clays and sandstones of the Laramie in the Big Horn and Wind River basins and the Clarks Fork valley are segregated into two broad divisions: the lower, 300 to 500 feet, composed chiefly of the sandstones; the upper, 400 to 600 feet, of the clays. East of the Big Horn Mountains this separation is not nearly so pronounced.

The thickness of the Laramie varies from a few feet to 1,000, or possibly over. The maximum thickness is attained beneath the prairies east of the Big Horn Mountains, the minimum along the base of the

Absaroka Range immediately south of Clarks Fork, where but a few feet now separate the Pierre from the overlying Wasatch. At other points the average thickness of at least 600 or 700 feet is maintained. The extreme thinness in the vicinity of Clarks Fork is due to denudation from the summit prior to deposition of the younger formations.

The area of exposed Laramie is extensive. East of the Big Horn Mountains it reaches fully half of the distance to the Black Hills, while to the north and west it constitutes the surface formation over much of the Yellowstone and Clarks Fork valleys. It underlies horizontally the Tertiary formation in the central portion of the Big Horn basin, and outcrops with gentle dip in a broad belt about its periphery. In the Wind River valley it appears from beneath the later beds in detached masses at the base of the inclosing ranges, and probably underlies the greater portion of the basin area.

Succeeding the Laramie in chronological order in the Big Horn and Wind River basins are the equivalents of the Wasatch and Bridger formations of an area further south, with possibly a third series of beds belonging to the Livingston, a formation of recent identification in Montana. The last has been assigned to the Cretaceous, while the first two belong to the Eocene Tertiary. Each at one point or another rests directly upon the Laramie, at the top of which is one of the greatest unconformities known.

The Livingston.—This formation, on account of its uncertain occurrence, will not here be discussed beyond the remark that in its recognized localities to the northwest of the present field it consists of a series of sandstones, grits, conglomerates and clays, made up very largely of the débris of andesitic lavas and other volcanic rocks and including local intercalations of volcanic agglomerates.[1]

The Wasatch.—This is a series of clays with occasional beds of sandstone and local conglomerates, the thickness variously estimated from 1,000 to 2,000 feet.

The clays are chiefly gray, but are banded white, buff and red, the reds being most conspicuous, and, taken with the composition of the beds and their stratigraphical position, a characteristic and determinative feature of the formation. Small calcareous concretions, more or less earthy, occur throughout the clays; these are fossiliferous.

The higher sandstones in the series are argillaceous and generally weather in slopes uniform with the clays. Occasionally, however, purer layers occur, which are more resisting and outcrop in ledges that break the otherwise monotonous descents. Towards the base of the formation the sandstones are usually more pronounced and the lower layers may become coarsely conglomeratic. This is especially the case in the vicinity of Clarks Fork Canyon, along the foot of the Absaroka Range, where there are 600 or 700 feet of conglomerates, grits, and sandstones,

[1] The Laramie and the overlying Livingston Formation in Montana, by W. H. Weed. Bull. 105, U. S. Geol. Surv., p. 21.

all more or less ferruginous. The pebbles constituting the conglomerates vary in size up to 6 or 8 inches in diameter, and consist chiefly of limestones, quartzites, and sandstones derived from the older sedimentary formations of the neighboring mountains; a small quantity of Archean débris is also present. Towards the top of the conglomerates or sandstones are intercalated thin beds of red clay, similar to, but passing with gentle easterly dip beneath, those so conspicuous further out in the basin. The conglomerates rapidly disappear to the south of Clarks Fork Canyon, but to the north continue beyond the Montana line, where, however, their relations to other formations were not investigated. In this direction, as the series is ascended, the material becomes finer, and the 5 or 6 miles of prairie along the Montana-Wyoming line next the range is chiefly occupied by grits and sandstones, with a minimum of the coarser constituents.

The beds which are here described as Wasatch have been studied jointly by Prof. H. F. Osborn and Dr. J. L. Wortman[1] with reference to their fossil mammalia. These have been found practically the same as those that characterize the Vermilion Creek beds of the Fortieth Parallel Survey, while lithological identity is apparent from the foregoing description. There is, therefore, no doubt as to the propriety of referring the series to the Vermilion Creek or Wasatch Eocene, the lowest division of the western Tertiary.

The Wasatch beds occupy a broad area in the central portion of the Big Horn basin. They have been traced and identified, both lithologically and by their fossils, in the Clarks Fork valley and northward to the Montana line, and they appear from beneath the lower Bridger beds in certain localities in the Wind River valley.

In the Big Horn basin they constitute the prominent McCullocks Peak, near the western edge of the formation, from here passing northward into the eastern spurs of Heart Mountain, and beyond into the bluffs of Pat O'Hara Creek and the hills on both sides of the Clarks Fork valley, in the vicinity of the canyon of the latter stream approaching within a half mile of the base of the range. South from McCullocks Peak, between the Stinking Water and Grey Bull, their western boundary lies at a distance of 10 to 15 miles from the base of the Shoshone Range. The formation appears in the high bluffs southeast of Meeteetse, and continues southward to the region of Twenty-one or Upper Cottonwood Creek, where its outcrop turns to the east and passes across the Big Horn basin on an irregular line 10 to 15 miles from the base of the Owl-Rattlesnake Range. East of the Big Horn River the series of clays again appears in a high ridge in the forks of this stream and No Wood Creek. The eastern line of the formation recrosses the Big Horn near the mouth of No Wood, and passes north-

[1] Fossil Mammals of the Wasatch and Wind River beds, collection of 1891, by Henry Fairfield Osborn and J. L. Wortman. Bull. Am. Mus. Nat. Hist., Vol. IV, 1892, Art. XI, p. 81 et seq. Also Proc. Am. Phil. Soc., December, 1891, p. 139.

west approximately parallel with the Big Horn Range at a distance from it of 15 to 20 miles. The thickness of the Wasatch beds within this area is possibly between 1,500 and 2,000 feet.

On the western side of the Big Horn basin, against the foot of the Shoshone Range, in the vicinity of the Grey Bull and Wood rivers, occur several isolated patches of Wasatch, consisting of sandstones, conglomerates, and red and gray clays, separated by erosion from the main body of the formation in the center of the basin. These remnants are probably nowhere over 100 feet in thickness.

In the Wind River valley the Wasatch clays appear to the west of the stage road from Embar to Fort Washakie, on both sides of the divide between Muddy Creek and Wind River. In the southern bluffs of this divide their outcrop passes eastward beneath the Bridger beds in the direction of Pavilion Butte. Their area in this valley was not determined, but they probably underlie much of the Bridger west of the Wind River, with a marked line of unconformity between.

The Bridger.—This formation consists of grits and sandstones, of which the material is largely quartz, with some feldspathic and other débris, derived possibly from an eruptive source, or perhaps from the Archean. The cementing substance of the grains is an opaque, white, siliceous material, apparently more or less characteristic of the formation as a whole, but less conspicuous in the sandstones than in the more gritty beds. The formation easily breaks down, and has been converted into a vast sand-desert over much of the area covered by it.

The identification of the beds with the lower portion of the Bridger to the south is based upon its fossil mammals, discovered and examined by Prof. Osborn and Dr. Wortman in the season of 1891.[1]

The extent of the Bridger in the Wind River basin is undetermined. A considerable area has been allotted to it on the map, but there have possibly been included in it other Tertiary divisions, some of which have been distinguished by the members of the early Hayden Survey.[2]

Volcanic breccias.—This great body of rocks is confined to the Shoshone and Absaroka ranges, and lies almost wholly beyond the present field. They will not be described in this paper.[3]

Quaternary.—These deposits in the Big Horn and Wind River basins and adjoining areas are limited chiefly to stream bottoms, the uplands being comparatively devoid of them. They are variable in areal extent, and no attempt to map them has been made.

The interrelations of the formations.—The Paleozoic measures are apparently conformable throughout. The Cambrian and Coal-measures show a marked variation in thickness, but this is probably one of ordinary nondeposition, and is not the effect of interformational

[1] Op. cit.

[2] Maps of the U. S. Geol. and Geog. Surv. of the Territories, F. V. Hayden, Geologist in Charge. Parts of Central Wyoming, and portions of Wyoming, Idaho, and Utah.

[3] For details of the composition and occurrence of these beds see Geological History of Yellowstone Park, by Arnold Hague. Trans. Inst. Mining Eng., vol, XVI, 1888.

erosion and unconformity. In the Owl Mountains the formations are locally thinner, and towards the west center of the range both Silurian and Cambrian are absent, the Carboniferous resting directly on the Archean; whether this is due to the presence of an Archean island of such height that the Subcarboniferous limestones were the first of the series that overlapped its summit, or to a possible fault which has brought these two formations into their present relations, was not satisfactorily determined.

Succeeding the Paleozoic measures, conformably and without apparent interruption among themselves, are the Mesozoic formations—the Trias, Jura and Cretaceous to the summit of the Laramie. Subsequent to the period of the Laramie, however, there follows a series of unconformities, chiefly by erosion, in which the later formations rest in broken succession not only upon one another but upon the several members of the Cretaceous as well. At many points evidence exists of the great amount of denudation that took place at the close of the Laramie—the Wasatch, for example, resting at one point on the lowermost strata of the Laramie, at another upon the Montana, and in a third locality even upon the Niobrara itself. In the latter instance, which happens just south of Sunshine in the high ridge separating Wood River from Gooseberry Creek, unconformity both by position and erosion exists, the Wasatch lying approximately horizontal across a sharp anticlinal fold in the Cretaceous series, the center of which is occupied by the Niobrara. With all the instances of unconformity, however, accidental conformity is often encountered.

The presence of the Livingston beds within the region explored has not been definitely determined, but this formation is strongly developed to the northwest, in the valley of the Yellowstone and the mountains to the north and south, and it is also reported by Mr. Arnold Hague north of the Stinking Water, west of Rattlesnake Ridge, where it rests successively upon all the older formations from Laramie to Carboniferous inclusive.

The Wasatch of the present area bears a certain lithological resemblance to the upper division of the Livingston as described by Mr. Weed,[1] which is composed of conglomerates derived from the older sedimentaries, and carries also beds of shales in which grays, purples, and reds occur. Mr. Weed himself suggests (p. 31) that some evidence exists that may prove sufficient cause for the separation of these conglomerates and silts from the Livingston and their recognition as the base of the Fort Union (Tertiary) group. It is therefore possible that in the absence of definite determination this series of conglomerates in the Yellowstone valley and vicinity corresponds with the Wasatch of Clarks Fork and the Big Horn and Wind River basins.

The Bridger, so far as observed by the writer, rests upon the Wasatch, except along the southern base of the Owl-Rattlesnake Range, where it

[1] Op. cit., p. 30.

apparently lies directly against the younger Paleozoic formations of the mountain, the border of the Cretaceous series being here buried beneath its sediments.

Regarding the statement of Dr. Wortman[1] that the "Puerco and Laramie do not underlie the Wasatch in the Big Horn basin, but the strata rest upon the older sedimentary rocks," it is to be remarked that the itinerary of Osborn and Wortman shows a comparatively limited area of exploration, rendered necessary by the special object to be attained by them. A broader examination would have proved the general existence beneath the Wasatch of the Laramie, except in the localities cited in the preceding pages of this report. The Puerco is absent and the Wasatch does locally rest on older formations than the Laramie.

Dr. Wortman[2] also states that the Stinking Water cuts Wasatch strata clear to its mouth. Probably from the same cause as the last he has been led to overlook the occurrence of the Colorado, Montana and Laramie Cretaceous in the valley of this stream over a belt extending from the Big Horn River westward beyond the mouth of Sage Creek.

STRUCTURE.

The structural features of the region under consideration have been developed upon two lines of force, one of the general direction N. 70° E. S. 70° W., the other of a N. 30° E. S. 30° W. direction. Upon the former have originated the Absaroka and Big Horn Ranges; upon the latter the Wind River, Shoshone, Owl-Rattlesnake, and Pryor Ranges. The influence of the forces thus acting has extended over the entire region of exploration, as may be seen by the multitude of subordinate flexures, parallel to the larger, which occur far out towards the centers of the inclosed basins, and also on the prairies to the east. The action of the forces on the two lines was probably synchronous, their interference resulting in the connecting portions between the main uplifts.

The great mountain ranges of northern Wyoming are all primarily anticlinal elevations which have subsequently been modified by erosion, or, as in portions of the Rocky Mountains proper, by erosion followed by local deposition over their summits of an enormous mass of volcanic breccias now deeply cut by modern stream courses.

The Absaroka Range.—This includes the general mountain mass between the Upper Yellowstone River and the prairie to the east, and lies for the most part beyond the region of reconnoissance. Its structure is complex, but in general is that of a broad uplift having an Archean core fringed along the prairie front with a band of Paleozoic and later sedimentary formations. The latter are usually in a highly inclined position, dipping east or northeast from 60° to 90°. The harder

[1] Op. cit., p. 144. [2] Op. cit., p. 139.

(Paleozoic) measures constitute the mountain face, while the softer (Triassic, Jurassic, and Cretaceous) beds form a zone of varying width along its base. The steep dip of the strata at the edge of the mountains rapidly diminishes beneath the prairie, and usually within 1 or 2 miles of the base of the range is reduced to between 5° and 15°, the curvature generally taking place in the Laramie, but in some localities lower down in the Cretaceous series. The trend of the sedimentaries varies between N. 20° W. on the Clarks Fork front to N. 60° W. on the northern or Yellowstone front. Along the latter front, at the base of the range, is a fault by which beds of Laramie age occupying an approximately horizontal or slightly undulating position are opposed to others of Carboniferous age and highly inclined, the downthrow being on the north of the fracture.[1] At the turn in the range the fault possibly bends around to the south, but disappears before reaching the Montana-Wyoming line. South of Clarks Fork the Paleozoic strata extend with easy dip far into the mountains, and, as reported by Mr. Hague, form a portion of the south wall of the upper canyon of this stream.

Between Pat O'Hara Creek and the Stinking Water two important anticlines extend southeastward from the range at angles of about 20° and 40°, their axes gradually sinking beneath the prairie. The north fold lies at the greater angle with the range. On its southwest side the Red Beds and underlying Carboniferous dip 50° to 80° southwest; on the northeast a bold escarpment of Paleozoic limestones and quartzites is presented, suggesting a line of fracture along the axis of the anticline with the northern half somewhat depressed. The throw disappears at the general level of the foothills, which are here somewhat elevated, and the anticline itself is lost but a short distance from the base of the range in the ridge that separates the drainage of Pat O'Hara Creek from that of the Cottonwood, a tributary of the Stinking Water. The western end of the fracture was undetermined, but it is probably near the origin of the subordinate fold in the range proper.

On a direct line with the foregoing anticline, and about 5 miles east of the main range, is the isolated peak of Heart Mountain, the structure of which was but indefinitely determined. The peak, twinned by denudation, is capped with the quartzites and limestones of the Carboniferous, which dip 10° to 20° northeast and present abrupt cliffs on all sides. Along the southern side of the peak, 500 or 600 feet below the summit, are shales closely resembling the Jurassic, and which are here regarded as such. Their strike and dip are obscure, but they have a general appearance of lying horizontal or slightly inclined from the peak, while at one or two points considerable irregularity in their position appears. Farther to the south the Laramie strata appear with

[1]This fault was first observed in 1882 by Mr. J. E. Wolff, of the Northern Transcontinental Survey. Tenth Census Reports, U. S., vol. x, p. 755 and opposite plate.

normal strike and dip. To the east and north of the peak the strata of the Vermilion Creek or Wasatch formation lie well up on the higher slopes, with a possible inner rim of the Jurassic between them and the Carboniferous. The Wasatch beds have a gentle dip to the northeast, an evidence of movement as late as Tertiary times. West of the peak the Laramie series pass uninterruptedly from the valley of Pat O'Hara and Skull Creeks to that of the Stinking Water and its tributaries, showing but few local irregularities of either dip or strike, the former being generally east-northeast. The relations between the Cretaceous and Tertiary formations and those entering into the structure of the peak itself are extremely obscure. The most plausible interpretation of the regional geology, however, seems to be that of an upward thrust, perhaps developed from extreme compression, by which the older beds, the Carboniferous and Jurassic, were carried through the surrounding formations of younger age, developing as it were between the two series of formations a practically circular fault, the strata in the immediate vicinity of which are in considerable confusion.

The southern of the two folds springing from the Absaroka Range forms an angle of about 20° with the trend of the main mountain mass, and is locally known as Rattlesnake Ridge. It is divided from the range proper for the greater part of its length by Rattlesnake Creek, which enters the Stinking Water just below the confluence of the North and South forks. The anticlinal structure is clearly shown in the Paleozoic measures on both sides of the ridge, while the canyon of the Stinking Water exposes the arch and the formations involved to the Archean. Between the northern anticline and the present, the strata form a sharp trough, the axis rapidly rising to the northwest. Both these folds spring from the main range at about the same point, and as their distance apart increases, the included angle shows other and subordinate folds, which are nearly parallel with the Rattlesnake Ridge. Of these, one of importance lies along the main fork of Cottonwood Creek, the present stream channel being a little east of the axis, the lowest beds exposed, the base of the Jura. The anticline extends the entire length of the creek, although the more pronounced portion, involving the Dakota and underlying formations, constitutes a sharp ridge 5 to 6 miles in length, considerably north of the Stinking Water.

South of the Stinking Water the Rattlesnake Ridge is continued in the knob-like peak of Cedar Mountain, which constitutes the southern end of the anticlinal fold in the Paleozoic measures. From this point southward the axis of the anticline rapidly sinks, but a crumpled structure is preserved in the Mesozoic formations underlying the prairie for a distance of 10 to 15 miles farther, quite to the valley of Grey Bull. The most important of these prairie folds commences just east of Cedar Mountain in the red sandstones of the Trias, which have not yet finally disappeared beneath the surface from the uplift of Rattlesnake Ridge; a short distance southeast the Red Beds are succeeded by the

Jura, and this in turn by the Dakota, Benton, and other Cretaceous formations to the summit of the Laramie, the fold showing conspicuously in each. This fold, together with one or two subordinate flexures, has an east and west extent of about 10 miles. The prairie thus included presents a series of low parallel ridges, inclosed valleys and isolated hills, the combined result of folding, erosion and the nature of the materials.

The region west of the Rattlesnake Ridge and north of the Stinking Water presents a number of crumples within a general synclinal depression, but little of the earlier mountain structure is shown, owing to the presence of the great series of volcanic breccias which lie unconformably across older formations and folds alike.

The Shoshone Range.—This embraces the great mass of mountains between the Stinking Water and Wind River and is the development of three distinct geologic incidents: a post-Cretaceous folding followed by a certain amount of erosion; deposition upon the area thus prepared of a heavy thickness of volcanic breccias and conglomerates which for the most part still retain their horizontal position; finally, erosion of later times, which has brought about the present configuration of the surface. So widespread is the deposit of breccias, however, that the earlier structural history is suggested only by the folds along the base of the range. These preserve a general trend of N. 30° to 60° W., S. 30° to 60° E., but local departures from this direction appear, however, as in the approximately east and west fold in the Stinking Water valley, and the north and south fold between Wood River and Grey Bull.

Commencing at the north, two anticlines occupy the northeastern slope of Meeteetse Mountain, crossing the heads of Sage, Carter, and Belknap creeks. One of these, the southwestern, has a N. 60° W. trend, with a lineal extent of 10 to 12 miles; the other, or northeastern, has a course a little nearer east and west and is somewhat shorter.

The crest of the former fold is exposed in strata of probable Laramie age at an altitude of 1,000 to 1,200 feet above the valley of the Stinking Water. The southwestern half of the fold, a short distance from the axis, becomes more or less obscured by débris from the mountain slopes above or passes into an area of broken and confused strata; at the few points, however, where clear observations are attainable, the dip of the beds along this side of the flexure varies from 20° to 80°. The northeastern half of the anticline is more regular, and the strata have a general dip of 25° to 30°, with a few, local, minor flexures. The anticline appears almost wholly in Laramie strata, but between the heads of Carter and Sage Creeks is a series of red, white and gray clays and yellow sandstones and conglomerates which closely resemble certain phases of the Wasatch. The stratigraphic relations of the two series of beds are, however, indefinite. This anticline disappears to the west in the valley of the Stinking Water; to the east in the slopes of Meeteetse Mountain at the head of Sage Creek.

The second anticline, northeast of that just described, lies along the base of the Meeteetse Range in the valley of the Stinking Water. It extends west nearly to Belknap Creek. To the east it enters the bluff of Carter Creek and is lost in the broad flat between this and Sage Creek. Transversely the fold is asymmetric, the strata on the southwest side having the steeper dip, 40° to 60°. North of the axial line the strata dip but 15° to 20°, and pass beneath the broad valley of the Stinking Water, to remain buried beneath the breccias of the Absarokas, or to reappear in the river bluffs or about the base of the Cedar Mountain and Rattlesnake Ridge. This profile of the fold therefore resembles that of the large anticline to the southwest. The crest of the smaller anticline is eroded to the Jurassic, while the highest beds on either side are now those of Niobrara age.

Between this anticline and that to the southwest there is a sharp syncline, so sharp, in fact, that it suggests the presence of a fault along a considerable portion of its length.

The structure beneath the valley of the Stinking Water, in the broad, triangular flat above Cedar Mountain, is doubtless that of a syncline modified by slight minor flexures, some of which appear in the bluffs on the north side of the river.

In the valley of Upper Sage Creek, between Meeteetse Mountain and the southern prolongation of the Rattlesnake fold, is a small anticline parallel with the Rattlesnake flexure, the northern end of which is within 5 or 6 miles of the Stinking Water, the southern in the high mesa separating Sage and Meeteetse creeks, the breadth of the fold being 3 or 4 miles. The fold shows a median ridge of Niobrara flanked on the east, across a valley of Montana shales, by a second ridge, of Laramie sandstones. West of the Niobrara ridge the area of the Montana is very broad, but the line between this formation and the Laramie is obscured by the structure about the immediate base of Meeteetse Mountain.

Between the anticline just described and that next east is a narrow synclinal valley, 1 to 2 miles wide, lying wholly in the Laramie shales and bounded east and west by the underlying sandstones of the same formation. The axis of the trough tilts up to the north of Sage Creek, and this end of the valley is also closed by a rim of the sandstones at the base of the Laramie. The southern end of the valley is closed by the Meeteetse mesa, in the sharp and eroded face of which the general structure of the trough is well exposed. The syncline is sharp, the sandstones on either side varying in dip from 45° to 70° or 80°. The details of the structure of the mesa between Sage and Meeteetse Creeks are obscured beneath wash and soil.

The Sunshine district.—In the southern face of the Meeteetse mesa, from a little above Arland Post-office to the mouth of Meeteetse Creek, strata of the lower Laramie are again exposed and show one or two broad, gentle anticlines, with a general trend of N. 40° to 50° W. and

extending southeast beyond the valley of the Grey Bull. Additional folds also appear in the bluffs of the latter stream, a series of anticlines with the intervening synclinal troughs extending from the edge of the Wasatch below Meeteetse Creek to the base of the Shoshone Range, greatly increasing by repetition the surface area of the Laramie, Montana, and Colorado beds. These flexures are, again, connected with others south of the Grey Bull, extending to the vicinity of Gooseberry and Grass creeks. The region thus indicated is so united in its geologic development that it may be regarded as a district in itself and designated "Sunshine," from its central post-office and settlement on Wood River. The area of the district is approximately 25 miles square. The flexures which it embraces have a general trend of N. 30° to 50° W., varying locally N. to N. 80° W., but their distribution is more or less irregular, the result of general crumpling.

The front of the Shoshone Range bordering this district is a bold escarpment of volcanic breccias and interstratified lava flows, from beneath which at the prairie level pass the great series of Cretaceous clays and, perhaps, other beds a little above or below. The Montana and Colorado groups constitute a broad zone, 5 to 10 miles wide, at the base of the range. Locally these are overlain by patches of Wasatch which have been separated from the main deposit in the center of the basin. Areas of this Tertiary formation occur north of the Grey Bull, between this stream and Wood River, and capping the high lands to the south of the latter valley. These beds show comparatively little flexing, the great series of folds in the district being confined to the Cretaceous, upon which the Wasatch rests unconformably.

Two or three miles below the debouchment of the Grey Bull from the Shoshone Range a prominent anticlinal ridge appears in Niobrara beds, extending from a mile or two north of the river to five or six south, the trend being northwest. West of the ridge the Montana underlies the surface nearly to the mountain, local outcrops of Laramie being reported immediately beneath the eruptive series. These were not observed by the writer, but it is quite possible that they exist.

Passing eastward along the Grey Bull from this anticline, a broad stretch of several miles is crossed, underlain by the Montana. The Laramie first appears below Franks Ranch, 6 or 7 miles above the mouth of Wood River, where it caps a line of bluffs presenting a sharp face to the west. From this line, which is approximately north and south, the Laramie extends eastward in a synclinal trough, followed still further to the east by an anticline which occupies the residue of the region to Wood River. The northward extent of these flexures beyond Grey Bull is 5 to 6 miles. Southward they are continued to Gooseberry Creek, crossing the Wood River valley in the vicinity of Sunshine.

The syncline is marked by a broad topographic depression, with the rim raised considerably above the surrounding prairie. The center is

occupied by the sandstones of the lower Laramie, which are chiefly confined to the region south of Grey Bull. The strata dip to the interior from 20° to 45° or 50°, those on the east and south having the steeper inclination; along the western rim the beds flatten considerably, forming a lip to this edge of the basin. In addition to the Grey Bull, the syncline is also cut about midway its length by a stream heading against the Shoshone Range. At the southwest corner of the area the Laramie measures are unconformably capped by the conglomerates and red clays of the Wasatch. The syncline derives special importance from the presence of coal seams of workable thickness and quality.

The anticline east of the syncline is chiefly exposed in the Montana, but the Niobrara outcrops for a few miles along the central portion of its axis. The fold appears in section in a hill a half mile north of Grey Bull, and again in the bluffs of Wood River near Sunshine. South of Sunshine it passes into the ridge between Wood River and Gooseberry Creek, where it is partially overlain by the conglomerates of the Wasatch. From this point it crosses Gooseberry Creek, a sharp flexure, and a little beyond becomes complicated by the presence of other folds, which extend into the higher foothills of the region further south, and probably eventually pass beneath the breccias of the Shoshone Range. Along the northern half of the fold Wood River occupies the broad belt of Montana shales east of the axis, while the Laramie appears in the high ridges east of this stream, crossing, however, to the west side a little above its mouth, and Grey Bull a little beyond. This outcrop of the Laramie is the western edge of the main body of the formation which now extends with a few local interruptions beneath the center of the Big Horn basin.

On Grey Bull, at the mouth of Rawhide Creek, another gentle asymmetric anticline may be seen in the basal sandstones of the Laramie. It extends north 4 or 5 miles, and south into the region between Wood River and Iron Spring Creek. East of this for several miles the bluffs of Grey Bull are occupied by the lower measures of the Laramie, the upper division of the formation—the lignitic clays—appearing just west of Meeteetse Post-office, while the lower beds of the Wasatch form the crest of the bluffs just below the mouth of Meeteetse Creek. The strata here dip gently east-northeast or northeast and gradually pass beneath the center of the basin. The rim of the Wasatch passes from the bluffs of Grey Bull with regular trend S. 30° E., a distance of nearly 20 miles to Gooseberry Creek, forming for most of the way a high prominent ridge with cliffs looking to the west.

In the hills south of the Meeteetse Post-office is one of the most prominent anticlines of the district. Its longitudinal axis, which has a general trend of N. 50° W., is from 15 to 20 miles long, its transverse, from 8 to 10 miles. The southern extremity is on Gooseberry Creek, at the mouth of Enos, where the axis has a local trend of N. 70° W. to conform with other folds of this vicinity. For 5 to 7 miles along the middle por-

tion of its axis the anticline presents a deep topographic depression locally known as the Upper Buffalo basin. The basin is occupied by the Montana shales and is surrounded by a high and almost impassable wall of Laramie sandstones dipping outward at angles from 20° to 45°, the drainage being by a single sharp cut on the eastern side. About the sandstone rim, on the exterior, is the upper, or shaly, division of the Laramie. The hills at the southern end of the basin, just north of Gooseberry Creek, are exceptionally high, the basal sandstones of the Laramie outcropping in bold spires and rugged ridges.

East of the Upper Buffalo basin, and forming a portion of the general prairie region, is the extensive Lower Buffalo basin. This is not, however, a structural basin, but, rather, one of accidental erosion, common in regions where variation in the component materials of the beds is marked.

Six or seven miles southwest of the Upper Buffalo basin and 2 or 3 above the confluence of Iron Spring and Gooseberry Creeks is another anticline, of similar structure and topography. This is cut transversely by the valley of Gooseberry Creek, and shows a central body of Montana shales inclosed by a rim of Laramie sandstones dipping outward from 10° to 20°. The longitudinal axis of the fold has a north-northwest trend, and is, perhaps, 5 or 6 miles long; the transverse axis, somewhat shorter. This anticline is the first below the western rim of the Laramie, which crosses the stream valley several miles farther up, south-southeast from Sunshine Post-office. Still another anticline, smaller than the foregoing, crosses Gooseberry Creek at the mouth of Iron Spring, being well shown in the heavy sandstone walls of both stream valleys.

Within the area between Gooseberry and the Grey Bull, in the confusion of hills and valleys that there exists, several other folds in the Laramie were observed, all of greater or less importance, but detailed examination was not undertaken.

In the lower portion of the canyon of Gooseberry Creek, from the mouth of Iron Spring to 5 or 6 miles below Enos, and in the region to the south, the folding is of considerable complexity. For 3 or 4 miles below Iron Spring Creek the valley of Gooseberry is cut in the trough of a syncline. A little lower down the strata bend from the syncline to an anticline, and a mile below this, in the sharp point of land between the middle and east forks, another syncline follows, showing in a patch of Wasatch sandstones overlying the Laramie shales. On a small tributary of Gooseberry from the south, 2 or 3 miles east of Enos Creek, an important anticline, 4 or 5 miles in longitudinal extent and having a trend of N. 50° W., exposes at the center a small area of Montana, within a rim of Laramie sandstones carrying workable coal seams. Separating this from the southern end of the fold of the Upper Buffalo basin is a slight syncline, and on Enos Creek, halfway between the mouth and head, is a broader trough, in higher Laramie strata.

The entire region between Gooseberry and Grass Creeks is an area of many folds, some in continuation of those already described, others orginating within the hills themselves. East of this region the high foothills give way to the gentler and more regular ridges of the prairies, and the formations appear in succession from periphery to center of basin.

Grass Creek displays in its walls three or four more or less important flexures in the lower Laramie series, both above and below the point at which the stage road enters it from the north. Near the head of the valley the Wasatch appears, and on the divide between this and Twenty-one Creek, a tributary of the Cottonwood, the breccias and conglomerates of the Shoshone Range, in an eastward extension. The latter formation indeed covers a considerable area between this and North Owl Creek, capping the greater portion of the higher foothills which lie between these streams.

The Owl-Rattlesnake Range.—The system of folds to which this range belongs extends from out the Shoshone Mountains and connects them structurally as well as topographically with the Big Horn Range 80 or 90 miles east. The system includes the folds which constitute the mountain mass proper and numerous others parallel with these and occupying a broad belt of prairie on either side of the base of the range. The total width of territory thus embraced is not less than 25 or 30 miles.

The Owl Mountains topographically trend N. 70° W. Structurally, however, the range consists of a series of folds and, possibly, faults, which trend N. 50° to 60° W. or somewhat diagonal with the topographic trend, and this direction, N. 50° or 60° W., is that on which the geologic features of the entire region are developed. Four folds, or the faults into which they are possibly developed along a portion of their length, occupy the summit of the range, their axes being intersected about midway by the crest-line. Erosion along the axes has left in the intervals large blocks of Carboniferous limestones and quartzites, which cap the higher portions of the range.

Both sides of the Owl Mountains send out subordinate folds, in one or two instances but slightly less important than the main flexures. On the north side of the range, just east of the point where the stage road begins the ascent of the mountain, a sharp anticline is cut by the South Fork of Owl Creek, the general trend of its axis being N. 50° W. The lowest beds exposed are the Carboniferous quartzites. The fold extends but a short distance beyond the North Fork. Eastward along the range are several folds showing the Red Beds and underlying quartzites and conglomerates of the Carboniferous sharply cut by the stream courses to depths between 200 and 400 feet. Of these folds some end at the base of the mountain slope, others reach far into the basin. In the vicinity of the Wind River canyon other folds occur, with occasional small displacements along short fault

lines. Through one of these flexures has been eroded, deep into the mountain, the gorge known as "Red Canyon," of which the walls are composed almost wholly of Triassic sandstones. The range itself, in the vicinity of the Wind River Canyon, is a simple anticlinal fold, of which the northern slope is very gentle, the southern, precipitous. The entire southern face of the Owl Mountains, however is steep, the strata on this side dipping from 60° to 90°.

South of the range several pronounced anticlines spring from the western third. Here three or four sharp flexures originating at the summit of the mountain rapidly succeed each other, corresponding synclines intervening. Their axes make an angle of about 20° with the trend of the main range, and sink more or less rapidly to the southeast, beneath the general valley of Wind River. The height of the ridges sharply decreases beyond the outcrop of Carboniferous quartzites, but the folds continue pronounced in the Jurassic and Cretaceous strata, far out from the base of the range. In the Niobrara the flexures show particularly well, the sandstones and harder shales of this formation constituting a sharp ridge between Benton and Montana shales, the latter underlying the broad valley of the Muddy and its tributary coulées. The region embracing the foregoing anticlines extends from a point in the range near the Embar and Fort Washakie stage road westward beyond the borders of the Shoshone Indian Reservation, and it is reported that flexures more or less similar occur nearly to the head of the Wind River valley.

Along the northern base of the Owl Mountains, within a belt of 10 miles, are many folds, all having an approximately N. 60° W. trend, some being confined wholly to the prairie, others extending a short distance into the range. From a high point opposite the confluence of the North and South Forks of Owl Creek, six anticlines are in view. Of these the most important extends across both Cottonwood and Owl Creeks, its axis intercepting the latter stream 10 or 12 miles below Embar. The linear extent of this anticline can not be less than 20 miles, passing to the northeast into the great body of Laramie strata between Cottonwood and Grass Creeks, and to the southeast into the lower Cretaceous and Jurassic beds of the lower slopes of the Owl Mountains. On the axis two low ridges of Niobrara are developed, one cut by Cottonwood, the other a little north of Owl Creek. The Niobrara ridges are surrounded by a broad expanse of Montana, and this in turn is inclosed on the north by a bluff of Laramie sandstones from 100 to 400 feet high. A smaller outlier of Laramie also caps a knoll a little southwest of the southern of the two Niobrara ridges, the strata forming a shallow syncline.

Northeast of the foregoing anticline is a second, a shallow syncline, 5 or 6 miles broad, intervening. The flexures show particularly well in the edge of the Laramie, which for several miles forms a wavy line in and out about the northern portions of the folds. A general easterly trend is, however, preserved for this edge of the formation,

which, after one or two additional flexures just west of the Big Horn River, crosses this stream and pursues its course 15 or 20 miles further east.

Opposite the confluence of North and South Owl Creeks, about midway between the large anticline first described and Embar Post-office, is another sharp anticlinal fold, also showing a low ridge of Niobrara for some distance along its axis. This anticline disappears a mile or two north of the stream, but to the south passes into the lower slopes of the range a distance of 5 or 6 miles. Southwest of this is still another small anticline, again with a small Niobrara exposure at its center.

In the region of the Red Canyon, and extending along the lower slopes and foothills of the range for several miles in either direction, is a broad, N. 70° W. fold, with nearly the whole series of Triassic Red Beds exposed at the center, in the canyon walls. On the outer or northern slope of the fold the canyon creek has also cut a broad expanse of Jurassic sediments, affording an exposure visible for many miles.

Owing to these folds, the strata along the base and on the lower slopes of Owl Mountain display considerable irregularity of outcrop. In general, however, the Red Beds extend for a distance upon the slopes of the range. The Jurassic measures lie at the immediate base or, by a fold, extend a short distance prairieward. The Dakota and Benton often form a line of low knolls or ridges just without, while the Niobrara occurs both along the front of the range and, by folding, in numerous ridges out in the basin; the Montana follows, and beyond this are the long bluffs of the Laramie and Wasatch sandstones.

South of the Owl Mountains and east of the Embar and Fort Washakie stage road and the region of anticlinal spurs given off from the western end of the range, are several flexures, extending along the front of the range a distance of 15 to 20 miles and embracing the formations from Trias to Laramie.

The first anticline encountered extends east from the Mail Camp for several miles, at a distance from the range of one-half to three-fourths of a mile, its axis being coincident with the center of a prominent Niobrara ridge. Between this and the mountain is a sharp syncline, while without, another separates it from a second and parallel anticline, 3½ to 4 miles south.

The second anticline appears in the Montana and Laramie formations. Its length is probably between 10 and 15 miles, the strata forming a low ridge most of the distance. The western end of the ridge is indented by erosion of the beds along the axis of the fold to a horizon low down in the Montana. North and south of this indentation are conspicuous promontories, formed of the portion of the Laramie still preserved, the strata showing slight synclinal flexures. The area north and south of the promontories is occupied by Montana shales. The heavy Laramie sandstones in the southern promontory

are continued eastward for 10 or 12 miles in a prominent bluff, 200 to 300 feet high, overlooking a broad, shallow depression in Montana, to the south. Around the eastern end of this depression the sandstones bend with one or two changes in dip, the most important showing the end of a gentle syncline which has a general east to west trend and a length of 10 to 15 miles, the axis being crossed by the stage road between Embar and Fort Washakie about 12 miles from the base of Owl Mountains.

South of this syncline is the final anticline observed in connection with the Owl Mountain system. It occupies the ridge dividing the drainage of Muddy Creek from that of Wind River, and has for its central formation the Niobrara shales and sandstones. It is a sharp crumple, the length of which is about 15 miles. At the western end it merges with the folds which spring from the western end of the Owl Mountains. The folding of this region has apparently extended to the Wasatch strata, a slight local dip to the southwest occurring in them at one or two points.

The Rattlesnake Range is the structural continuation of the Owl Mountains. It is in general a broad anticlinal uplift, with steep southern and gentle northern slope. It unites with the Big Horn Range, apparently by gradual change in axial trend, but the region of their union was not visited.

On the south side of the general fold, for some distance east of the Wind River Canyon, the Paleozoic measures, dip from 60° to 90° south. Along portions of this front of both the Owl and Rattlesnake mountains erosion has removed the Carboniferous and underlying formations nearly to the prairie level, while the Mesozoic beds, which further west occupy a broad superficial area at the base of the range are, in the vicinity of Wind River, concealed beneath deposits of Tertiary age. Several miles east of the Wind River Canyon the Carboniferous and older strata entirely span the range, while even the Cretaceous beds locally reach well towards the summit.

The north side of the Rattlesnake Range presents an even, gentle slope, with a minimum amount of subordinate folding; but in a belt about 10 miles wide along the base of the range, especially in the valley of the Big Horn River and its tributary, Kirby Creek, several important flexures were observed together with an occasional fault.

Passing down the Big Horn River from the base of the range, the strata dip gently northward for a distance of 2 or 3 miles, the formations succeeding each other to a horizon a little above the base of the Montana, the Red Beds forming a prominent ridge next the foot of the mountain. Within a mile or two of the Hot Springs, the dip changes to the south and at the springs the axis of an anticline is encountered, the trend of which is approximately N. 75° W. The fold forms a prominent ridge for 10 to 15 miles along the front of the Owl-Rattlesnake Range, the Big Horn River cutting it about one-third the distance from

the western end. The center of the anticline is occupied both east and west of the river by the red Triassic sandstones. The flexure in these is very sharp and the rocks are extensively cracked, the copious waters of the present hot springs finding their way through some of the still open fissures. The largest of these springs is fully 25 feet in diameter, with an unmeasured and possibly unmeasurable depth. The Jura, Dakota, Benton and Niborara succeed one another in regular order no the flanks of this anticline, and at the ends close around and over the formations lying within.

Between the Hot Springs nticline and Kirby Creek, 6 or 7 miles north, several other east and west flexures of greater or less importance occur in middle Cretaceous clays, but the details of their structure and their interrelations were not examined.

North of Kirby Creek the Laramie sandstones form a line of bluffs extending east from the Big Horn River for 15 miles. Ten miles out the bluffs are doubled by a strike fault, which is 4 or 5 miles long and ends to the east with the bluff line. The displacement along the fault is about 300 feet, the strata to the south being downthrown. East of the line of bluffs a gentle anticline appears, involving both upper and lower divisions of the Laramie and the Montana. The area embraced by the fold is very extensive, and is one of the most broken, topographically, in the entire Big Horn basin. The Laramie sandstones and shales, with their slight dips, have been eroded into innumerable and labyrinthine gulches, utterly devoid of water except in the winter or in a cloudburst in the summer. The whole region about, from the Big Horn to No Wood Creek, is intensely barren and parched, and is considered almost impassable.

Down the Big Horn the formations preserve considerable regularity of dip, but about 8 miles above the mouth of No Water Creek, in the bluffs east of the river, the axis of a broad syncline is passed. North of it is a low anticlinal arch, this in turn being succeeded by another syncline. The trend of these folds is more to the northwest than those nearer the base of the Rattlesnake Range, holding a position intermediate between the Owl-Rattlesnake and Big Horn systems of flexures.

The Big Horn Range.—This is structurally a broad anticlinal fold, the general trend of which is, for the southern half, north to south, to the north of this veering round to N. 20° W., and finally, as the Montana line is approached, to N. 40° W. In the Pryor Range—the structural continuation of the Big Horn—the trend is N. 60° W. A cross section of the Big Horn fold shows it to be asymmetric, but the steeper inclination of the strata is now on one side of the range, now on the other. In a profile west from Sheridan the gentler slope is to the east, the strata dipping but 35° or 40°. On the west the dip passes sharply from 25° or 30° on the higher slopes of the range to vertical on the lower with, possibly, even local faulting. Toward the Montana line the dip on both sides the range shallows considerably, on the west

diminishing to but little over 20° and, locally, even below this. From the region of Shell Creek south the dip on this side the range again decreases to between 20° and 30°, and this, so far as observed, holds to the southern end of the fold. On the opposite or eastern side of the range, for a long distance south of Fort McKinney, the strata are nearly vertical. Thus the force which brought the range into existence, or the resistance opposed to it, seems to have been unequally distributed along the length of the fold, the effect being greatest now on one side, now on the other. The Big Horn anticline is a comparatively flat-topped flexure, the distance from base to base of the present range as limited by the harder (Paleozoic) formations being about 50 miles, and the general elevation above the prairie approximately but 5,000 to 6,000 feet. This, with 2,000 to 3,000 feet added for erosion of the Paleozoic strata from the summit, would increase the original height to between 7,000 and 9,000 feet, or considerably below the ratio of 2 to 50. But the topographic range of to-day is of considerably less area than that of the original fold. From the Carboniferous quartzites at the present base of the range outward, on both sides, the fold is continued in the Mesozoic measures, with diminishing dip, in some localities a distance of 10 to 15 miles.

In the development of the general fold of the Big Horn Mountains a considerable number of subordinate flexures came into existence both in that portion which constitutes the present topographic range and in the region along its base. In the range itself several flexures are shown in transverse section in the Paleozoic beds upon the slopes and crest, particularly east of the median line, in the canyon walls of the present stream courses. Folding of this nature has taken place over the entire length of the range, but the linear extent of the individual flexures is rarely greater than 5 or 10 miles. Conspicuous among the observed flexures on the eastern face and crest of the range are: one 4 to 5 miles long cut by the canyon of Wolf Creek, showing particularly well in its northern wall and occupying the slope of the range; a second in the canyon of Little Tongue River; a third, several miles in extent, on the summit of the range west of Dayton, the axis of which lies in a longitudinal valley just within the outer or easternmost line of crests, and which is crossed by the Bald Mountain trail a mile or two after reaching the summit; a fourth, southeast of the latter, of still greater extent, also just within the outer line of crests; a fifth on a branch of Pass Creek, which now flows along its axis. On the western side of the range, in the vicinity of the Bald Mountain trail, only a few minor and very gentle flexures exist, confined to the more horizontal portion of the strata on the higher slopes. On the Canyon Creek trail, several miles south of Cloud Peak, and along the range to the south of this, both east and west of the median crest line, are several slight undulations, hardly sufficient, however, to give local character to the crest.

In addition to the folds, strike faults, usually of comparatively slight throw—between 200 and 500 feet—are quite numerous, especially on the summit of the range within the first or outer rim. Not only have these caused a reduplication of the strata and the area occupied by them, but to the fracture lines and the folds are often due the long north and south courses within the range peculiar to so many of the streams. Just north of Canyon Creek, on the west side of the range, a prominent east to west fault crosses the Carboniferous quartzites and limestones, by which a sharp bluff of several hundred feet is created by the elevation of the beds north of the fracture. This bluff overlooks the range to the south and constitutes from this direction a most noticeable landmark.

The Big Horn Mountains present a massive granitic core, which is exposed at the summit of the range over a maximum width of between 20 and 30 miles. Remnants of the Paleozoic shales, limestones and quartzites are left here and there upon the Archean, forming buttes from 300 to 500 feet high, the strata showing but moderate dips in any direction. Toward the periphery of the crest the area of the early sedimentaries rapidly increases, and at the rim all are complete. In the central or Archean area large bodies of eruptive rock and also dikes of the same material were observed, the former constituting many of the prominent peaks; whether all, however, are of eruptive material, was not determined by the writer, their mapping as such being based upon reports of members of the topographic corps of the Geological Survey. Flanking the range at either base are the Triassic Red Beds (here and there constituting a low ridge), the Jura, the Dakota (occurring locally in sharp, comb-like exposures), the Benton, Niobrara, Montana, and Laramie. The Niobrara also locally forms a slight ridge separating the two Cretaceous formations of shale, while the Laramie often outcrops in low bluffs capping slopes of Montana shales.

The anticlines of the Big Horn basin that belong to the present system of folds are: two in the northeast portion, at a distance of 10 to 12 miles from the base of the range; and a complex to the south, along the valley of No Wood Creek, from 3 to 5 miles from the base. The latter is parallel with the range, but the axes of the others lie a little more to the northwest than the axis of the range. These folds constitute the Five Spring Ridge, Sheep Mountain, and the Bonanza Ridges, the first being the northernmost. The Five Spring Ridge and Sheep Mountain have a position en échelon with each other, while the Bonanza complex is nearly in line with Sheep Mountain, with a possible slight offset to the west. Together these folds extend nearly the entire length of the Big Horn Range.

The Five Spring Ridge extends from the Stinking Water valley south to the vicinity of Salt Creek. The exposed core of the anticline is of Triassic Red Beds, which outcrop for 8 or 10 miles of its length and near the southern end are cut transversely by the Big Horn River.

The section at this point shows an asymmetric fold, the westerly dip being 15° to 20°, the easterly 45° to 60°, the present elevation above the surrounding prairie 300 to 400 feet. On the east the Jurassic, and Cretaceous formations to the Montana succeed in turn the Red Beds, the Montana entering into the fold but slightly. West of the ridge, for some distance along the middle portion of its length, the younger measures have been eroded, leaving only the gently dipping Red Beds, which, after occupying a slight depression between this and the Sheep Mountain fold, pass directly into the latter, with, possibly, a small intervening fault. To the north and south the younger formations close around those lying within, the axis dips in both directions beneath the prairie, and the fold gradually disappears.

The Sheep Mountain anticline has a like trend with the Five Spring and overlaps it on the west for several miles. The distance between the two axes is about 4 miles. The Sheep Mountain fold extends from near the Stinking Water valley to a little beyond Shell Creek, although the elevated ridge which marks its median line is somewhat shorter than the extreme length. The flexure is sharp and for much of its length asymmetric, the easterly dip being between 60° and 80°, the westerly somewhat less. The ridge formed by the anticline has a maximum height of 500 or 600 feet; this in the vicinity of the Big Horn River, which cuts it transversely about midway. The cut exposes in its walls a central body of Carboniferous limestones and quartzites, that also extend along the crest and slopes of the ridge 5 to 10 miles north and south of the stream. Beyond this the topographic ridge consists of the softer Triassic and overlying beds, and has been eroded to a height usually less than 300 feet. The fold finally disappears in the Pierre shales.

The effect of the Five Spring and Sheep Mountain anticlines has been to greatly enlarge the areas of exposure of the formations involved, particularly those of Mesozoic age; to increase their line of outcrop to more than twice that under ordinary conditions; and, in the case of the Laramie, to throw the main line of its coal-measures far to the west—in some localities 10 to 25 miles from the base of the Big Horn Range. Both the Five Spring and Sheep Mountain folds are clearly visible from the western edge of the Big Horn basin, 60 to 70 miles distant.

The Bonanza complex of anticlines extends from a few miles north of No Wood Creek nearly to the head of this stream, a distance of 50 miles. The general system of folds is parallel with the Big Horn Range and occupies a belt from 5 to 10 miles wide along its base. Some of the folds appear in the Colorado and Montana, while others, nearer the range, occur in the Dakota, Jurassic and Triassic formations. The anticlinal axes vary in length from 10 to 30 miles, and the east and west slopes of the folds are usually between 20° and 40°.

Passing up No Wood Creek, the first important flexure is crossed 4 or 5 miles above the mouth of the stream, the axis having a N. 25° W. trend, the fold being in Middle Cretaceous shales.

East of this 2 or 3 miles, and separated from it by a narrow syncline, is a second anticline in Niobrara and Benton shales. This also trends N. 25° W., and extends from a point several miles north of No Wood to one 7 or 8 miles south of Bonanza, where it merges into other folds. The axis of the anticline passes east of Bonanza, the strata being thrown into a prominent ridge 200 to 300 feet high, which is more or less eroded on the west.

One mile west of Bonanza is the axis of a third parallel anticline. This appears several miles below Bonanza, and extends beyond it, to the south, between 15 and 20 miles. The axis of the anticline is occupied along its middle portion by the Niobrara, in the shales of which opposite Bonanza a petroleum spring occurs.

Twelve miles south of Bonanza a fourth and very large anticline occurs, the strata exposed along the axis being the Red Beds. Other folds of considerable prominence were observed still farther south. The folds of this entire complex are all more or less intimately related, the synclinal troughs usually being narrow, the anticlines sooner or later merging into one another. The entire area of this complex is, indeed, one of much crumpling.

The anticlines between the foregoing and the Big Horn Range occur in the lower Mesozoic formations, but were not examined in detail by the writer.

The Pryor Mountains.—These are structurally the northwestern continuation of the Big Horn Range, extending from the Big Horn River, south of the Montana-Wyoming line, some 30 or 40 miles west-northwest, into the State of Montana. The range belongs to the N. 60° W. series of flexures, or to the same system as the Owl Creek Mountains and the Wind River Range.

Though excellent exposures occur in the Big Horn Canyon and on the slopes of the mountain above, a transverse section of the range was observed only at a distance, from points to the southeast and southwest on the general route of reconnoissance. The range is an anticline, but has a double crest, induced by a longitudinal fault along the western slope of the fold. The fault passes along the valley between the two crests, the strata on both sides the fracture dipping southwest about 30°, those on the east being downthrown. Southeast the fault probably does not extend beyond the Big Horn Canyon; northwest it disappears at the head of Sage Creek, beyond which the range is single, a continuation of the eastern of the two ridges.

The formations which constitute the Pryor Mountains are of Paleozoic and Archean age, the latter exposed in the canyon of the Big Horn River. The Mesozoic formations—the red sandstones of the Trias and overlying series—have been eroded to the base of the range both on the north and south, and from between the crests they have disappeared except a few scattered outcrops. The backs of both ridges consist of the Carboniferous quartzites, which in the western

ridge particularly, have been deeply channeled with sharp canyons that diagonally cross dip and coincident topographic slope. The extent of the Pryor fold is considerably greater than the area of the range itself. The Trias, Jura, Dakota and Benton, outcrop along the base of the mountain, continuous with the outcrops farther to the south. Their dip in the Big Horn basin is usually below 15°, shallowing still further as distance from the range is gained. The formations appear, therefore, in wide terranes, the Laramie lying well out in the valley of Sage Creek. Moreover, the area of Laramie has been further diminished by a gentle rise of the strata along a portion of Sage Creek and their removal from the arch by erosion.

The Pryor Range disappears to the northwest by a gradual sinking of its axis. The region about, however, for a long distance is maintained at a considerable elevation and shows numerous minor folds, spurs of the main flexure or crumples of a secondary character but of synchronous development.

The divide between the Big Horn basin and the Yellowstone.—One of the minor folds given off from the western end of the Pryor Range is the gentle anticline which now forms the divide between Sage Creek and the tributaries of the Yellowstone. The trend of the fold is nearly east and west, and along the axis Bridger Creek, a confluent of Clarks Fork, has cut a deep canyon, walled in with Dakota, Jurassic and Triassic formations. On approaching the valley of Clarks Fork a number of irregularly disposed folds or crumples are locally developed in the Mesozoic beds, but beyond, the strata resume a gentle north and south dip which continues with undulations to the Yellowstone on the one hand and to the Stinking Water on the other. Toward the southwest a gentle fold in Laramie and Wasatch strata forms the remainder of the divide to Heart Mountain. In the vicinity of this peak and also west of Clarks Fork these flexures blend with the north and south system of folds developed with the Absaroka Range.

In the foregoing description so much of the Big Horn basin has been considered as is structurally peculiar. Within the zone thus defined about the periphery of the basin—that is, towards the center of the depression—the strata have undergone hardly more than an occasional flexure, and the formations occupy a practically horizontal position.

The Wind River Mountains.—These were observed only from the north. On this side, the range appears as a massive body of Archean, with a belt of Paleozoic measures at the base. The general trend is N. 60° W., and the sedimentaries dip from 30° to 80° north-northeast, locally reaching the vertical. The fold is apparently a simple anticline. The Carboniferous quartzites, which form the slope of the range for 1,000 to 1,500 feet above the base, are somewhat thicker than in the other mountain ranges examined, and, moreover, are accompanied by a series of shales not elsewhere encountered. The blue limestone is

also heavily developed. The Silurian appears about as in the Big Horn Mountains, but the shales of the Cambrian are less conspicuous. Terminal moraines occur at the entrances to the many canyons. Prominent among these is one across the mouth of the canyon of the South Fork of Wind River. This is from 400 to 500 feet high and between 1 and 2 miles broad at the summit, covering a considerable area of the older Mesozoic formations. Existing glaciers also are reported on the higher peaks of the range.

Within a zone of 10 to 15 miles along the base of the Wind River Mountains, from the vicinity of Fort Washakie east, there are several prominent anticlines, some of which are of special interest from the presence of petroleum springs along their axes. The two most important have been referred to by others as the Shoshone and Washakie anticlines.

The Shoshone anticline is the most western. It has a N. 50° W. trend, and a length of 12 to 15 miles, the center being opposite Fort Washakie and 2 or 3 miles north of it. The western end lies in the vicinity of Sage Creek, 7 or 8 miles northwest of the fort, while the eastern is at an equal distance east-southeast of this point. The strata north of the axis dip 15° to 20°; south of it, between 45° and 80°. The center of the anticline is occupied by the Red Beds, which, besides forming the bottom of a valley 2 or 3 miles wide, also constitute its rim. The valley is cut transversely by the Little Wind River, and appears therefore as an amphitheater on either side of the stream, extending 4 or 5 miles to the west of it and 1 or 2 east. The Jurassic and Cretaceous measures lie about the Trias in successive outcrops, the Montana shale constituting the valley bottom between the anticline and the base of the Wind River Range. The Laramie measures have been deflected to the north or northeast by this fold and are seen outcropping in the low bluffs to the north of Lower Sage Creek at its confluence with Little Wind River. The western half of the anticline has been considerably denuded by the drainage of Sage Creek, and from this cause and from the presence of one or two minor folds, the lines of outcrop are somewhat irregular. The eastern end of the fold is a prominent ridge 100 to 200 feet high, composed of the Niobrara, and encircled about the base by the Montana shales. The axis of the fold is at this end slightly deflected to the east, towards the Washakie anticline 6 or 7 miles off. The center of the Shoshone anticline displays an important petroleum spring, a mile or two west of the channel of Wind River, and a very large hot spring in close proximity to the stream.

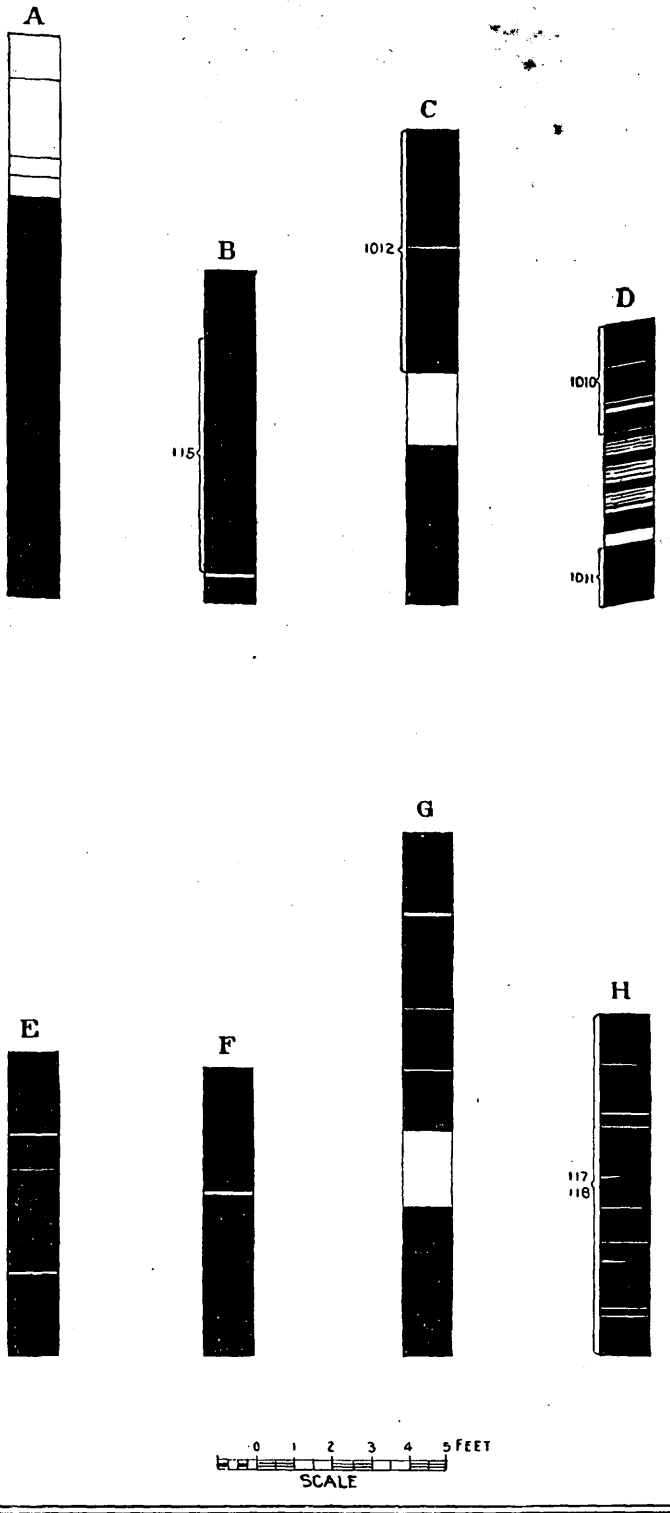
The Washakie anticline lies about 7 miles southeast of the Shoshone, the northern end of the former overlapping a little the southern end of the latter. Where confined to the Montana shales the fold does not appear above the general level of the prairie, but the Niobrara and underlying beds form a prominent ridge which extends from the point above mentioned southward to the head of Twin and Beaver

Creeks. Below Lander the anticline is cut transversely by the Popoagie, and again several miles to the south by its branch, the Little Popoagie, the latter stream now occupying its axis to the forks of Twin Creek. From the Popoagie south, far beyond Dallas, the central rocks exposed are the Red Beds, which along Little Popoagie are eroded to a depth of several hundred feet, forming lofty cliffs east of the stream and others less lofty west of it. North of the Popoagie the ridge chiefly consists of the Cretaceous series, the Niobrara occupying over half its length along this portion. Between the ridge and the sharp bluffs of the Laramie to the east is a broad valley of Montana shales; west of the ridge the Laramie does not occur, and the Montana and underlying beds are bent into a well-pronounced syncline which occupies the space to their westernmost outcrops along the base of the range. Almost on the axis of the Washakie anticline, near the northern extremity of the Niobrara ridge, is the Washakie oil spring, and a little north of Dallas, in the canyon of the Little Popoagie, are several oil wells of large capacity.

Northeast of the Washakie and Shoshone anticlines the flexures belonging to the Wind River system are but slight undulations, hardly visible except under favorable circumstances of outcrop. Along the immediate base of the range, however, the strata are here and there thrown into folds which, while not of the extent and size of the Shoshone and Washakie folds, are nevertheless well defined and contribute to both the structural and topographic features of the country. These minor anticlines usually occur in the Niobrara or in the underlying formations to a horizon near the top of the Trias.

The Wind River basin.—This was crossed twice in the present reconnoissance: once on the Embar and Fort Washakie stage road; and once on the road leading from Lander down Wind River to its canyon in in the Owl-Rattlesnake Range. On the former line the folds encountered belonged either to the Owl Mountain or Wind River systems, and have been described. On the latter road the valley between ranges is much broader and the area beyond the region of the mountain folds proper much greater. In crossing on this line the beds of the Bridger formation occupy the valley for nearly its entire width, covering all the older Cretaceous formations. A single flexure of importance was observed in the Tertiary beds. The axis of this lies about 12 miles north of St. Stephens Mission, and extends east and west bebetween 5 and 10 miles, forming a noticeable elevation in the otherwise flat valley. The rise of the arch is but slight, the beds dipping hardly more than 5° or 6° north and south. The occurrence of the fold is, however, important, and establishes the action of forces in later Tertiary times, already noticed in connection with the Wasatch Tertiary both in this basin and in the Big Horn.

For a description of the region east of Wind River the reader is



SECTIONS OF COAL SEAMS.

EXPLANATION OF PLATE II.

A. Sheridan district; prospect 2 miles east of Beckton; portion above the coal a mixture of lignitic shale and sandstone.
B. Sheridan district; mine 5 miles north of Sheridan.
C. Buffalo district; mine 1 mile east of Buffalo.
D. Prospect at mouth of No Wood Creek.
E. Red Lodge district, Montana; No. 1 or Yankee Jim seam.
F. Red Lodge district, Montana; No. 2 seam.
G. Red Lodge district, Montana; No. 3 seam.
H. Red Lodge district, Montana; No. 4 seam.

referred to the reports of the Territorial geologists[1] and to the maps of the Hayden Survey,[2] from which the data for the accompanying map have been obtained.

ECONOMIC GEOLOGY.

COAL.

STRATIGRAPHY.

The workable coal of the region under discussion is of Laramie age. Reports of its existence in the Dakota formation, in the foothills at the east base of the Big Horn Range, 5 miles southwest of Dayton, are current. The locality was visited by the writer and the "coal" found to be merely a very carbonaceous sandstone. Coal occurs in the Niobrara in the vicinity of the Clarks Fork Canyon, but the seam is very irregular—a mixture of shaly coal and slate, and of but 2 feet or 2 feet 6 inches maximum thickness. The chief interest lies in its presence in the Niobrara, heretofore not known to be carbonaceous or, indeed, except in Canada, to carry even an occasional leaf bed, both of which conditions exist here.

The coal beds of the Laramie are distributed throughout the formation from base to summit. No distinguishing features exist for determining the horizon of a particular bed except by direct reference to the base of the series or to one of the broad divisions of the formation—the lower, sandstone division, or the upper, clay division—and this only in an area where both are present and their relations may be clearly observed. Reference by direct measurement has been impracticable in the present reconnoissance, and it has therefore been impossible to establish the absolute position of all the seams encountered. However, some are known to occur near the base of the formation, and it is believed that others belong to a horizon about midway but in the shaly division of the series.

Beginning at the bottom, the first workable coal bed anywhere encountered occurs about 100 feet above the base of the Laramie; the second, in some localities, 70 feet higher. With these exceptions the seams in the lower or sandy division are thin and unimportant.

In the upper or shaly division the coal seams are numerous and form one of its characteristic features. With two or three local exceptions, however, all are too thin for economical working, and the coal is usually of a poorer quality than that at the base of the formation. The exceptions are the heavy beds north and west of Sheridan, east of the Big Horn Range, and a bed about 2 feet thick on Grey Bull, a little above the mouth of Meeteetse Creek, in the Big Horn basin.

[1] Annual Report of the Territorial Geologist to the Governor of Wyoming. Years 1886–1888 and 1890.

[2] Maps, U. S. Geol. and Geog. Surv. of the Territories, F. V. Hayden. Parts of Central Wyoming. And U. S. Geol. and Geog. Surv. of Terr. Geological Map of Portions of Wyoming, Idaho, and Utah.

In the lower part of the formation the succession of the component strata and of the coal beds is very changeable; and a single coal seam of 10 feet in one locality may in another be split into two 8 to 10 feet apart, or, in a third, into a half dozen seams embracing a thickness of measures of 30 to 50 feet. Such separation is effected by the increase of sandstone or slate partings already present, or the acquirement of others wholly new. Again, the coal seams themselves may thicken to a workable size or diminish to the merest trace.

AREAS.

The distribution of coal within the confines of the Laramie in the region examined is quite general; but the localities of workable coal, so far as exposed in outcrop, are limited to four: that east of the Big Horn Range; the Red Lodge district, in Montana; the Sunshine area on the western edge of the Big Horn basin; and the Lander district, in the Wind River valley. That these four districts, however, embrace all the areas of coal of a workable thickness in this region is doubtful, for, from the general manner of occurrence of this mineral in the West, it is quite possible that beds of sufficient size may exist at other points, beneath the formations of later age.

Powder River field.—This name has been assigned by the Territorial geologist, Dr. L. D. Ricketts,[1] to the area of Laramie east of the Big Horn Mountains. It extends from a parallel at least 20 miles south of Buffalo north far into Montana and in an easterly direction it covers nearly half the distance to the Black Hills. Coal probably underlies much of it. Examination in the present reconnoissance has been confined to the western periphery and the region about Sheridan in the valley of Goose Creek.

The western rim of the Laramie for the greater part of its length is clearly defined by the outcrops of the more prominent sandstones at the base, these often constituting a line of low ridges, 6 to 10 miles from the foot of the Big Horn Range. Along other portions of the rim, however, the sandstones are broken down, the ridges disappear, and the limiting line of the formation, is concealed beneath superficial deposits. The general trend of this line and consequently of the coal horizon at the base of the formation, from the vicinity of Trabing, its southern end, to the Montana line, is N. 35° W. It passes close to the town of Buffalo, either a little to the east or west, continuing thence to the valley of Little Goose Creek. Along this portion of its course the edge of the formation was not followed but its trend is apparently direct, except, perhaps, in the vicinity of Massacre Hill, or the divide between Piny and Prairie Dog Creeks, a region of topographic peculiarities. On Big Goose Creek the basal sandstones of the formation outcrop about 1½ miles above Beckton Post-office, passing thence directly across ridges

[1] Annual Report of the Territorial geologist of Wyoming. January, 1890, p. 38.

and valleys to a point on Tongue River a mile above Dayton. North of Tongue River, for much of the distance to the State line, the sandstones form a series of low ridges, defining the lines of drainage and giving to the streams a direction parallel with the strike of the beds. The dip of the strata along the western edge of the Laramie is usually less than 25°, shallowing rapidly to 5° or even less, as distance from the mountain increases. Over the interior of the Laramie area the strata vary in the direction of their dip, but the amount of dip is everywhere slight, rarely over 5° or 10°.

The stratigraphical distribution of the coal in the Laramie of the Powder River field has never been determined in detail. Seams from 1 inch to 10 feet thick are encountered at various horizons—almost, indeed, from base to summit. The workable seams, however, are apparently of two horizons, near the bottom and midway the series.

The lowest coal recognized is that opened in the vicinity of Buffalo, which is probably within 200 feet of the base of the formation; but nowhere else along the western rim has a workable seam either been observed or reported at this horizon. The next highest seam of economic value is that opened on Big Goose Creek, about 2½ miles east of Beckton and just north of the road to Sheridan. This seam occurs several hundred feet above the base of the formation, in the more shaly series of beds usually forming the middle and upper portions of the Laramie. Five miles north of Sheridan, on the line of the Burlington and Missouri Railroad, a mine has been opened by drift on a seam the horizon of which is not satisfactorily determined but may be either the same as that of the one near Beckton or still higher in the series, a point that can be settled only by a profile and section of the measures from the base up. North of this, still other openings, of local importance, occur, and in the Tongue River valley, several miles below Dayton, coal of uncertain horizon is again reported. Several hundred feet of shale and sandstone overlie the Sheridan seam, constituting the high region east of Goose and Prairie Dog Creeks and extending beyond the Powder River. In this region several outcrops and openings have been reported but no attempt at correlation has been made.

The mines in the vicinity of Buffalo are three, and lie to the east, north and northeast of the town from 1 to 5 miles. They are opened in strata of gentle and somewhat variable dip, but withal 2° to 3° eastward. At a recently developed mine, which is 1 mile east of Buffalo and of all the openings the nearest to the western rim of the formation, the coal is reached at a depth of 103 feet beneath the surface, and presents the general section given in C, Plate II. The coal of the Buffalo district varies but little in appearance, and probably but little in its chemical constituents, in both particulars being an especially typical lignite. The woody structure is maintained in a remarkable degree, while the streak is a dirty brown, the fracture

conchoidal, and its resistance to weathering slight. The analysis given in the general table at the end of the chapter affords an insight into the relative proportions of its components, and its fuel ratio is far below the limit usually adopted as the dividing line between lignite and bituminous coal. Moreover, both water and ash are high. The coal, however, is extensively used for domestic purposes in Buffalo and the United States military post, Fort McKinney, and is said to afford a considerable degree of satisfaction.

The openings near Beckton are hardly more than prospects, from which, however, a small amount of coal has been taken to supply local demand. Sec. A, Plate II, represents the seam at the outcrop, but the coal was not sampled.

In the Sheridan district but a single mine is at present worked. This is on the line of the Burlington and Missouri Railroad, 5 miles north of Sheridan, and is the most extensive opening in the Powder River field, the main entry extending about 500 feet from the outcrop. The section represented in B, Plate II, varies little from that at other points in the mine, the coal maintaining itself comparatively clean and free from partings—with the exception of the clay streak 6 to 8 inches from the bottom, which is persistent, and local developments of slate or bone. The coal is fibrous, jointed and compact, and in texture it occasionally resembles a coal of the bituminous variety. In composition, however, it is a lignite, the fuel ratio being generally below 1, although one or two analyses made by the mine-owners place it at 1.12 to 1.14. The moisture is high, but the ash is remarkably low, a percentage as low as 4 being rarely encountered in this class of coals. Another noticeable feature brought out in the analyses of the Sheridan coals is the marked variability in the relative proportions of fixed carbon and the volatile hydrocarbons; the samples taken being illustrative not only of different localities on the seam but as well of different parts of the seam in the same vertical section. This important feature was unlooked for, and whether it will be found general for the mine and, indeed, for the field, must be decided by future analyses.

The Sheridan coal is largely used for domestic purposes and is said to be satisfactory in this respect. For stationary engines also it answers well in the absence of coals of higher grade, but for locomotive steaming it is reported too light. It also yields easily to atmospheric influences.

The No Wood region.—West of the Big Horn Range, at the mouth of No Wood Creek, a coal seam has been prospected to the depth of 40 or 50 feet, showing the section given in D, Pl. II. The seam is too much split by slate and sandstone partings to be of value, but its presence is indicative of the possibilities of the region, which is, perhaps, the western continuation of the Powder River field, from which it may have been separated by erosion across the crest of the Big Horn anticline.

The coal of the No Wood seam is in appearance and constitution a lignite. The single analysis of it shows a higher fuel ratio than that of the Powder River field, the upper division of the seam reaching but little short of 1. The moisture is also noticeably lower than in the coal east of the Big Horn Range, but this can not be regarded general from a single sample. The ash is much higher, as anticipated from the appearance of the coal, in which the distribution of impurities is marked.

The Red Lodge district of Montana.—Although this is beyond the confines of Wyoming and was but incidentally visited in connection with the present reconnoissance, it has so many features important for the comparison of coals further south, in the Big Horn basin, that a brief reference to it is here made. Sections of the seams thus far opened are given in E, F, G, H, Pl. II, and A, B, C, Pl. III.

The field was first examined and reported upon by Mr. J. E. Wolff, of the Northern Transcontinental Survey, in 1881 or 1882.[1] Since then it has been visited by Mr. W. H. Weed, of the U. S. Geological Survey,[2] from whom also a brief statement has come, in connection with other coal fields in Montana. To these two reports the reader is referred for more extended information than is given below.

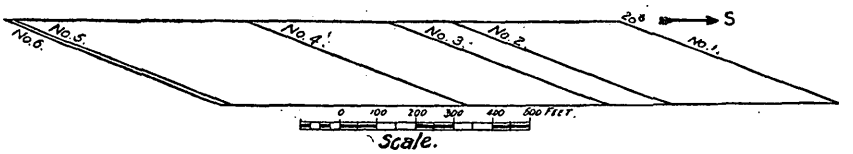


Fig. 1.—Section showing relative positions of coal seams.

The field extends several miles east and west of Rocky Fork, occupying a belt 3 to 5 miles wide along the northern base of the Absaroka Range. The productive coal-measures occur in a zone of 1,000 feet, apparently somewhere in the middle of the formation, but the exact stratigraphical position has never, so far as known, been determined. The coal-measures, along their northern edge, outcrop with varying southerly dip—in the region of Rocky Fork about 20°. To the south this dip gradually shallows to horizontal or slightly undulating, which position is maintained to the fault line at the base of the mountains, a distance of 3 to 4 miles. The coal horizon abuts against the fault-plane at a considerable distance beneath the surface.

The relative positions of the coal seams already opened, in the upper half of the zone, are shown in the accompanying section (Fig. 1).

In addition to these, seven others are reported within 600 or 700 feet below, five of which are said to be of workable thickness.

A point of special interest in the coal seams of this district is the number of partings of slate or other material. These vary in thickness

[1] Vol. xv. Tenth Census of the United States, p. 755 and plates.

[2] Engineering and Mining Journal, Vol. LIII, No. 20, May 14, 1892, p. 521.

from $\frac{1}{16}$ of an inch to 6 or 8 inches, on the one hand too thin for separation in mining and of necessity going into the coal shipments, on the other hand too thick to pass into the coal product and therefore requiring separation in the mine. This is, moreover, a feature of many of the seams in the Rocky Mountains in southern Montana, and yet both vertical and horizontal beds are mined with advantage. In illustration of the effect of inclusion in the shipping product of partings too small for separation in mining, two samples, Nos. 117 and 118, were taken at the same section in the slope of the No. 4 seam, the former including all partings finding their way into the shipments, the latter of clean coal. The analyses show a diminution of one-third in the amount of ash in the coal from which the partings were excluded.

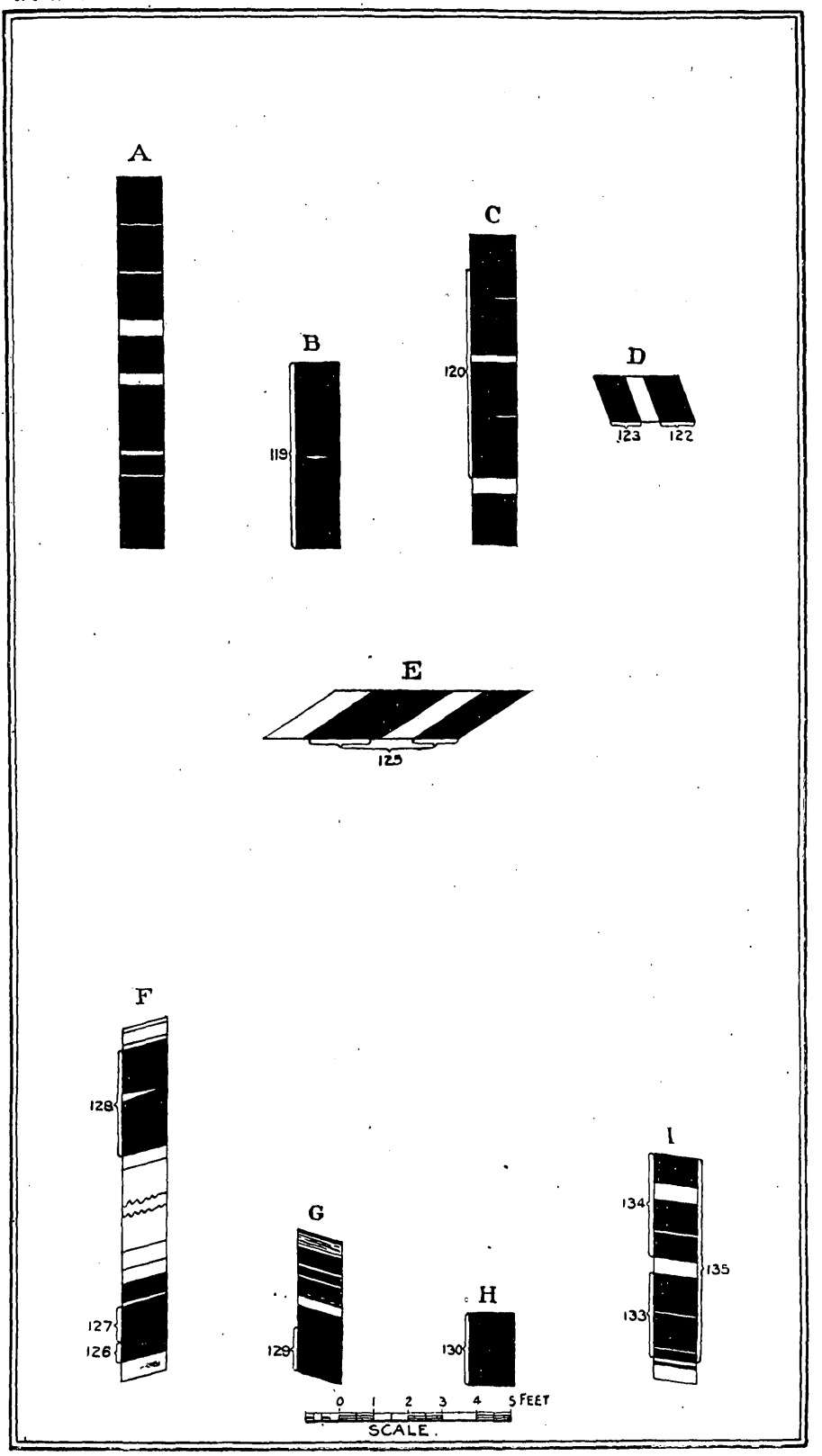
The analyses of the Rocky Fork (including Bear Creek) coals show them to be of a higher grade than any sampled elsewhere during the present reconnoissance. The fixed carbon is higher and the volatile combustible matters, the moisture and the ash, are lower than in the others, while the fuel ratio is very noticeably advanced.

Before passing from the consideration of the coals of the Rocky Fork district, attention is called to the sample No. 120, obtained from a Bear Creek prospect. It illustrates the slight change that some coals of the lignite class occasionally undergo in the mine, even after long exposure, in the present instance three years having elapsed since the face was cut, and in sampling but an inch or two having been removed. This coal is well up to those taken at depths in other portions of the district, even allowing for a possible higher quality of coal.

The front of the Absaroka and Shoshone Ranges.—From the Rocky Fork coal field, which extends to a point 7 or 8 miles north of the Montana-Wyoming line, southward to the Sunshine district, the northern limit of which is between Meeteetse and Grey Bull Creeks, there are numerous exposures of coal, but all, so far as explored, show a seam too thin for economic development on an extended scale and with one or two exceptions even below the limits of a working thickness to supply local demands. The coal beds of this belt occur both in the lower, more sandy division of the Laramie, and in the upper or shaly zone of the formation. In the former but a single seam has been observed, this extending through the entire length of the belt with the preservation of all its characteristic features. In the shaly division the seams are numerous, but generally either very thin or of a low grade of lignite intermingled with dirt streaks. The seam of chief importance in this division has a thickness of 2 feet of clean coal and is exposed on Grey Bull above the mouth of Meeteetse Creek (H, Pl. III). The chief exposures of the lower coal are: on a branch of Line Creek, near the boundary of Wyoming and Montana; along the base of the Laramie in Heart Mountain; on Sage Creek, near the Frost ranch; and at Arland on Meeteetse Creek. Besides the foregoing seams and their exposures, two others of undetermined geological horizon exist

EXPLANATION OF PLATE III.

A. Red Lodge district, Montana; No. 5 seam.
B. Red Lodge district, Montana; No. 6 seam.
C. Red Lodge district, Montana; Bear Creek mine.
D. Big Horn Basin; Nutting outcrop; near Montana-Wyoming line.
E. Big Horn Basin; Frost outcrop; Sage Creek south of Stinking Water.
F. Big Horn Basin; Brundage outcrop; SE. spur of Meeteetse Mountain.
G. Big Horn Basin; Arland mine.
H. Big Horn Basin; Grey Bull River; outcrop, 1 mile above mouth of Meeteetse Creek.
I. Big Horn Basin; Sunshine district; outcrop, north bank of Grey Bull River, 1 mile below mouth of Iron Spring Creek.



SECTIONS OF COAL SEAMS.

high up on the northeast slopes of Meeteetse Mountain, at the head of Carter Creek and the north fork of Sage. (F, Pl. III.)

The coal bed in the lower portion of the Laramie occurs between 100 and 150 feet above the base of the formation. It is included in a narrow zone of lignitic clays, which are quite generally underlain by a heavy bed of white sandstone and overlain by one of yellow. The seam itself is usually made up of two benches of coal, separated by a 2 to 4 inch band of brown lignitic slate, which weathers a milky white. These features are so pronounced and persistent that, with the constant position of the bed, they serve as a general means of its identification. Sections D, E, G, and I, Pl. III, and B, Pl. IV, give the general character of the seam, excepting that in the region affording the last two (the Sunshine district) the coal has increased to workable thickness.

The coal of this horizon usually lies within the region of mountain folding, either on the flanks of the main uplifts or included in the subordinate (parallel) folds along their base. The dip is, therefore, rarely less than 15°, often 45°, and occasionally 70°, and the direction generally eastward, except where, as on Sage Creek, it is included in a subordinate fold, either eastward or westward, according to the side of the flexure upon which it is.

In appearance the coal is hard, black, of bright and sometimes oily luster, and bears a close resemblance to coals of the bituminous variety. It is, however, a lignite, with high moisture contents, ash from 6 to 15 per cent, and a fuel ratio considerably below 1. This applies also to the coals of uncertain horizon in the slopes of Meeteetse Mountain, and, indeed, to the seam in the upper Laramie series, on Grey Bull, near the mouth of Meeteetse Creek. The latter coal, however, has a more general resemblance to lignite than the former.

Sunshine district.—This embraces an area approximately 9 by 15 miles, the greater dimension being east and west. The northern limit is between Grey Bull and Meeteetse Creeks; the southern, probably between Gooseberry and Grass Creeks; the western, a north and south line a few miles west of Sunshine Post-office; and the eastern, arbitrarily taken, along the edge of the region of subordinate folds, a few miles east of Enos Creek, a tributary of Gooseberry from the south. It is highly improbable that this entire area is underlain with coal, but the general distribution of known outcrops and the thickness of the beds render it a region of considerable possibilities.

The coal area of the district is separable into a main body lying almost wholly east of Wood River, and an inlier west of this stream, the two separated by erosion along an anticlinal fold.

The coals occur in both the lower and upper divisions of the Laramie, but the most important seams are found in the former. Two occur in this division: the lower and larger, Sec. I, Pl. III, and Sections A, B, C, D, H, Pl. IV, about 100 feet above the base of the formation; the upper,

E, Pl. IV, smaller and of local prominence only, 70 feet higher in the series. The lower, by its stratigraphical position and component layers—two benches of coal separated by a characteristic slate—is identified with that already described at this horizon further north. In the upper division of the Laramie the single seam of importance is that shown in Sec. G, Pl. IV; it occurs in the lower portion of this division.

The observed northernmost outcrop of the large seam near the base of the formation is in the banks of Grey Bull, 1 mile below the mouth of Iron Spring Creek and about 7 miles north-northeast of Sunshine Post-office. The outcrop presents the appearance in I, Pl. III. The dip of the measures is here about 7° N. 60° E., or down stream. West of this the coal rises in the bluffs of the valley, and after one or two gentle flexures reaches the line of its north and south outcrop a little above the mouth of Wood River. North of Grey Bull this outcrop passes into the prairie and, with one or two irregularities of trend caused by local folds, finally unites with that passing south from Arland. Beneath how much of the area north of the stream the coal maintains a workable thickness is undetermined, the examination not having been carried beyond the immediate river valley. South of Grey Bull the coal horizon passes into the bluffs in the forks of this stream and Wood River, crosses the channel of the latter between 1 and 2 miles above its mouth, and thence enters the high ridge to the east, in which it continues to Gooseberry Creek, a distance of 7 or 8 miles. On this line of outcrop the only exposure of importance encountered was in the banks of Wood River, 4 to 5 miles below Sunshine, where is a seam comprising two benches of coal separated by 2 to 4 inches of slate. This, except for the thinning of the upper bench to 5 or 6 inches, closely resembles the bed of general occurrence along the range to the north, and in its main divisions, also the larger seams of the Sunshine district. There is thus an indefinite area in this vicinity over which the main coal bed has either been reduced below workable thickness or has been split into a number of minor seams, as on Gooseberry Creek, on this same line of outcrop, where the section in F, Pl. IV, is to be seen. South of Gooseberry Creek the basal series of Laramie rocks was not followed.

Within the periphery of the main body of Laramie in the Sunshine district the several anticlines already described in the structural chapter each expose a rim of the lower coal-measures of the formation. These have not all been explored for coal, but in two instances seams of workable thickness have been, one observed by the writer, the other reported to him. The anticlines that have brought to the surface these seams are the one crossing Gooseberry Creek, 2 miles above Iron Spring, and that south of Gooseberry Creek, 2 or 3 miles below the mouth of Enos Creek.

The exposure of the coal horizon in the former or upper anticline is

EXPLANATION OF PLATE IV.

A. Big Horn Basin; Sunshine district; outcrop, Wood River, 1½ miles above its mouth.

B. Big Horn Basin; Sunshine district; outcrop, north side Sunshine Gulch, 2 miles NNW. of Sunshine post-office.

C. Big Horn Basin; Sunshine district; outcrop, tributary Sunshine Gulch, 2¾ miles NW. Sunshine post-office.

D. Big Horn Basin; Sunshine district; outcrop, tributary Sunshine Gulch, 3 miles NW. Sunshine post-office.

E. Big Horn Basin; Sunshine district; outcrop, tributary Sunshine Gulch, 3 miles NW. Sunshine post-office. An upper seam locally developed.

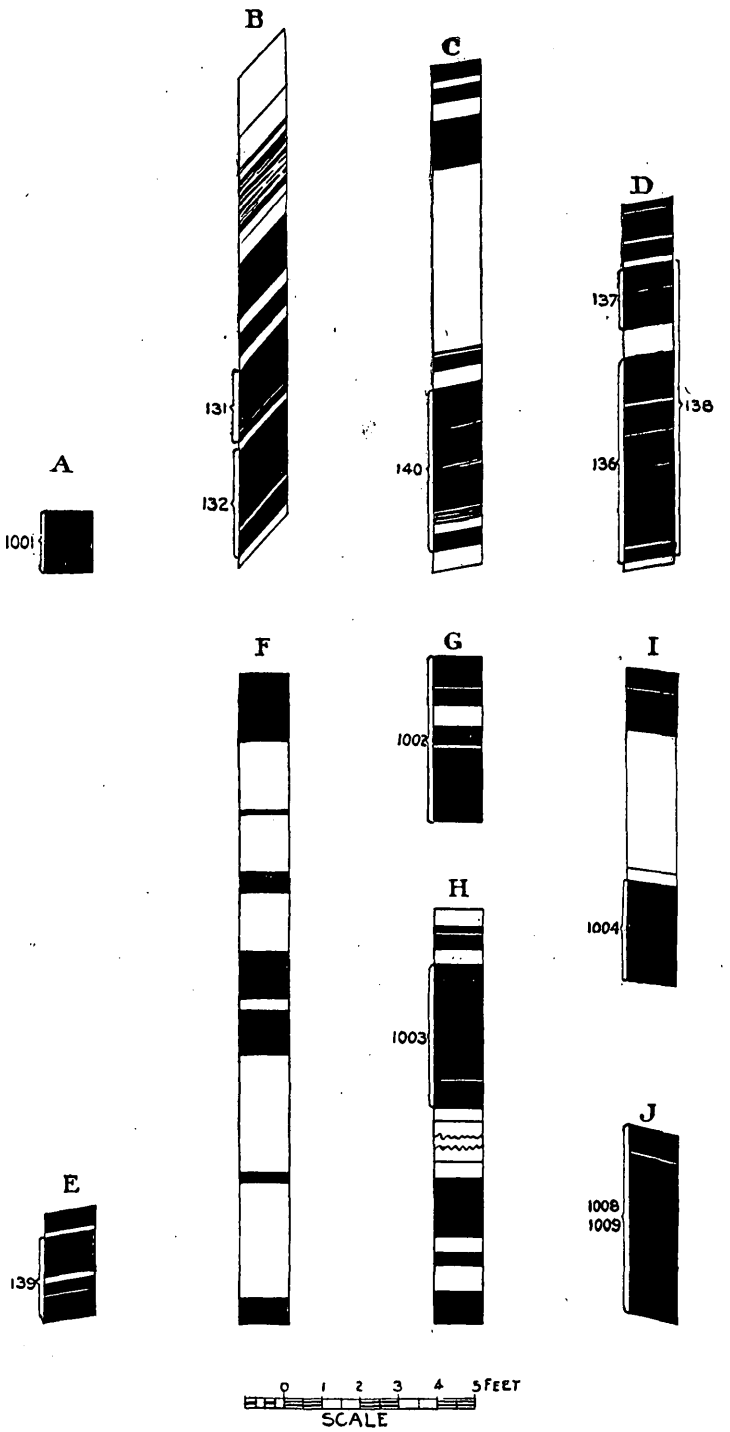
F. Big Horn Basin; Sunshine district; outcrop, south bank Gooseberry Creek, 4 miles SE. Sunshine post-office.

G. Big Horn Basin; Sunshine district; outcrop, Gooseberry Creek, 2 miles above mouth of Enos Creek.

H. Big Horn Basin; Sunshine district; outcrop, tributary of Gooseberry Creek from south, 2 or 3 miles east of Enos Creek.

I. Big Horn Basin; Embar district; Smith prospect; outcrop, 4 miles NE. of Embar post-office.

J. Wind River Basin; Lander district; mine, 8 miles NE. of Lander.



SECTIONS OF COAL SEAMS.

about 10 miles long, and the workable coal is reported on the northeastern side of the fold in a sharply eroded gulch entering Gooseberry Creek one-quarter to one-half mile above Iron Spring. Here an opening is said to show 5 feet of coal in 3 or 4 benches separated by partings of slate from 1 to 3 inches thick. The bed is probably identical with the main seam of the district, and the appearance of the coal is said to be the same in both. The area of workable coal in this portion of the district is undetermined.

The anticline below Enos Creek presents an exposure of the coal horizon of 4 or 5 miles. The coal outcrops in workable thickness near the northern end of the topographic basin eroded along the axis of the fold, having a dip of 5° northeast. Two beds are present, separated by 10 to 20 feet of sandstone and shale, the entire section being given in Fig. H, Pl. IV. The upper bed affords 3 feet 7 inches of workable coal; the lower 2 feet 8 inches, separated into three bands. The latter somewhat resembles the seam so generally present near the base of the formation north of the Sunshine district, there being two main benches separated by a bluish white slate parting. The bed widens to 12 feet a few hundred feet southeast, the amount of coal remaining the same, but its benches being further separated or split into minor layers by fresh partings. The sandstone layer separating the two main beds is also variable from point to point. The variability of this series of coal, shale and sandstone renders an estimate of the possible productive areas of the district very difficult. Only careful prospecting along the outcrop of the beds and drilling in the interior portions will furnish reliable answers to questions of this nature.

The inlier of Laramie west of Wood River, which is in structure a syncline, is approximately 8 or 10 miles long by 2 or 3 wide. It is completely encircled by the horizon of the coal, the chief exposures of the seams being near the southern end, from 2 to 4 miles northwest of Sunshine Post-office, in the bluffs of Sunshine Gulch and its tributaries. The beds here dip 10° to 35° northwest to north, according to their position on the periphery of the syncline, the axis of which has a general north and south trend. The sandstones of the formation are heavily developed, and the individual beds for 150 or 200 feet above the base are readily recognizable by their thickness, persistence and color. Those immediately underlying and overlying the main coal seam are particularly prominent, the former being a heavy bed of white sandstone, the latter of yellow, characteristics that are maintained, not only over the Sunshine district, but along much of the area bordering the mountains to the north and south.

Two beds of coal occur in this region. The lower is the important one, the upper, 70 feet above, being but 2 feet 8 inches thick and apparently of local development only. Exposures of the lower seam are given in Sections B, C, and D, Pl. IV, and its identity with that generally

developed at this horizon to the north of this district is clearly established by comparison of the component layers; two broad benches of coal appear in Sections B and D, Pl. IV, more or less split by narrow partings, indeed, but separated from each other by the usual 2 to 4 inch band of brown carbonaceous slate, weathering bluish white. Section C, taken at a point midway between the localities of B and D, also shows this parting, but there has apparently been a local interpolation of sandstone and shale in the upper part of the seam. The extent of outcrop covered by the three sections is about 1 mile, but other prospects, showing the seam still of workable thickness, are reported further west, which would increase the length for this region to between 1 and 2 miles. Coal also outcrops at other points about the syncline, but the seams were of necessity left unopened.

Comparison of the lower seam of the Sunshine district with those of the Rocky Fork region, shows a similarity between them in the proportion of coal to partings, and in the distribution of the latter throughout the seam, that enables the statement to be made that, notwithstanding the amount of dirt contained in the Sunshine beds, they can be economically worked on a large scale.

The coal of the lower seam in the Sunshine district is of two varieties: that of the upper bench—above the middle parting of brown or bluish white slate—is fibrous, dry and brittle, with a brown streak, and tendency to rapid weathering; the lower bench, on the contrary, has a black streak, is oily in appearance, hard, only slightly fibrous, breaks in blocks, and resists weathering far more than the upper coal. The physical properties of the lower bench indicate it to be of the better quality, and this implication is borne out in the chemical analysis of the few samples taken.

The chemistry of the coal shows it to be lignite. Its true value as a fuel can not here be correctly estimated, owing to the necessarily few samples and their proximity to the outcrop of the seam, but the analyses combined with a field acquaintance with the coal warrant the statement that while it may fall a little below the coals of the Rocky Fork mines, it will yet compare favorably with them upon being opened. The fuel ratios of the samples are, with one or two exceptions, very low, but it is believed that the higher ones will more nearly represent the character of the coal. The ash is comparatively low; the moisture comparatively high.

The coal is, in its combined physical and chemical properties and in the size and character of the seam, superior to other coals of the Big Horn basin, and by reason of this the Sunshine district is to be recommended for private exploration to individuals or corporations directing their efforts toward opening this intermontane region to commerce and settlement.

The upper or shaly division of the Laramie in the Sunshine district

has but one coal seam of prominence, although many from an inch to a foot exist wherever the series has been preserved from erosion. The seam referred to outcrops on Gooseberry Creek opposite the mouth of Middle Fork, about 2 miles above Enos Creek. It is represented in Sec. G, Pl. IV. There are 3 feet 6 inches of coal, separated two-thirds the way from bottom to top by a 7-inch band of black slate, which is locally very carbonaceous. The strike at the outcrop is N. 50° to 70° W., but the trend of the strata in the vicinity is variable by reason of the folding to which they have been subjected. The dip of of the coal is 10° southwest. The extent of the seam is undetermined. The appearance of the coal is much more that of a typical lignite than the coals of the lower division of the formation, and the chemical analysis shows it also to be slightly higher in water, with a low ash, and a very low ratio between its fixed carbon and volatile combustible matter.

The coal of the Sunshine district is said to outcrop as far south as Grass Creek, and, again, on the Middle Fork of Gooseberry, probably along the western rim of the Laramie. So far as observed by those reporting it, the seams are not of workable thickness, but in an unprospected region of such rapid variation this signifies but little.

Embar district.—The exposure of coal next south of the Sunshine district is the Smith prospect, 4 miles northeast of Embar.

The coal lies at a distance of between 3 and 4 miles from the base of the Owl Mountains and the seam is somewhat beyond the area of the larger folds which there exist. The locality of the outcrop is in a point of Laramie projecting southeastward between Cottonwood Creek and the North Fork of Owl Creek. The edge of the formation lies in the bluffs north of the latter stream, and opposite the forks turns north and passes into the high ridge beyond Cottonwood.

The coal seam is of the lower Laramie series. The section at the outcrop is given in I, Pl. IV, and shows the coal to be below workable thickness. The dip is here 5° east, but the strata of the region are slightly folded and the dip consequently somewhat variable. The coal is a bright, hard, and oily-looking lignite, higher in its fuel ratio than some other coals of the Big Horn basin. The ash is low, but the water content is one of the highest met with.

The information concerning the occurrence of coal in the Big Horn basin does not show it to be a region of general promise. The nature of a reconnoissance precludes detailed examination, but the Laramie has been crossed on many lines, and it is believed that little if any coal of importance has escaped attention. Even if some coal fields have not been found, the future lines of examination by private individuals are here suggested. Of the different areas the Sunshine district is the most favorable for coal enterprises, but it requires the most careful and detailed examination before investment and development.

The important coal beds of the Wind River valley are chiefly con-

fined to the lower or sandstone division of the Laramie, the seams probably corresponding to those of the same stratigraphic horizon in the Big Horn basin.

Muddy Creek field.—This embraces the area of Laramie immediately south of the Owl Mountains. Several small seams were observed near the base of the formation in the two promontories southeast of the Mail Camp at a distance of 2 to 4 miles from the Owl Creek Range, and 6 or 7 miles farther east, in the southern face of the outer ridge, between 3 and 4 feet of coal are reported dipping southeast 15° to 25°. The coal is a lignite, of use for domestic purposes but unfitted for the heavier demands of commerce. This coal is on the reservation of the Shohone and Arapaho Indians, and at present not open to prospectings or development by private individuals.

Lander field.—This field is at present the most important in the Wind River valley. It lies 8 miles northeast of Lander, the coal being opened just south of the confluence of the Big and Little Popoagie Creeks. The basal sandstones of the Laramie here outcrop in a prominent line of bluffs, dip northeast about 13°, and pass beneath the prairie beyond. The area of workable coal is unknown, but is probably several square miles, with portions where the seams would be unprofitable to open. Northwest of the Big Popoagie the coal has not been opened and little is known of the character of the seam in this direction. The measures pass across the prairie to the valley of Little Wind River, where they are found in the bluffs north of the stream, dipping slightly northeast.

A section of the Lander seam is shown in Sec. J., Pl. IV. The coal is fibrous, bright and hard, and has a splintery fracture, but weathers rapidly. In appearance it resembles a lignite of the higher class, and the chemical analyses place it among the better coals encountered in the reconnoissance.

Upper Wind River region.—On the Upper Wind River and its tributary, Warm Spring Creek, and also on several other streams in this vicinity, coal is reported in seams of a thickness somewhat below the requirement for economic working. The locality was necessarily left unvisited, but three samples were sent by owners of properties or their representatives, the analyses of which have been incorporated in the general table at the close of the chapter. The samples sent did not coke, and they still appear to belong to the class of lignites, but their high place in the scale of the coals of the Big Horn and Wind River basins is clearly perceptible upon comparison of analyses, and their quality, and their position within the more massive part of the mountains, merit for them special attention in the future.

District.	Mine or prospect.	Locality in mine.	Remarks.	Thickness of seam.	Number of sample.	Contents.					Fuel ratio $\frac{C}{V H \cdot C}$
						Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	
				Ft. inch.							
Sheridan	5 miles N. of town	Breast of main entry	Fresh	5 10	112	14·78	46·56	35·39	3·27	0·24	0·76
	do	do	do	5 10	113	15·23	46·25	35·74	2·78	0·37	0·77
	do	do	do	5 10	114	14·07	56·20	25·76	3·97	0·74	0·46
	do	Breast of return (air) entry	100 feet southeast of 112-114. Fresh.	5 10	115	14·00	53·98	29·50	2·52	0·46	0·55
	do	Room 125 feet from outcrop	3 months idle	5 10	116	13·56	57·59	26·78	2·07	0·28	0·46
Buffalo	1 mile E. of town	Room near foot of slope	Fresh. Cover, 103 feet.	6 0	1,012	15·23	48·72	25·25	10·80	0·82	0·52
No Wood	No Wood	Side of entry, 40 feet from outcrop.	6 to 12 months idle; top.	2 4	1,010	11·62	39·23	39·09	10·06	2·98	1·00
	do	do	6 to 12 months idle; bottom.	1 6	1,011	9·75	43·52	38·17	8·56	1·51	0·88
Lander	8 miles NE. of town	Room near slope, 250 feet down.	Fresh	4 4	1,008	15·35	45·91	35·00	3·74	0·50	0·76
	do	Room near slope, 200 feet down.	do	4 8	1,009	14·32	48·74	33·57	3·37	0·44	0·69
	The slope, No. 4 seam	From side of slope, 830 feet down.	Comparatively fresh; included small partings.	8 2	117	8·27	42·62	38·50	10·61	1·91	0·90
Red Lodge	do	do	Comparatively fresh; clean coal.	8 2	118	9·08	40·35	43·47	7·10	1·73	1·08
Clarks Fork	No. 6, No. 6 seam	Considerable distance in	Comparatively fresh	5 0	119	8·68	42·02	40·39	8·91	2·24	0·96
	Bear Creek	Entry, 60 feet in	Exposed 3 years	5 6	120	8·69	43·40	43·86	4·05	1·52	1·01
	Nutting	Surface. Sample from A bed (top).		1 0	122	16·26	61·07	17·32	5·35	0·73	0·28
	do	Surface. Sample from B bed (bottom).		0 10	123	16·08	47·30	20·92	15·70	0·67	0·44
Sage Creek	Frost	Surface		2 8	125	11·81	43·44	37·77	6·98	0·61	0·87
	Brundage	Surface. Lower seam	Bottom	0 7	126	14·73	59·06	14·89	11·32	1·58	0·25
	do	do	Top	1 0	127	16·90	51·80	19·43	11·87	0·88	0·37
	do	Surface. Upper seam		2 6	128	11·84	40·93	40·39	6·84	3·59	0·98
Arland	Arland	Entry, 30 feet in	Exposed 6 to 10 months.	1 2	129	13·75	51·68	30·17	4·40	0·63	0·58
Meeteetse	Meeteetse	Surface, at edge of stream		2 0	130	14·01	45·01	35·31	5·67	0·22	0·78
Sunshine	Grey Bull	Surface. Bluff at stream level	Bottom	2 5½	133	12·15	46·99	35·92	4·94	0·68	0·76
	do	do	Top	2 4½	134	10·26	54·45	27·32	7·97	0·75	0·50
	do	do	Whole	4 10	135	11·03	52·10	30·32	6·55	0·84	0·58
	Wood River	do		1 6	1,001	11·79	44·75	40·13	3·33	0·60	0·90
	Sunshine Gulch, No. 1	Surface pit	Top	1 3	131	13·96	44·19	36·65	5·20	0·51	0·83
	do	do	Bottom	1 4	132	13·79	66·40	18·17	1·64	0·55	0·27
	Tributary of Sunshine Gulch, No. 2.	do	Bottom of series occurring in other pits.	3 5	140	12·37	52·29	29·51	5·83	0·58	0·56

CHEMICAL ANALYSES—Continued.

District.	Mine or prospect.	Locality in mine.	Remarks.	Thickness of seam.	Number of sample.	Contents.					Fuel ratio $\frac{C}{V\ H\text{-}C}$
						Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	
				Ft. inch.							
Sunshine	Tributary of Sunshine Gulch, No. 3.	do	Bottom	4 11¾	136	11·51	40·42	40·85	7·22	0·62	1·01
	do	do	Top	1 6	137	12·56	60·13	22·23	4·98	0·56	0·37
	do	do	Whole	6 5¾	138	12·40	50·78	30·29	6.53	0·59	0·60
	Tributary of Sunshine Gulch, No. 4.	do	Seam overlying that of the foregoing three prospects.	1 11½	139	10·95	52·41	19·12	17·52	0·47	0·36
	Tributary of Gooseberry Creek.	Surface. Ridge outcrop		3 7½	1,003	14·87	44·80	35·22	5·11	0·40	0·79
	Gooseberry Creek.	Surface. Bluff, edge of stream		3 6	1,002	13·71	61·51	20·58	4·20	0·34	0·33
Embar	Smith	Surface		2 6	1,004	15·00	46·69	34·27	4·04	·39	0·73
Upper Wind River		Prospect			1,005	9·36	44·89	41·87	3·88	2·88	0·93
Do		do			1,006	9·95	41·39	37·95	10·71	3·07	0·92
Do		do			1,007	7·73	43·92	35·45	12·90	4·77	0·81

PETROLEUM.

The oil resources of Wyoming have already been described in a preliminary manner by the territorial geologists, Drs. Samuel Aughey and Louis D. Ricketts,[1] and to their reports the reader is referred for more extended information than is here given.

The petroleum observations during the present reconnoissance were limited to such localities as lay directly in the line of exploration. These were the vicinity of Fort Washakie, the region about Dallas, and the neighborhood of Bonanza, on No Wood Creek in the Big Horn basin.

The petroleum in each of these localities occurs along an anticlinal axis, coming to the surface in two instances in strata of Niobrara age, in the other in the Triassic Red Beds. The structural details of the anticlines have been given.

The petroleum spring of the Shoshone anticline, 2 or 3 miles northeast of Fort Washakie, occurs in a broad flat just off and west of the main valley of the Little Wind River, closed in by a low escarpment of Triassic Red Beds. Its position is near the axial line of the anticline, perhaps a little to the southwest of it. The escape of the oil at this point, as well as of the great hot spring 1 mile to the southeast, is probably due to the fracturing of rocks along the axis of the fold, where the bending has been sharper than elsewhere. The fold is asymmetric, the strata on the southwest dipping from 45° to 80°, those on the northeast 15° to 20°. The dip, however, flattens considerably on either side as distance from the center is gained.

The petroleum comes to the surface through a wash that occupies the flat, but the Red Beds are just beneath, their horizon being roughly estimated at about 500 or 600 feet below the summit of the formation. The oil, together with a small amount of gas and water, rises in a number of little springs within an area of 100 or 200 square yards. A hard crust of asphalt has been formed about the springs by the evaporation of the more volatile hydrocarbons. The oil is brownish black, and evidently heavy, though its gravity was not measured. The asphalt from this deposit has been very satisfactorily employed at the military post near by in the construction of walks and for other purposes in and about the buildings. The oil is occasionally used in the crude state as a lubricant.

A second oil spring, to which the name Washakie has long been applied by Indians and others, occurs 8 or 9 miles southeast of the first, near the northern end of the long ridge of the Washakie anticline. The oil rises to the surface nearly in the axis of the fold, in somewhat sharply crumpled Niobrara strata. The Niobrara is a series of argillaceous, arenaceous and calcareous shales, and it is apparently in

[1] Ann. Report, Territorial Geologist, Jan., 1886, Laramie, Wyo.; Ann. Report, Territorial Geologist, Jan., 1888, Cheyenne, Wyo.

the somewhat more sandy varieties that the oil here seeps to the surface. The amount of seepage is small, collecting slowly in two or three little holes dug for the purpose. The petroleum saturates a belt of strata from 10 to 20 feet wide, and nearly 100 feet in length. The spring has long been famous among the Indians for its healing properties.

The Dallas oil field is 12 to 15 miles southeast of Lander, near a post-office of the same name. This region was designated by Prof. Aughey as the Shoshone oil field. The central feature is the anticlinal structure, at the western end of which is the Washakie Spring. It is parallel with the Wind River Range, from which it is separated by a long, narrow syncline. The anticline is several miles wide, the center being occupied by the Red Beds of the Trias, fully 2,000 feet thick, one-third of which are exposed along the canyon of Little Popoagie Creek, which here occupies the axis of the fold. The strata dip outward 10° to 20°. The oil is said to have been discovered near the mouth of Twin Creek as seepage from the rocks along the edge of the valley and as saturating a considerable area of the soil and wash occupying the bottom. The locality is fully described by both Drs. Aughey and Ricketts, and it is desirable in this reference only to emphasize the mode of occurrence of the petroleum. At present three oil wells have been sunk in the valley bottom, at points forming nearly an equilateral triangle, the maximum distance apart of any two being about 600 feet. The wells are sunk at the base of the cliffs, a little on either side of the anticlinal axis, and are 400, 600 and 1,000 feet deep, respectively. All are productive in a large degree, and have a steady surface flow when turned on. They are, however, kept plugged, and only so much oil is lost as escapes by accident or comes up outside the casing. The product forms an excellent lubricant, and supplies the several mining camps, and town and farm requirements, throughout a large adjoining area. The petroleum is said to contain about 45 per cent of illuminating oil. A strong accumulation of gas is acquired by keeping the well closed. The details of various analyses and tests to which the product has been submitted are given in Prof. Aughey's report for 1886.

The Bonanza district, on No Wood Creek, in the Big Horn basin, is again illustrative of the occurrence of oil springs in close proximity to the axis of a strongly developed anticline. The petroleum here reaches the surface in two or three small springs in the more or less argillaceous strata of Niobrara age near the northwest end of the prominent ridge and fold which extends for several miles along the western base of the Big Horn Mountains, and to which the name Bonanza has been applied. The springs occur in a gulch just within the ridge and are but slightly off the central line of the fold. The oil is accompanied by a small amount of water and gas, the globules breaking and spreading on the surface of the water in a thin irides-

cent film which may be collected by skimming. For some distance on all sides the strata are heavily saturated with oil. The product is the lightest observed during the reconnoissance, and probably contains much the largest amount of illuminating oil. The color is green by reflected light and a rich wine by transmitted light. The spring is not a large one, affording in its present condition about a barrel a day.

Other springs are reported on the general line of this anticline at points 1, 17, 25 and 50 miles south, that 25 miles distant being the largest.

Reports of other petroleum occurrences in the Big Horn basin could not be corroborated.

The geologic horizons at which the oil of the foregoing springs finds the surface are the Triassic Red Beds and the Niobrara shales. In other portions of Wyoming, particularly east of the Wind River, oil appears at the surface in the Trias, the Dakota, and what is regarded by Dr. Ricketts as the Fox Hills formation. Minor amounts are also found seeping from other formations, as the Benton and Laramie, and possibly even some of the Tertiary beds. The actual source of these oils can not be determined with the small amount of data at present available. The reservoirs may be the more sandy strata of either of the formations mentioned, or there may be one primary reservoir—the Triassic sandstones and conglomerates—from which the oil has escaped to the others, which would then be regarded as secondary reservoirs. Transmission would have been greatly interfered with by intervening shales, but it is not impossible that a most potent aid to it was derived from fissuring. Between the Trias and Dakota, perhaps the two chief reservoirs, the deposits of shales are not heavy, and passage from the lower to the upper may easily have been established. With the Fox Hills such communication across the broad band of Colorado and Montana shales would have been opened with much greater difficulty, and perhaps between the Dakota and Fox Hills there may have been an intervening source of oil. Very considerable differences exist in the gravity and other characteristics of the oils from the various localities, but from them little satisfactory evidence as to the source of the oils has thus far been adduced.

Regarding structural influences upon the appearance of oil at the surface, it is a significant fact that in nearly every case, whether observed by the writer or by the local geologists, the oil escapes at the surface along the axis of an anticline or in a region where the rocks have been folded, and crushed or fractured in some degree. Fracturing is most pronounced along the axis of a fold, and it is here, therefore, that the springs, the natural oil wells, are most often found.

The natural occurrences of oil and the success thus far attained in the drilled wells, warrant firm and favorable belief in the future of the Wyoming petroleum fields.

BUILDING MATERIALS.

The building materials of the region explored will be found numerous, varied and accessible when the demand is created for them. Granites and schists occur in the mountains, and sandstones, limestones and clays for the manufacture of brick, on their flanks and over the adjoining prairies. The variety of grain, color, texture and composition is great, and, with the effects of combination, the most exacting demands of architecture may be successfully met. With the exception of the eruptive series of rhyolitic tuffs and a few marbles, the same building materials are found as exist in Colorado, which is the leading, as it was the pioneer State in the production of architectural and ornamental stones of the West.

Among the stones which will be found of special importance are the granites of the Archean and the quartzites of the Silurian and Carboniferous, for foundations and the lower courses of higher buildings. For the middle and upper portions and for private dwellings there are the red Triassic sandstones, and the grey, yellow, and white sandstones of the Laramie. The several varieties are coincident in their distribution with the formations to which they belong, but careful search for localities of superior stone must be made, for even within the same layer the properties vary from point to point. No attempt was made, in the work of the past season, to determine these details.

The clays particularly adaptable for brick-making are the Cretaceous, although doubtless much of the Wasatch of the Big Horn basin would likewise be found suitable. Many horizons in both the Laramie and the upper portion of the Montana are well suited to the manufacture of pressed brick; in other regions also yielding materials of excellent color, durability and strength.

For flagging and paving purposes, the stones, excepting the granites, are not well adapted, unless, perhaps, an occasional layer of quartzite in the Silurian. None was observed of the hardness and durability of the upper beds of the lower Trias in the vicinity of Denver, Colorado.

Limestone and gypsum occur in the Carboniferous and Jurassic, respectively, in enormous quantities. The gypsums are very pure and from 5 to 30 feet thick. They are distributed about the periphery of both the Big Horn and Wind River basins, and are also found to the east of the Big Horn Mountains, and northward in Montana along the Pryor Mountains and the Absaroka Range.

GOLD.

The only metal at present produced along the route of reconnoissance is gold. This occurs about Bald Mountain on the summit of the Big Horn Range a few miles south of the Montana-Wyoming line. The productive strata are a series of red conglomerates and sandstones of Archean débris, lying directly upon the Archean; but whether they

were local developments of Cambrian age or merely deposits of recent times was not determined. They occupy broad flats on the summit of the range, between the high, surrounding Cambrian hills. Their material was apparently derived from a source near at hand. Thus far mining has been only experimental.

HOT SPRINGS.

Three enormous hot springs exist in the Big Horn and Wind River basins, the waters of which are in greater or less degree charged with sulphur, and salts the nature of which is not determined. The springs are located on the Stinking Water just below the canyon between Rattlesnake Ridge and Cedar Mountain; on the Big Horn, 5 miles below the base of the Owl Mountains; and on the Little Wind River 3 miles below Fort Washakie.

The Stinking Water springs.—These are the present remnants of early geyser action. The original area was about 1 mile square. Within this, besides a heavy deposit of calcareous tufa, several old geyser cones still exist, from which, however, all traces of activity have long since departed. There are also the usual circular depressions from 10 to 30 or 40 feet deep and 50 to 100 feet in diameter, peculiar to such regions. The tufa now forms a broad flat on either side the river gorge, about 150 or 200 feet above the present stream level. The flat is limited by the higher hills of the Triassic sandstones and their débris of denudation, which constitute a rim 30 to 50 feet high. The Red Beds also formed the platform upon which the tufa layer was deposited, outcropping in the canyon walls with a general dip of 10° to 15° downstream, but showing some flexures, with a dip for a short distance in the opposite direction. The beds have been more or less altered, and deposits of foreign salts have taken place in certain layers while in others the rock itself seems to have been replaced by matter derived from the springs. The present seat of activity is limited to a number of springs, of greater or less volume, at the water's edge, or rising directly from the bottom of the river through the superincumbent waters. At high water nearly all the springs are covered. The temperature was not taken, but the water was warm, not hot. The waters, besides sulphuretted hydrogen, contain a greater or less amount of sulphuric acid and are otherwise considerably mineralized.

The Big Horn Hot Springs.—These occur in the axis of an anticline parallel with the Owl-Rattlesnake Range. Like the Stinking Water Springs, they reach the surface in the Triassic Red Beds. They were originally active for a mile or more along the anticline on both sides the present river channel, but now are chiefly confined to the eastern bank where a heavy deposit of calcareous tufa exists, extending along the stream for a half mile with a width varying between 100 and 300 feet. The largest spring flows from a circular hole in the steeply dipping Triassic strata, in diameter 20 to 25 feet, and of undetermined depth. The body of water coming to the surface through this spring is enor-

mous, and so hot that cooling by passage through an open channel is necessary before it can be used for bathing purposes. Besides this duct, there are others leading to the river edge beneath and through the tufaceous bed. The waters are quite strongly impregnated with sulphur and with their high temperature are said to be most efficaceous in rheumatic and many other diseases. The springs are at all seasons above the level of the stream. They already have a wide local reputation and are visited yearly by numbers of invalids with reported satisfactory results.

The Fort Washakie Hot Spring.—This is situated in the valley of Little Wind River, its waters reaching the surface through Quaternary deposits; but the red sandstones of the Trias appear at short distances to the east and west and underlie the river débris at no considerable depth. Like the Big Horn Hot Spring this also is found at the axis of an anticline, the nature of which has already been described. The crater of the spring is several hundred feet across and of considerable depth, constituting an excellent swimming pool. The temperature is considerably lower than that of the Big Horn Hot Springs.

The waters of all three of the foregoing springs will doubtless display marked curative properties, but the Big Horn Spring stands highest in point of temptrature.

AGRICULTURE.

The agricultural possibilities of the Big Horn and Wind River basins are limited to local areas at the foot of the several mountain ranges, including both bench land and stream bottoms, and to the valleys of the larger streams in the central part of the basins, chief among them being the Wind River, the Big Horn, Stinking Water, Grey Bull, Wood River, and No Wood.

In the Big Horn basin the belt at the base of the mountains has a general width of 3 to 5 miles, which with the areas of Montana and Laramie shales along the stream bottoms from reduplication through folding, is very considerably increased. Below the line of the Laramie, however, the smaller streams run dry. In this belt, adjacent to the mountains, agriculture has already been carried sufficiently far to indicate a general success under similar conditions for much of the periphery of the basin. Grain and grasses, including alfalfa and timothy, grow in heavy crops wherever care is used in sowing, cultivation, and irrigation. Vegetables, excepting corn, and berries of all kinds may be raised with no more than the ordinary efforts in the productive portions of the West. Much of the present productive area is located on the Montana clays, but this is due to position—where water is available and the valley broad. The uplands are not generally of a topographic form to permit cultivation, being too rugged next to the mountains and too high and far removed from water in the more interior portions of the basins. There are localities, however, on both the east and west

sides of the basin where considerable areas of this nature may be found, advantageously situated for crop growing. Of the foothill valleys the most highly cultivated and productive at present are those of Wood River, Grey Bull, Meeteetse Creek, Owl Creek and No Wood. In the central part of the Big Horn basin the Big Horn River, the Stinking Water and Grey Bull are the only streams which can be advantageously settled, the water of these streams alone being abundant all the year for the demands of agriculture. Away from these streams the basin is a vast desert, intensely heated in summer, wind-swept in winter, with hardly a spear of grass for grazing.

The productive area of that part of the Wind River basin on the route of reconnoissance is confined to a belt of 5 or 6 miles along the base of the Wind River Mountains, and to the Wind River valley, all else being even more barren than the center of the Big Horn basin. In the part adjacent to the Wind River Range the possibilities of agriculture are unexcelled. The bottoms of Popoagie Creek about Lander are uninterrupted in the stretch of hay, grain and vegetable fields, and well indicate what can be attained elsewhere along the range; here, again, the cultivated area is on Montana shales. Water in this belt is abundant. Along the southern base of the Owl Mountains there are only a few small springs, capable of irrigating a minimum acreage of land. The Wind River bottoms are capable of irrigation and present considerable acreage for agriculture. Nearly all the other portions of the basin are covered with the loose sands derived from the Tertiaries which there prevail.

East of the Big Horn Mountains and north, in Montana, the capabilities of the soil are well known, and farming is already in an advanced stage.

Artesian wells are possible in many parts of the Big Horn and Wind River basins.

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