MONTANA COAL-FIELDS.

By Geo. H. Eldridge.

The area comprising the explorations mentioned beyond includes the eastern slopes of the Rocky mountains in Montana, the portions of this Territory lying east of them, and what may be designated as the Mouse river district in northern Dakota. It must not be understood that this entire stretch of country is explored in detail throughout, but only those portions which at the outset promised the largest and most important coal deposits. c
The remainder was only examined in so far as it could be done in the casual movements of our corps from one locality to another during the two years spent in the work.

The western boundary of this area is in most instances the front ranges of the Rocky mountains (*vide* general map, Plate LV), though toward the south, in the vicinity of the Bozeman pass, the natural thoroughfare of the Northern Pacific railroad, exploration has extended within this limit to the headwaters of the Missouri river.

The ranges constituting the Rocky mountains in Montana reach an altitude above sea-level of from 6,000 to 11,000 feet, the average being nearer 8,700 feet, with the plains at their eastern base coming usually between the levels of 4,000 and 5,000 feet.

The region drained by the headwaters of the Missouri and Yellowstone rivers, since it has to do more directly with some of our fields of exploration, needs a little closer attention. At Helena we have but two ranges. "The d
Main," to the west of which the western slopes form a part of the Pacific water-shed, and "The Belt", just east and across the valley of the Missouri, on the eastern slopes of which rise the waters of those tributaries of the Missouri, which drain the prairies farther out, the "Deep" or "Smith's river", and the northern branches of the Musselshell. Above Helena the main divide between the waters of the Atlantic and Pacific forms a prominent and large arc, one end, the northern, lying just west of Gallatin city, the point of confluence of the three tributaries forming the Missouri—the Gallatin, Madison, and Jefferson rivers; the other end, the southern, lying at the western boundary of the Yellowstone National Park, the interior of this extensive curve being drained by the Jefferson river and its tributaries. The Madison and West Gallatin both flow northward from the Yellowstone Park, separated from each other and the Jefferson to the west and the Yellowstone to the east by bold and lofty spurs running down from the main divide. e

The Belt range from the latitude of Helena passes southward in a rather broken line and unites with the range forming the divide between the West Gallatin and Yellowstone rivers, and by this also with the Yellowstone range south and east of the Yellowstone river. From the Belt range, as thus described, extend eastward on to the prairies several important spurs. The highest and most imposing of these is known as the Crazy range, passing off from the Belt range at a point about 30 miles north of the Yellowstone and running southward to a point opposite the Old Crow agency on this river. It is geologically an independent range, over 11,000 feet high, and almost wholly a mountain of erosion, while the topography of the Main and Belt ranges proper is generally that due to the combined effects of upheaval and erosion. Against the eastern slopes of the Belt and Crazy ranges and their spurs rise the southern tributaries of the Musselshell and the smallest of the streams feeding the Yellowstone, this river receiving the bulk of its waters from streams coming from the mountains lying to the south of it. f

The second prominent range passing off from the Belt mountains is that of the "Little Belt," which is continued eastward in the upheaval of the Snowy and Little Snowy ranges, the three together forming the prominent divide between the Musselshell and Judith rivers. The first two reach an altitude of over 8,600 feet the last of about 6,000 feet above sea-level, the prairies at their bases being in the neighborhood of 5,000 feet. Still farther to the north comes the group of the Highwoods, another geologically independent height, having an altitude of 7,000 feet, and occupying the bend of the Missouri river at a distance of 18 miles from it. The Highwoods, with the high country connecting them with the Little Belt mountains, form the western rim of the agriculturally-important Judith basin, and the divide between it and the Missouri river, the eastern wall being the anticlinal of the Judith mountains with the hills connecting them with the Snowies farther south. The two important anticlinal upheavals of the Moccasins, near the eastern side of the Judith basin, should also be noted in passing. The streams draining these border mountains northward, via the Judith basin, all have a fair amount of water, while the southern and eastern slopes furnish only the slightest amount, most of the coulées being entirely dry, the valley of the Musselshell having all its large streams on the south side, coming down from the Elk ranges, between it and the Yellowstone river. Owing to the Crow Indian reservation occupying the country south of the Yellowstone, our explorations there were very limited, but may be regarded as bounded by the bold and rugged heights of the Snow mountains, the front wall of the Rockies at the head of Clark's Fork, and by the Big Horn mountains farther east. These ranges with the mountains and valleys beyond to the south, furnish nearly the entire amount of water of the Yellowstone river, the streams being numerous and large, while those coming from the north are for the most part dry.

The topographical features of the prairies are very much the same throughout the entire area, consisting as they do of a general prairie level, on the one hand cut with coulées usually from 20 to 100 feet deep, and on the other dotted with buttes or marked by low ridges; one side among these last has often a gentle slope to its summit, while the other presents an abrupt bluff of sandstone or arenaceous clays, the crest being usually marked by a scant growth of stunted pines. Concerning the drainage of this great Cretaceous basin, it is a remarkable fact that the three large rivers receive the bulk of their waters from the south, the streams from the north being either dry or of very little importance.

The general geology of the Rocky mountain ranges will be found in the report of Mr. Davis, who has made their features a subject for special study. Our own explorations were conducted entirely with reference to the discovery of coal deposits, and we shall therefore present our notes on the general geology in a manner that will have a direct bearing on the occurrence of the coal and its relations to the associated strata. Coal-beds are found at various horizons in the Cretaceous from the Dakota upward, and we naturally turn first to the identification of the base of this group. Along the western border of the great plains of Montana, either forming the foot-hills next the higher ranges or occurring on the slopes of the ranges themselves, are to be found the strata of Jurassic age. On all the subordinate ranges also, the Little Belt, the Snowy, the Moccasins, and probably the Big Horn, great anticlinal folds, there occur the same Jurassic rocks, varying very slightly if at all in their characteristics. Noticeably persistent and uniform is the development of the limestones with their accompanying fossils, rendering them most easily recognized wherever met, and a most excellent indicator of our proximity to the overlying coal-bearing Cretaceous strata. The following section (Figure 1 of the geological cross-sections, Plate LVI) from the lower cañon of the Yellowstone river outward onto the prairie will give an idea of the rocks met with in the Belt mountains in the southern portion of our field. It is by Professor Pumpelly. The section is numbered from below upward, the numbers in the text and figure corresponding.

No.		Feet.
1.	Heavy beds of gray limestones, 1,000 to 2,000 feet thick, probably Carboniferous, in part at least	
2.	Drab limestones with red stained face	60
3.	Covered, but probably shales	158
4.	A white quartzite stained brown	60
5.	A white quartzite with cavernous layers	48
6.	Covered, but probably a conglomerate	36
7.	Drab slaty limestone, overlaid by a quartzite	44
8.	Conglomerate and white quartzite	48
9.	Limestones, very fossiliferous	72
10.	No distinct outcrop, but apparently light quartzites or sandstones weathering with rounded corners	318
11.	Coarsely crystalline fossiliferous limestone	28
12.	Covered, but probably a shaly sandstone	60
13.	Sandstone, slightly ferruginous	53
14.	Covered, but probably same as No. 13, excepting that the upper part is more shaly	112
15, 16.	Sandstone	120
17, 18.	Sandstone with conglomerate layers	355
19 and upward.	Generally sandstones with shaly layers	
30.	A sandstone just below which probably occurs the coal-beds of the Bozeman field	

No attempt is made to assign the strata to their proper age, as our data are not sufficient. In a general way, however, the points to be noted are the heavy beds of pre-Mesozoic limestones (No. 1 of the section just given), the Jurassic limestones (No. 9), and the interbedded conglomerate and sandstone (No. 17), which are probably near the base of the Cretaceous. Another characteristic not observed at this point but generally present and very prominent, even at great distances, is the presence of beds of shale and sandstone of a very brilliant red occurring beneath the Jurassic limestones, usually somewhere between 100 and 150 feet, which may possibly rightly be considered of Triassic age. These features of the strata underlying the Cretaceous are everywhere present, though marked more prominently at some points than at others. On the east side of the monoclinal ridge of the Bridger mountains, seen in the map of the Bozeman coal-field (Plate LXII) they are especially prominent.

The Belt mountains at the head of the South fork of the Musselshell, 5 or 6 miles above its junction with the North fork, present these same general features (Figure 5, Plate LVI). We have at the base of the section given the Jurassic limestones (No. 2 of the section), which are underlaid by about 400 feet of red and green shales (No. 1), interbedded with one or two thin strata of limestone and a thin basal conglomerate, there coming under all the Carboniferous limestones. The Jurassic limestones are overlaid, as shown, by sandstones which are alternately heavy-bedded and shaly, succeeded at about 400 feet by a conglomerate of coarse and fine pebbles, a showing an outcrop of about 40 feet, and followed at about 200 feet by another bed of much heavier and coarser material, the two beds being separated by sandstones of varying texture and color. The entire section, numbered from below upward, would be:

	Feet.
1. Red and green arenaceous shales, with limestone intercalations and a basal conglomerate	400
2. Jurassic limestones	90
3. Gray sandstone	90
4. Covered, but probably like No. 3, perhaps a little more shaly	175
5. Light-colored and yellowish-gray sandstones forming prominent crests	32
6. Covered, but undoubtedly like No. 5, though shaly	60
7. A rusty-gray sandstone, weathering red and forming a prominent ridge	27 b
8. Like No. 7, but more thinly bedded	15
9. Conglomerate, pebbles of size of a bean and upward, probably Cretaceous	40
10. Light calcareous sandstone, reddish at top	90
11. Covered, probably like Nos. 10 and 12	50
12. Heavy-bedded gray sandstones	70
13. Heavy bed of coarse conglomerate	65

As in the Yellowstone section, the actual base of the Cretaceous was not determined, but the strata are all so clearly defined that no doubt can ever be entertained as to the proximity of the series which is liable to contain important coal-beds. Though some members of the series are altogether wanting, or at least thinner in this section than in the first, still the important general features referred to above remain unchanged. c

On the southern slope of the Snowies we meet with comparatively the same section of red and variegated shales, and Jurassic limestones, overlaid by heavy-bedded sandstones, followed by the coarse conglomerates. In the Judith basin, in the foot-hills on the north of the Little Belt mountains, we have a variation of the sequence thus far observed in the conglomerates coming immediately above the Jurassic limestones and not being again met with in the ascending Cretaceous strata. This same condition occurs in the Bozeman coal-field also, of which the section (Fig. 2, Plate LVI) is distant from that at the mouth of the Yellowstone cañon only about 10 miles (*vide* map of the Bozeman coal-field). On the eastern rim of the Judith basin the core of the Judith mountains, to the south of the mining district of Maiden, *consists of the heavy beds of the Carboniferous limestones. Upon these lie conformably* the post-Carboniferous rocks, but there is at this point, as also in the slopes of the Moccasins, a decided departure from the series so often observed along the main ranges and the belts mentioned above. The following section d represents the series on the Judith mountains just referred to, numbered from below upward. It is taken at a point about 3 miles southwest of Maiden.

	Feet.
1. Carboniferous limestones, very massive	1,000
2. Silicious limestones of a light yellow color, gradually changing to	111
3. Yellow sandstones, weathering red	23
4. Yellow sandstones, becoming at top very calcareous	92
5. Slightly silicious limestones, weathering reddish	12
6. Covered	70
7. Jurassic limestones, outcrop of	10
8. Covered	60
9. Thin, laminated, calcareous shales	6 e
10. Limestones; also Jurassic, fossiliferous	21
11. Shale	49
12. Sandstones, of alternate heavy-bedded and shaly layers; Cretaceous	70
13. Gray sandstones, weathering yellow	12
14. Shales, or very argillaceous and thin laminated sandstones, with upper 20 feet somewhat calcareous	116
15. Sandstone	6
16. Ferruginous sandstone, lower 25 feet shaly	35
17. Ferruginous sandstone	12
18. Clays, or arenaceous shales	45
19. Shaly sandstones	35
20. Lignite, 1½ feet to 3 feet; very poor, dirty, and variable	3
21. Ferruginous sandstone, rather yellow	32 f
22. *Ferruginous sandstone*	12
23. Red shales and sandstones interbedded, with one or two limestone strata	420

It will be observed that the distance between the Carboniferous and Jurassic limestones, about 300 feet, is the same in both this and the section from the Yellowstone cañon, and wherever observed the distance was always approximately the same; but in the section just given the conglomerates at the base of the Cretaceous have disappeared altogether. However, the very decided differences between the Jurassic and Cretaceous strata here enable one to draw the line of union very closely.

The section represented in Fig. 4 (Plate LVI) is from the western slope of the North Moccasin, and is a wide variation from the sections met with elsewhere in our area of explorations. There is no doubt about the underlying limestones (No. 1) being Carboniferous, and probably Nos. 5 and 7 are Jurassic, but the distance between these and a the Carboniferous limestones is greatly increased over that in other portions of the field. Furthermore, there occurs what are very like granite injections between the strata, but as much of the intermediate space was covered it was impossible to determine definitely their exact character. Notwithstanding this abnormal condition, the base of the Cretaceous is as readily recognized here as in other localities, by its relation to the underlying rocks.

In the region of the Snow mountains, south of the Yellowstone river, the relations between Cretaceous and older rocks differ from the foregoing cases, in that the Snow mountains, in proximity to the coal-field, are faulted up, exposing the limestones to view, and we do not have, therefore, the same succession of strata as elsewhere. Within the mountains, on the Upper Yellowstone river, just above the second cañon, and on the Upper Gallatin above the lower cañon, the usual succession of Jurassic and Cretaceous strata of limestones, sandstones, conglomerates, and overlying shales are met with, and differ in no respect from the typical deposits already b mentioned.

Such, then, are the chief and important characteristics of the rocks underlying the Cretaceous, in reference to their bearing on the identification of one's proximity to the Coal Measures.

As already stated, in the Cretaceous of Montana, there occur at several horizons, from the base to the top, various seams of coal. The Dakota and Laramie groups are the most important in this respect; the Colorado has a few seams of minor importance, while as regards the Fox Hills, none have been discovered that could be absolutely referred to this group. The general character of the Dakota has already been touched upon in connection with the pre-Cretaceous rocks. It is remarkably barren of fossils, but, as is seen in the sections presented, usually consists of heavy-bedded white and yellow sandstones, and conglomerates of a varying coarseness, perfectly conformable with the strata below. The conglomerates are by no means evenly developed, being much c thicker and occurring in more numerous beds in some localities than in others. The thickness of the Dakota was nowhere determined, as our labors were necessarily in another direction, and, moreover, in the vicinity of the main ranges of the Rocky mountains, the transition from it to the overlying Colorado was very gradual and the exact line of junction very obscure. Out of the influence of the shore line, however, on the prairies, the union, had it been specially observed, would have been very marked, as the lithological characteristics of the Colorado are there very decided. There are one or two peculiarities in the northern part of our field that have not been observed elsewhere in the great rim of the Cretaceous that this group forms along the base of the Rocky mountains and most of its great spurs. These consist in the thin beds of limestone observed in the sections in the Judith basin presented in Figs. 3 and 4, Plate LVI, and in a thin bed of red shales occurring some distance up in the group, at least in the upper half, I should say. The limestones are very silicious, and, so far as observed, are non-fossiliferous. d The red shales, if occurring with a sufficiently gentle dip to cover any extent of surface, are very advantageous to farming, since wherever their materials are washed from the benches formed of them onto the stream bottoms a very productive soil is formed, clearly showing its superiority over the portions of the bottoms not affected by it, in the quantity and quality of the crops. This feature of coloring does not seem to be due to the effects of combustion of coal-beds, as is the case often in the Laramie group, none of the usual results of such phenomena being met with. Neither the limestones or red shales have been seen in any other part of our area of exploration, but form a decided characteristic of the Judith Basin strata. These features have been spoken of in connection with the Dakota, for they seem to have a closer connection with that group than with the Colorado. The important coal-bed of the Judith basin and Belt creek is also referred to the Dakota, by reason of its association with heavy beds of sandstones, which furthermore underlie beds known to belong to the Colorado.

e The Colorado group, comprising the three members, the Fort Benton, the Niobrara, the Fort Pierre, underlies the entire prairie lands in Montana within the border formed by the outcrop of the Dakota. In the valleys of the Yellowstone, Musselshell, and Judith rivers the Fort Pierre alone is usually met with, excepting in the immediate vicinity of the mountains, where, in the Yellowstone and Musselshell valleys, by upheaval and subsequent erosion, it is exposed in connection with the underlying Niobrara and Fort Benton. In the Judith basin proper the lower two divisions of the Colorado are much less prominent, and may be absent altogether, which inference is drawn from the section afforded by the Moccasin mountain on the eastern side of the basin (Fig. 4, Plate LVI) the black shales (Nos. 18–23, inclusive) there given being unmistakably Fort Pierre.

The middle member of the Colorado, the Niobrara, was nowhere in the area of our explorations positively identified. The Fort Benton is typically developed along the Missouri river north and west of the Highwood f mountains, and especially opposite the town of Fort Benton, from which the name of the sub group is derived. In this vicinity it underlies a large extent of the prairie on both sides of the river. There is also an excellent exposure of the Fort Benton, though slightly different from the typical beds, in the Belt Butte on Belt creek overlying the large coal-seam found there. The section is given in Fig. 6, Plate LVI, as follows: [Numbered from younger to older.]

(1) Sandstone; thin laminated, fine-grained, gray weathering brown.
(2) Sandstone; heavy-bedded, fine-grained, white.
(3) Sandstones and arenaceous clays.
(4) Black shales.
(5) A granitic sandstone.
(6) Shales; very dark blackish-gray.
(7) Sandstone; yellowish-gray, upper 2 feet ferruginous.

(8) Clays; red and yellow.
(9) Clays; red, arenaceous. a
(10) Four interbedded and alternating layers of red and green clays. Layers are of equal thickness.
(11) At the top a concretionary layer of red arenaceous clays, underlaid by 15 feet of greenish-gray sandy clays, these succeeded in turn by more red clays, similar to the upper ones.
(12) Concretionary clays; yellow and drab. Concretions are ferruginous.
(13 and 14) Sandstone; gray. No. 13 is fossiliferous.
(15) Shales; red, purple, and drab, with thin intercalations of drab sandstones. It is separated by 10 feet of gray sandstone from (16)
(16) Shales; red and purple.
(17) Sandstone; moderately fine-grained, white to gray, weathering buff in most places. Upper part usually softer and more pliable than lower numbers. b
(18) Coal. The large seam of this field.
(19 *et seq.*) The section in the southern part of the Judith basin shown in Fig. 3 (same plate) and regarded as Dakota.

The thickness of the strata above the coal, 1,349 feet, would indicate that perhaps much more of the Colorado than the Fort Benton is here exposed. Hayden puts its thickness at 800 feet where typically developed, which fact would place the upper portion of this section in the upper part of the Colorado. The heavy sandstones above might by chance belong to the Fox Hills group.

In other prairie localities than those already mentioned, and especially in the Judith basin proper, the Fort Benton sub-group seems to be far less prominently developed. In the southern part of our area of exploration, near the Bozeman coal-field, it is recognized by its fossils, together with the Niobrara, but lithologically it is totally unidentifiable with the typical Fort Benton of the Missouri river. This distinction between the prairie c beds and those at the eastern base of the Rocky mountains characterizes the entire Colorado group. Where at a distance of a few miles out from the mountains we meet with the dark-gray and black shales and clays so universally characteristic of this group in like positions, along the base of the mountains they are replaced by very arenaceous light-gray and whitish shales, coarsely laminated and interbedded with numerous layers of sandstone from 15 to 70 feet thick. This is particularly noticeable in the section taken at the Bozeman coal-field (Fig. 2, Plate LVI), where the lower members of the Colorado are recognized by their fossils, and also in the strata overlying the section at the head of the Musselshell (Fig. 5, Plate LVI), where the same features predominate. But the Colorado, with its typical characteristics, does occur within the mountainous area, for in the Cretaceous areas on the Upper Yellowstone river, near Cinnabar mountain, and on the Upper Gallatin, above the lower cañon, the dark-blue shales of the Colorado are again met with, underlaid by thin, laminated, arenaceous shales, undoubtedly belonging to the same group, all overlying the Dakota and underlying the upper members of the Cretaceous. d

As these latter localities were comparatively unimportant from an economic point of view, but little attention was paid toward deciphering the complicated problem of the local geology, rendered very difficult by the disturbed condition of the rocks over this entire mountainous country.

The Colorado group is remarkable for the abundance of gypsum occurring in thin scales throughout the strata, especially in the dark deposits of the prairies, while in the vicinity of the mountains, in the more arenaceous beds, it seems to be less abundant. Here, however, the strata that would reasonably be included in this group, especially the shaly sandstones, are calcareous, oftentimes showing a slight effervescence with dilute acid.

The thickness of the Colorado was not measured, but at Billings, by artesian borings made by the Northern Pacific Railroad Company, it is proved for at least 900 feet. e

The Fox Hills group in the region of the mountains was not identified owing to its gradation into both the underlying and overlying members of the Cretaceous. Eastward, in the Yellowstone valley near Billings, and in the Musselshell valley north of the river, and in the Judith basin, 5 or 6 miles west of the Moccasins, it was plainly observed in its bold and unchanging outcrop of heavy beds of white and yellow ferruginous sandstone, overlying the Fort Pierre, the union of the two groups showing finely, owing to their decided lithological differences. Wherever observed it occurs in long, low, but prominent ridges, comprised of a bluff on one side and either a smaller bluff or a gentle slope, generally the latter, on the other, and invariably having its crest-line marked with a growth of stunted pines. The entire group seemed to be rather barren of fossils, but our searches for them were not prosecuted untiringly. Its thickness in Montana is probably a little under 400 feet. The only localities in which a special study of the Laramie group was made were those of the Bull mountains, forming the prominent buttes f northeast of Billings, on the divide between the waters of the Yellowstone and Musselshell and Missouri rivers, and the area between this point and the Snowy mountains, 50 miles northward across the Musselshell. The localities of its occurrence in the northern part of the Judith basin were not visited, and for this section of country reference must be had to the writings of others.

Of the geology of the Laramie, which covers nearly the entire area of the localities referred to, a careful study was made by Mr. Lindgren, of our party, in connection with the general exploration for coal occurring in the Bull mountains, and on Swimming Woman and Careless creeks, north of the Musselshell. Mr. Lindgren's notes are here inserted, with one or two additions by way of comment by the writer.

The first and rather surprising result of the examination is the immense thickness of the Laramie strata. While it was generally supposed till now that the formation had a maximum thickness of from 4,000 to 5,000 feet, (*a*) it is now shown to have a total thickness of

a Geological Exploration of the Fortieth Parallel, vol. I, p. 335.

a about 8,600 feet. The sections on which these conclusions are founded are perfectly continuous, and as far as ascertained, contain no faults, certainly no large ones. Moreover, the difference between the subdivisions in this large series is very distinct and would permit a larger repetition by faulting to be easily discovered.

The sections are—

No. 1. From Big Coulée northward to the Musselshell river and Careless creek, 8 or 9 miles, exposing a small portion of the Fort Pierre, Fox Hills, and the Laramie, to a thickness of 3,000 feet. (Plate LVII.)

No. 2. From the mouth of Swimming Woman creek northward to the Big Snowy mountains, exposing the Fox Hills and 7,800 feet of the Laramie. (Plate LVII.) *a*

No. 3. From Billings northward across the Bull mountains to the Musselshell river, exposing 8,600 feet of the Laramie. (Plate LVIII.) This section is composed of two parts: (*a*) A monoclinal 24 miles long with a constant 3 degrees dip comprising the strata up to the Bull b mountain series, 7,060 feet thick; (*b*) a series of horizontal strata, 1,550 feet thick, comprising the Bull mountain series and extending down to the Musselshell river.

No. 4. (Not drawn.) From the Bull mountains westward along the Musselshell river to Olden, about 19 miles, exposing the Bull mountain series, the Lower Laramie (measuring again 7,000 feet), the Fox Hills, and the Fort Pierre.

If we want to subdivide this enormous series, it must be done with reference to petrographical distinctions, for the fauna of the series remains essentially the same throughout. Precisely the same fossils found at 2,000 feet above the Fox Hills we see again at 7,000 feet above the same. Petrographically, however, the difference between the various parts is very distinct, and they retain their character very well throughout the district. Such a division is very useful, as it greatly facilitates the determinations of the horizons of the different lignite seams found in this formation. The 8,000 feet of Laramie strata divide very naturally into two distinct parts.

1. The Lower Laramie; about 7,000 feet thick, which is easily further subdivided into at least four petrograpically distinct parts. General characteristics: A succession of dark, black, and green clay beds, thin sandstone layers, a few very heavy sandstones, and thin lignite seams. Generally speaking, no valuable lignite beds occur in the Lower Laramie. The upper part shows a rapid succession of c white sandstones and green clay beds.

2. The Upper Laramie, or Bull mountain series, containing the more valuable lignite beds. Thickness, about 1,600 feet, characterized by a succession of light-colored clays, white, soft, argillaceous, sandstones, and, heavy benches, of a thickness of from 10 to 30 feet, of yellow massive sandstone, with rounded corners and faces, and generally carrying round nodules of brown iron ore. Abundant fossil leaves, and plant remains generally.

Before beginning to discuss the different parts of the formation, a few words may be said about the fossils.

Fauna.—As before remarked, the fossils from nearly all parts of the formation indicate a deposit in fresh and brackish water. The same or similar fossils occur in very widely-separated parts of the series and consist mainly of fresh-water gasteropods, and fresh- and brackish-water bivalves, such as Ostrea, Corbula, Corbicula, Anomia, Unio, Helix, Physa, Bulinus, and Goniobasis. A few of the Gasteropods belong, according to Mr. R. P. Whitfield, to new species. A few indistinct vertebral remains were found in the clays some hundred feet above the Fox Hills sandstones.

In the Swimming Woman creek section (Plate LVII) there is a most remarkable exception to the general rule. As it may be seen from the section the Fox Hills sandstone is exposed near the mouth of Swimming Woman creek; 5 miles farther up, 2,350 feet vertically, above d the Fox Hills, are the coal-beds of Swimming Woman, surrounded by fresh-water clays. (*b*) Fifty feet above the coal and 120 feet below, a rather heavy white sandstone with Ostrea glabra, Corbula and Corbicula, a calcareous sandy layer was found by Mr. Eldridge, containing a perfect Placentaceras placenta, var. intercalaris M., a Baculites, young specimen, and a Mactra Warrenana. These are all purely marine forms, indicating Fort Pierre or Fox Hills. A fault is hardly possible, for the general sequence of the layers coincides very well with that of the other sections, and the conspicuous Fox Hills would certainly have been seen if repeated above the mouth of the creek. The only plausible explanation is that a temporary influx of marine water with marine forms took place in the brackish Laramie sea. The case is of very great importance as showing that, during the deposition of the Laramie, the Cretaceous marine forms had by no means yet disappeared, and, consequently, proving the Cretaceous age for at least the lower part of the Laramie.

Flora.—Plant remains are found throughout the series, but most abundantly in the upper part.

Lower Laramie, No. 1.—Thickness about 1,200 feet. It is composed of dark, often quite black, soft, and crumbling fresh-water clays, very different from the dark shales of the Fort Pierre. Nowhere did I succeed in finding any distinct fossils. Sometimes thin sheets of harder sandstone are intercalated. Wherever this series is exposed it has a tendency to form "bad lands." Near Billings, it is well e exposed on the south side of the Yellowstone in the Crow reservation. The sequence of the Fort Pierre, Fox Hills, and Laramie is beautifully seen from the bluffs on the north side of the river. Another very good exposure is on Painted Robe creek, some miles south of the Musselshell river. It here forms bluffs of black clay 300 feet high, and in the wider part contains the worthless lignite of Painted Robe. This is geologically the lowest coal in the region, 400 feet or 500 feet above the Fox Hills. The corresponding strata also crop out around Big Coulée and on Swimming Woman creek. These clay-beds are always covered by a hard, slaty sandstone, sometimes with peculiarly twisted and oblique lamination. It is seen on Five-mile creek, near Billings, and on Painted Robe creek.

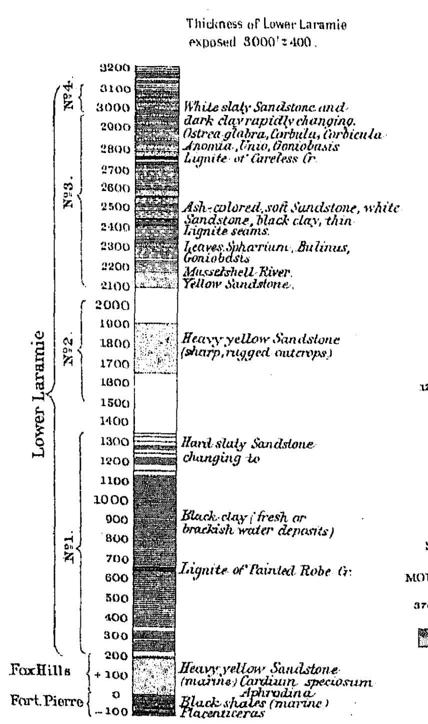
No. 2. At about 1,700 feet above the Fox Hills group a very remarkable heavy sandstone occurs; it is about 200 feet thick, heavy-bedded, massive, and yellow, and has the peculiarity of cropping out even on the level plateaus in sharp peaks and rugged outlines. Well exposed 7 miles north of Billings, the sharp peaks are seen from far away. It is also well exposed beyond the black clays at Painted Robe and on the southern side of the Musselshell opposite the mouth of Careless creek.

No. 3. The next portion, about 600 or 700 feet thick, is a succession of dark, soft, sandstones, black clay beds, thin white sandstones, and worthless lignite beds. It comes a short distance above the sandstone of No. 2, and forms dark bluffs with a tendency to the formation f of "bad lands." It is very well exposed at the mouth of Careless creek in dark bluffs capped by vermilion-colored sandstone, resulting from the burning out of some lignite seam. The same series is exposed in Spring butte north of Billings. In the dark clays at the mouth of Careless creek there are found plants, fruits, a large Sphærium, Goniobasis, and Bulinus. Closely above this group we have the coal of Careless creek immediately covered by a perfect oyster-bank containing also chips of coal. The fossils found in this bank are Ostrea

a Mr. Lindgren states elsewhere that his horizontal distances in passing over the Swimming Woman section were in part estimated. A previous casual examination, in which the distances were all paced or measured, was made by the writer, and his results give to this section a thickness of 6,570 feet, necessarily the more correct. [Eldridge.]

b The overestimation referred to in the above note, of the thickness of the Swimming Woman section of Mr. Lindgren, seems to lie at the base of the series, for the coal lies at the most only 1,000 feet up in the Laramie, if the sandstones at the mouth of the Swimming Woman are indeed Fox Hills, instead of 2,350 feet as stated in the text above. This decrease in the thickness would also very closely harmonize the sections of Mr. Lindgren and myself. Regarding the thickness of the Lower Laramie elsewhere, Mr. Lindgren's sections are taken as the authority. [Eldridge.]

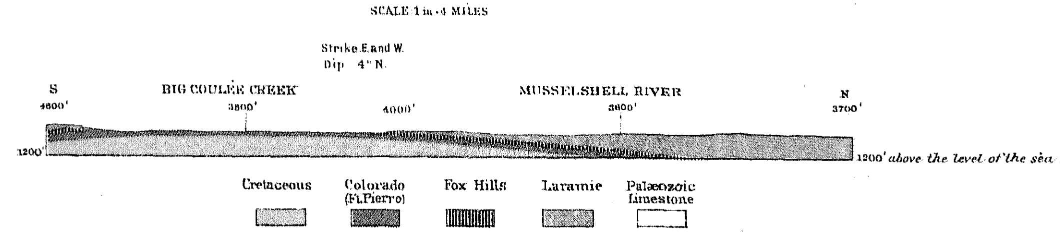
SECTION FROM BIG COULÉE TO CARELESS CR.



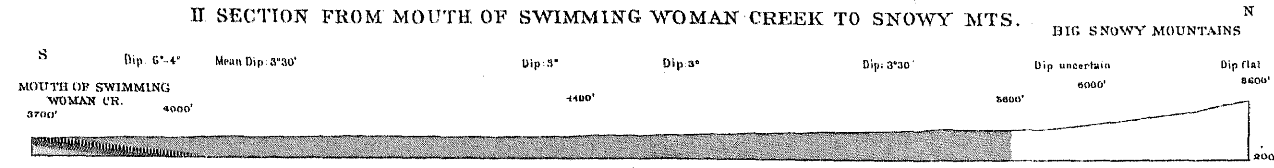
From top of Fox Hill Sandstone to end of series on Careless Cr. 8, 2 miles, Dip 4. Thickness per mile 5280 × sin 4° = 5280 × 0,070 = 370'. Consequently thickness exposed of Lower Laramie 370' × 8.2 = 3034'.

I SECTION FROM BIG COULÉE TO CARELESS CR. (CRAZY MT. MAP)

SCALE 1 in = 4 MILES

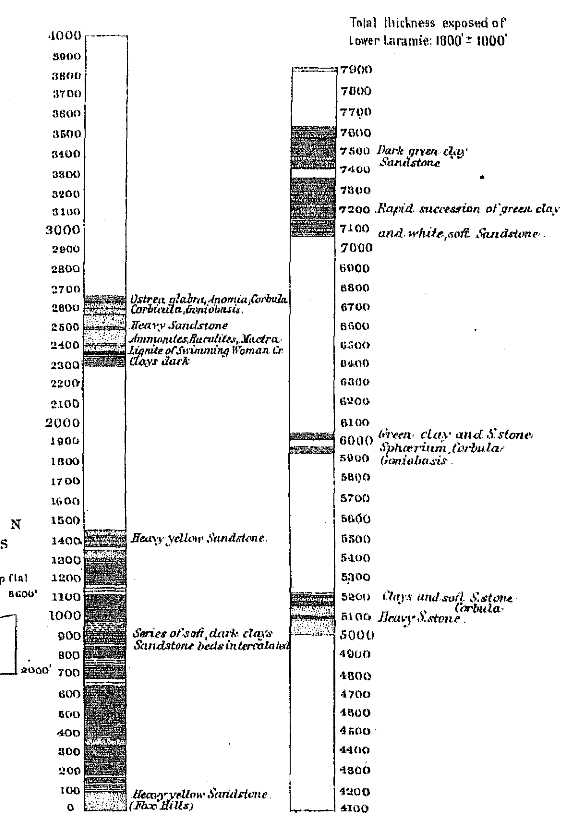


II SECTION FROM MOUTH OF SWIMMING WOMAN CREEK TO SNOWY MTS.



By Waldemar Lindgren, 1884.

SECTION ALONG SWIMMING WOMAN CREEK.



From mouth of Creek to Coalbed 5 miles. Average dip 4°30'. Difference in height about 280'. 5280 × sin 4°30' = 5280 × 0,078 = 414' per mile. Total 414 × 5 + 280 = 2350'. From Coalbed to base of Mountains 14.5 miles. Difference in height 1620'. Average dip 3° (low average: dip 4° to 2°3°). 5280 × sin 3° = 5280 × 0,052 = 270' per mile. Total 270 × 14.5 + 1620 = 5550. Total thickness of Laramie (Lower series) 2350 + 5550 = 7900.

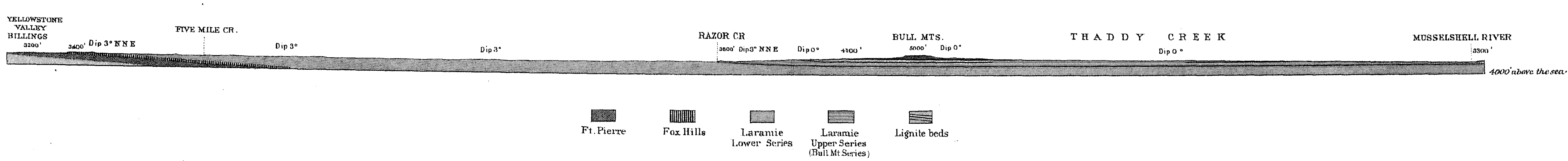
From unpublished M.S. material of the Northern Transcontinental Survey.

Julius Bien & Co. Lith.

SECTION FROM THE YELLOWSTONE RIVER ACROSS THE BULL MTS. TO THE MUSSELSHELL RIVER.

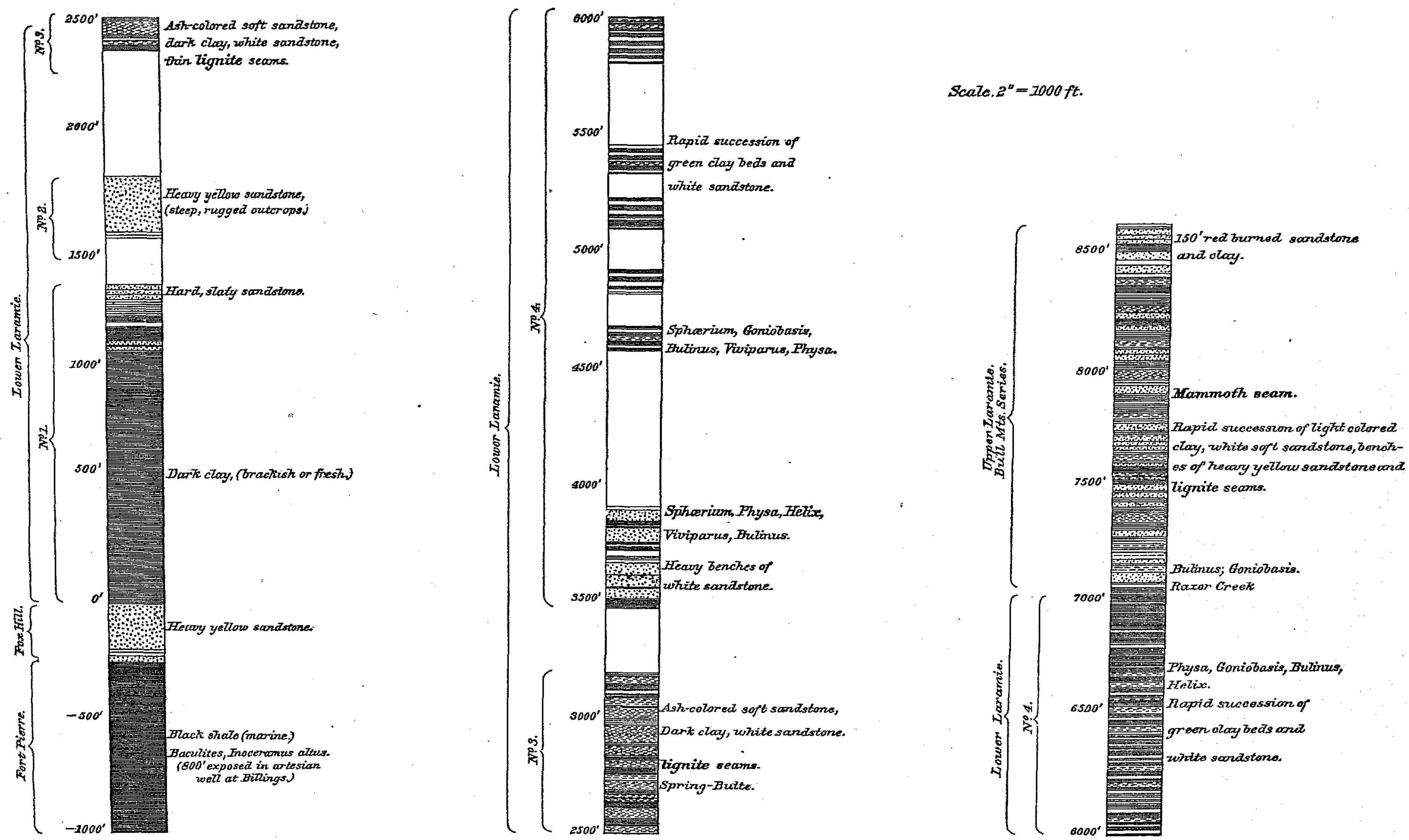
By Waldemar Lindgren, 1884.

SCALE: 1 in. - 4 MILES



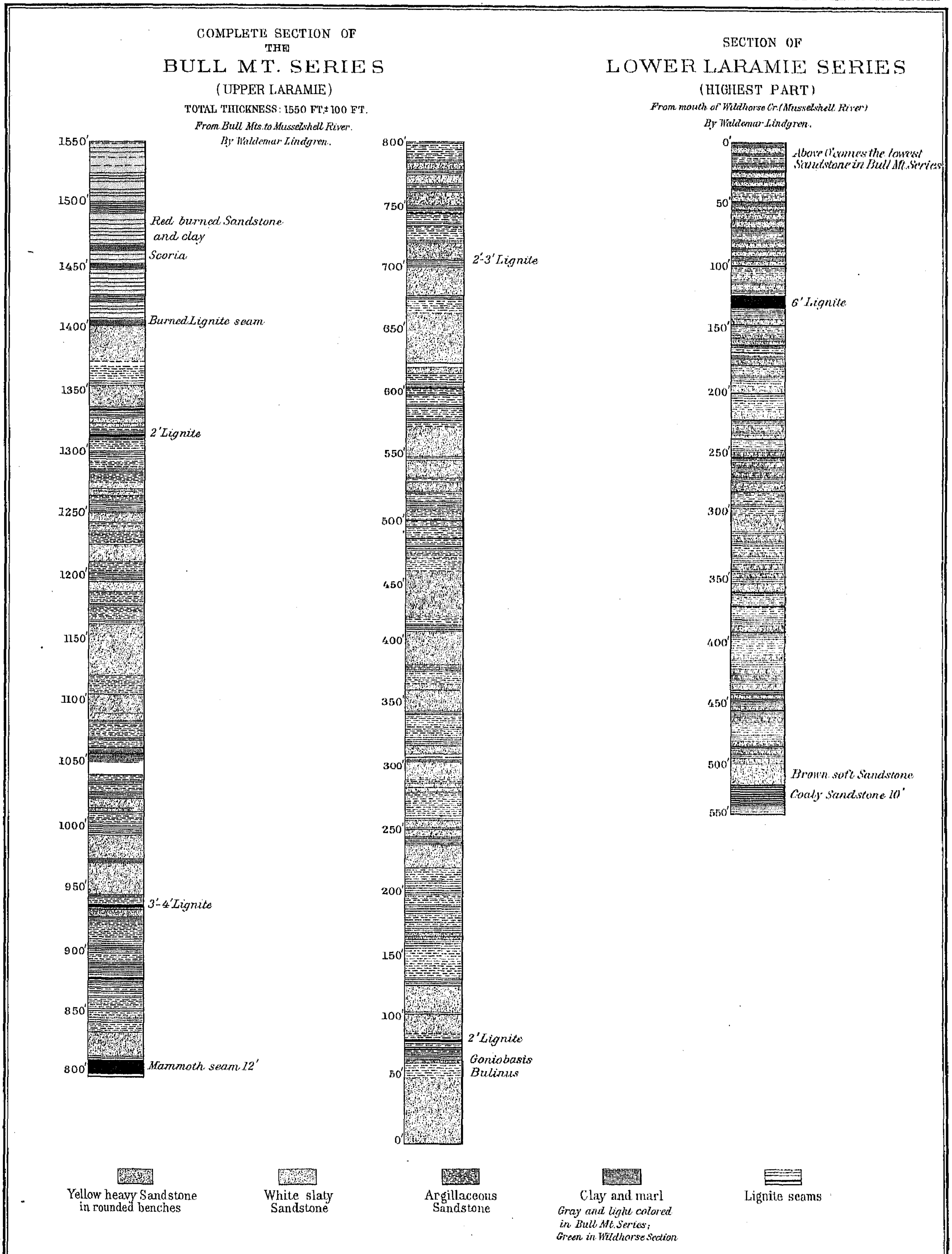
From unpublished M.S. material of the Northern Transcontinental Survey.

Julius Bien & Co Lith.



From unpublished MS. material of the Northern Transcontinental Survey.

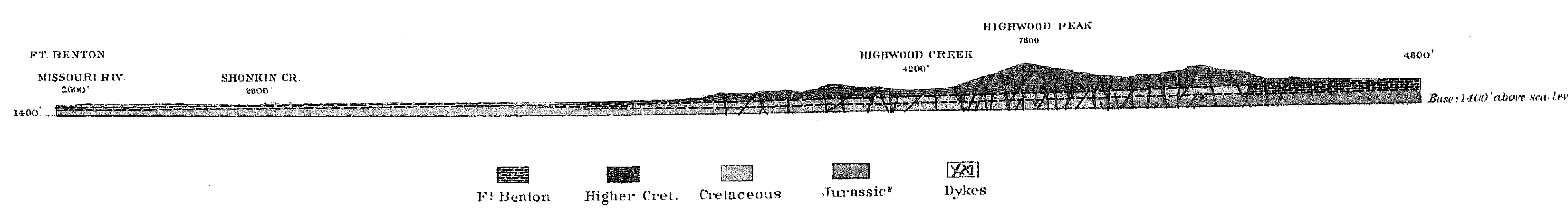
SECTION OF THE LARAMIE GROUP, IN THE REGION OF BULL MOUNTAIN, MONTANA.


COMPLETE SECTION OF THE BULL MT. SERIES
(UPPER LARAMIE)
TOTAL THICKNESS: 1550 FT.± 100 FT.
From Bull Mts. to Musselshell River.
By Waldemar Lindgren.
1550′
1500′
Red burned Sandstone and clay
Scoria
1450′
Burned Lignite seam
1400′
1350′
2′ Lignite
1300′
1250′
1200′
1150′
1100′
1050′
1000′
950′
3′-4′ Lignite
900′
850′
800′
Mammoth seam 12′
800′
750′
2′-3′ Lignite
700′
650′
600′
550′
500′
450′
400′
350′
300′
250′
200′
150′
100′
2′ Lignite
Goniobasis
Bulinus
50′
0′
SECTION OF LOWER LARAMIE SERIES
(HIGHEST PART)
From mouth of Wildhorse Cr. (Musselshell River)
By Waldemar Lindgren.
0′
Above 0′ comes the lowest Sandstone in Bull Mt. Series
50′
100′
6′ Lignite
150′
200′
250′
300′
350′
400′
450′
500′
Brown soft Sandstone
Coaly Sandstone 10′
550′
Yellow heavy Sandstone in rounded benches
White slaty Sandstone
Argillaceous Sandstone
Clay and marl
Gray and light colored in Bull Mt. Series; Green in Wildhorse Section
Lignite seams

SECTION OF THE HIGHWOOD MOUNTAINS.

By Waldemar Lindgren, 1884.

SCALE: 1 in. = 4 MILES



From unpublished MS. material of the Northern Transcontinental Survey.

Julius Bien & Co. Lith.

glabra, M. & H.; Anomia micronema, M. & H.; Anomia gryphorynchus, White; Corbicula cytheriformis, M. & H.; Corbula perundata, **a** H.; Unio Couesii, M. & H.; Melania or Goniobasis, and above the coal on Swimming Woman creek there is a rather heavy-bedded white sandstone with Ostrea glabra, M. & H.; Anomia micronema, M. & H.; Anomia gryphorynchus, White; Volsella laticostata, White; Corbula subtrigonalis, M. & H.; Corbicula cytheriformis, M. & H., and Goniobasis. (*a*)

No. 4. The lowest part of this series seems to be characterized by some heavier white sandstones (12 miles from Billings) in which Sphærium subellipticum, M. & H.; Bulinus longiusculus, M. & H.; Physa Bridgerensis, Meek; Viviparus Conradi, M. & H., and Helix vetusta? M. & H., were found. The upper part, comprising a series of about 3,000 feet, is a rapidly varying succession of white sandstones and green clays. The appearance of this part on the plateau between Billings and the Bull mountains is very uniform. A series of small ledges of the harder white sandstone, generally weathered brown, protruding as low reefs, the soft clay beds being eroded and leveled. Sometimes a heavier bench of the same sandstone appears. The green clay between the sandstone strata is well exposed in the numerous dry, broad gulches which the creeks have cut in the level plateau. Numerous fossils were found in the clays in the Billings series—Sphærium formosum, M. & H.; Goniobasis tenuicarinata, M. & H.; Goniobasis Endlichi, White; Bulinus longiusculus, M. & H.; Viviparus Conradi, M. & H.; Physa felix, White, ? and Helix. In the Swimming Woman Creek series, in the sandstone, Corbula subtrigonalis, M. **b** & H., and in the clay and near the mountains, plants, fruits, Sphærium formosum, M. & H.; Sphærium subellipticum, M. & H.; Corbula undifera, M. & H.; Goniobasis tenuicarinata, M. & H.; Tulotoma Thompsoni, White, and Colemeateres, M. & H.?

The uppermost part of No. 4, just below the Bull Mountain series, represented on a larger scale in the section of the latter, shows some peculiarities. Thin lignite seams here abound. Several layers of a sandy coal or coaly sandstone, from 1 foot to 10 feet thick, and not found elsewhere, appear. Above these coaly layers we generally find a deep brown, very soft, argillaceous sandstone. This is seen on Razor creek, on the road from Billings; at the mouth of Wildhorse creek, where we find a disturbance with 6° to 8° dip, just beyond the horizontal Bull Mountain series; farther up on the Musselshell, at the mouth of Golden creek; and equally 3 miles eastward again at the mouth of Denis creek. At the last place the coaly sandstones come approximately 700 or 800 feet below the Bull Mountain series, and, furthermore, sometimes change into streaks of pure coal, alternating with sandy layers, but never having a predominance of the coaly layers sufficient to be of economic value, except, perhaps, locally.

About 100 feet below the last heavy sandstones of the Bull Mountain series some more important lignite seams are found. At the **c** mouth of Wildhorse creek is a seam 6 feet thick, of good quality, but thinning out laterally or separating, for at Fisher creek, farther down the Musselshell, we find, just below the sandstone, two seams of 2 feet each, and still lower, 3 miles up Fisher creek, a bed of 3 feet 2 inches. I am not, however, quite certain of the position of the last-mentioned coal. At Razor creek, all thicker seams have disappeared or thinned out.

UPPER LARAMIE (BULL MOUNTAIN SERIES).

The upper part of the Laramie, occupying the center of the district, that is, the high mesa and surrounding hilly and wooded country, is a well-defined and distinct series. The map (Plate LXIX) shows its extension by the run of the lowest sandstone bench, a conspicuous bed of yellow sandstone, 50 feet thick, presenting a mural face, seen for a long distance of about 30 miles, near the Musselshell river, and also well exposed where the road from Billings crosses Razor creek. The thickness of the series, measured repeatedly from the top of the Bull mountains down to the Musselshell, and to Razor creek is nearly 1,550 feet; the largest lignite seam of the Bull mountains being found in the middle part of the series. Lignite beds are found in great numbers, although by far the most of them are practically without any **d** value. The character of the series is shown in the section of the Bull Mountain strata. It is a rapid succession of light-gray and grayish-green clay-beds, white argillaceous sandstones, numerous thin lignite seams, and 10-foot to 30-foot benches of yellow, massive sandstone in rounded outcrops. These sandstones often contain numerous small, rounded concretions of brown iron ore. The clays become somewhat darker near the bottom of the series. Numerous sections were uncovered in different parts of the mountains, all showing a great constancy in the sandstone benches. Indeed, the most important of these can be traced all around the mountains. The highest white sandstone bench is capped by brick-red layers, sometimes attaining a thickness of 150 feet, of hardened yellow and red sandstone, purple, black, and brick-red fritted clay, perfectly jasper-like, with sometimes a layer of black, porous scoria. The above peculiarities are undoubtedly due to the burning of a large lignite seam near the summit of the mountains. Thus the section given is a general one. The distribution of the coal-seams may best be seen by reference to the section (Plate LX).

Flora.—The whole series is very rich in impressions of leaves and other vegetable remains, the clay-beds especially abounding in them. Leaf impressions are found all through the Laramie, but nowhere in such number as in the upper series.

The *fauna* i sexceedingly scarce. Above the Mammoth seam no animal remains were found, in spite of very close examination. I **e** am told, though, that two gasteropods have been found in the mines of the Northern Pacific Coal Company. No trace of brackish-water bivalves could be found in the sandstones. Seven hundred and fifty feet below the Mammoth seam I succeeded in finding a Bulinus subelongatus, M. & H., and a Goniobasis tenuicarinata, M. & H.

It is clear that, in a series of such a thickness and extent as the Laramie, the results necessarily must show several gaps and the accuracy be limited, especially as the calculations are based on slight dips, not to be measured with less probable error than 30 minutes. However, I do not believe the inaccuracy to be greater than estimated at each calculation.

In connection with the Cretaceous strata of Montana there are two other localities worthy of special note—that of the Highwood mountains (Plate LXI), in the north, and that of the Crazy mountains, in the south, a short distance northeast of the Bozeman coal-field. The former mountains attain an altitude above sea-level of 7,604 feet, and above the prairies at their base of 3,000 feet. The latter range attains an altitude above sea-level of 11,178, and above the prairies at their base of 6,000 feet. Both ranges are made up of horizontal strata of chocolate, gray, and white sandstones, and a few thin-bedded, fine conglomerates. Evidently these ranges are far above all of our known coal horizons in the immediate vicinity of the Rocky mountains, and therefore will be found to be either Upper Cretaceous or **f** Tertiary. They have been preserved from erosion by reason of their being traversed by innumerable dikes, occurring in close proximity to each other, which, here and there, slightly alter the sandstones, especially next the line of contact. The dikes are not only vertical,

a Owing to Mr. Lindgren's overestimation in the lower part of the Laramie, a note of explanation is here also needed. (1) The coal on Swimming Woman creek and Careless creek is undoubtedly at the same horizon. (2) It would therefore come lower down in the Lower Laramie series than is assigned by Mr. Lindgren on the preceding page, unless a thickening of the underlying beds had occurred in the area from which the section between Billings and Bull mountains was taken. Since Mr. Lindgren places the strata at the mouth of Careless creek in his No. 3, Lower Laramie, the argument is that the measures below the coal must be thickened in the area just mentioned above, for the Careless creek coal comes only about 300 feet above that part of No. 3 exposed at the water-level at the mouth of Careless creek. The only other alternative by which this coal can occupy this position in No. 3 is that Mr. Lindgren may be mistaken in assigning the sandstones at the mouth of Swimming Woman to the Fox Hills. They may indeed come higher up. [Eldridge.]

a or at high dips, but also extend in floors between the sandstone strata, and thus, by their own hard texture and that which they have imparted to the strata through which they have passed, have enabled these lofty ranges to resist the erosive powers which have held sway on all sides since the elevation of the lands from beneath the Cretaceous and Tertiary seas. In a few instances only do the dikes extend outward onto the prairies, and then for but a few miles, say from 5 to 15. Here and there also do we find a dike cutting the prairies or mountains many miles apart from any of the great areas of eruptive phenomena.

Finally, from our explorations, we draw the following conclusions as to the least probable thickness of the Cretaceous of the prairies of Montana. From the section given in Fig. 6 (Plate LVI), which includes that of Fig. 3. if we regard as Dakota all below the top of the first sandstone above the coal on Belt creek (No. 17 of the figure), we have a thickness for this lower group of the Cretaceous of 860 feet. In Fig. 4 (on the same plate) we have a thickness of at least 1,800 feet for the Colorado, which is clearly overlaid by 400 feet of the Fox Hills sandstones **b** as exhibited in a prominent bluff a few miles west of the North Moccasin in the Judith basin. From Mr. Lindgren's explorations we are led to assign 8,600 feet as the thickness of the Laramie group, which together give a total thickness for the Cretaceous of 11,660 feet.

THE BOZEMAN COAL-FIELD.

This field lies in the midst of the Belt range, 12 miles east of Bozeman, the leading town of the extensive and most fertile Gallatin valley. The Belt range here forms the divide between the waters of the Yellowstone and Missouri rivers, and is constituted of two subordinate ranges, (1) the Bridger and its continuation southward, the Bozeman range, fronting on the Gallatin valley and forming its eastern wall, and (2) the much lower main range **c** proper just east of the meridian of 110° 45′, with its continuation in the mountains which border the Yellowstone river on the west, and finally cross and find their fellows in the lofty Yellowstone range south and east of the river It is this second range that contains the low Bozeman pass, only 5,565 feet above sea-level, and 800 feet above the Yellowstone and East Gallatin rivers, over which the Northern Pacific railroad passes on to the Upper Missouri river after its long course up the Yellowstone. The interior basin formed in this manner by the two parallel subordinate ranges mentioned is drained by numerous small creeks of the clearest water, the chief being Bridger creek, along the eastern base of the Bridger mountains, and Middle creek, heading against the Bozeman pass, and having its outlet into the East Gallatin through the wild and picturesque Rock cañon. On the eastern slope of the main range we have but one important creek, within the area of our map, called locally Fleischman creek, receiving numerous small tributaries from the mountains south of it, but few from the hills at the north. At the **d** northeast extremity of our map (Plate LXII) lies the mouth of Shields river, draining the wide valley between the main Belt range and the lofty Crazy mountains farther east.

There is nothing intricate in the general geology of the Bozeman coal-field. In the southern part we have three anticlinal folds, which as the effects of erosion, have exposed on their flanks the pre-Cretaceous rocks, indicated by the colored portions on the map. Their axes lie normally a little west of north, with a downward curve at their northwest extremities, but in the easternmost anticlinal another influence has been brought to bear, causing its axis 2 miles south of its northern end to be deflected to the eastward, which strike then continues with minor unimportant curves across the Yellowstone river for at least 30 miles. The westernmost anticlinal is also connected with other folds to the southwestward which join it to the high ranges forming the southern wall of the Gallatin valley. As these did not promise good results in the way of coal explorations, their geology was left unstudied **e** for more immediately important fields. A peculiar feature of all these anticlinals is their ends being cut by deeply eroded cañons, not one of the leading upheavals escaping. The influence of these folds, with their inclined axes at their northern ends, and their subsequent erosion, upon the line of outcrop of the successive strata may be seen in the line of outcrop of the coal as represented on the map. In the northwestern corner of our map we have one other pre-Cretaceous area, that of the Bridger mountains, which are an enormous overthrow with a reversed dip to the westward, the older measures lying on top of the younger. The line of coal outcrop is approximately represented with its dip in toward the mountains. A short distance farther out from the range, toward the southeast, we find the rocks normally dipping to the southeast. In the eastern portion of the map area the folds are more numerous, but of minor importance and very gentle, with a general direction west of Shields' river to the westward. A few miles beyond the northern limit of our map the disturbances have been much more irregular and less studied, as **f** but slight exploration proved them practically worthless for coal deposits. There is, however, a connection with the geology of our region in a gentle southerly dip over a small area and away from the influences of more powerful disturbances northward. From what has been said, we now see that the Bozeman coal deposits occupy a large synclinal basin, oftentimes covered with from 3,000 to 4,000 feet and more of superimposed Cretaceous strata, as is well represented in the high hill constituting a geological outlier cut by the meridian of 110° 45′, and lying just north of the Northern Pacific railroad, and also in another similar eminence west of this in 110° 52½′.

The only important development of coal lies along the southern edge of this synclinal basin, becoming quickly covered in its high dip of 45° and over by an enormous thickness of strata rendering it unavailable for mining beyond a certain depth, however valuable it may be. This vein of coal undoubtedly connects with that just southeast of the Bridger, and again appears in unimportant seams in the region just beyond the northern limit of the map.

From unpublished MS. material of the Northern Transcontinental Survey.

Julius Bien & Co. Lith.

Referring, now, to Fig. 2 of our plate of geological cross-sections (Plate LVI), we find here represented the chief **a**
stratigraphical features of the rocks occurring in the coal-field. We have represented at the base of the Cretaceous the Jurassic limestones, No. 6 of the figure. Immediately overlying these, and perfectly conformable, comes the basal conglomerate of the Dakota in the figure.

(7) A very massive conglomerate passing through (8) a transition bed to (9) a fine-grained sandstone.
(10) Covered, but undoubtedly a sandstone like (9), perhaps more shaly.
(11) A very massive, fine-grained millstone grit.
(12) Covered.
(13) A fine white sandstone.

From here upward to the coal we have at various horizons prominent outcrops of sandstones very much like No. 13, portions of the same or different layers, perhaps, containing a little more iron than others, as shown by the yellow and rusty weathering. Interbedded with these sandstones, and forming by far the larger part of the **b**
Cretaceous strata, are the characteristic shaly sandstones, very thinly laminated and usually uniformly breaking down under the weather, unless by chance the arenaceous constituents of the rock happen to be somewhat in excess of the usual amount or the argillaceous portion below the average amount usually present. Wherever this is the case we are liable to find a reef of sandstone standing out for a distance of from a few feet to half a mile. Midst these shales, and the heavier-bedded sandstones also, there appear to be layers decidedly calcareous, even effervescing with dilute acid, but, nevertheless, true fine-grained sandstones. As we approach the horizon of the coal we meet at about 600 feet below it a sandstone (No. 22 of the figure) forming a very prominent bluff in the eastern part of our field, but which in the western part, across the divide, has changed to one of the thin laminated **c**
variety, and no longer shows as a distinct outcrop. The sandstone, No. 24, just below the lower seam, acts in the same manner, and not until we come to the sandstone immediately underlying the principal bed do we find any persistency in the behavior of the strata in this particular.

Near the horizon of No. 14 or 16, probably the former, numerous fossils, characteristic of the Fort Benton and Niobrara divisions of the Colorado, were found by Mr. W. M. Davis. They were—

Inoceramus umbonatus, M. & H.
Inoceramus problematicus, M. & H.
Inoceramus, sp. ? fragment of large sp.
Inoceramus undabundus, M. & H.
Ostrea congesta, Con. **d**
Ostrea strigilecula.
Ostrea, or possibly
Gryphæa vesicularis, M. & H.; cast only.
Gryphæa, sp.? This is what Meek called *P. vesicularis*. It is probably an undescribed species, as it does not seem to be vesiculose.
Gryphæa, sp.? shell resembling *Mactra Siouxensis*, Meek.
Exogyra, sp., possibly young of *Ex. costata*.
Gyrodes depressa, Conrad.
Naticopsis (gyrodes) depressa, M. & H.
Panopea, or *Glycimeris*, sp.? too indistinct.
Glycimeris, *Berthoudi*, White.
Pinna Lakesi?
Pteria, sp., *P. linguiformis*, sp.? perhaps new. **e**
Pteria, sp.?
Pholadomya Berthoudi, White.
Cast of *Gasteropod* like *Turritella*.

Mr. Whitfield makes the remark that "the Cretaceous fossils are apparently all from a single horizon, and would be classed as No. 2", (Fort Benton) generally, although they partake somewhat of No. 3 (Niobrara), so that I am inclined to think that both horizons are here blended together.

About 50 feet above the principal coal-bed we find a heavy bed of white sandstone showing an outcrop of 20 feet in thickness, though in places broken down and disappearing altogether. At No. 29 in the figure there is a small outcrop of a chocolate-colored conglomerate, and indeed from here upward we find thin beds of conglomerate of fine composition, interstratified with coarse sandstones of the same color, with here and there in the series the **f**
usual gray and ferruginous sandstones similar to those occurring below the coal, the latter at times shaly and very argillaceous, and at times forming bold outcrops 30 to 50 feet wide.

The sandstone No. 30, about 400 feet above the coal, is usually exceedingly characteristic and persistent throughout the entire field, forming the first prominent and high ridge above the coal. It is of a dark chocolate color, rather coarse-grained, oftentimes containing small pebbles of the size of a French pea, very hard, and breaks uniformly into small and very sharp angular fragments of an inch or two in diameter, and usually forms a broken-down but prominent outcrop of fine pieces, strewn over a width of 30 feet or so, upon which very little vegetation grows—mostly cactus, a few tufts of bunch-grass, and a few low-flowering plants. It consists largely of volcanic materials. It is most peculiar, is easily recognized, and has the appearance at times of having undergone the early stages of metamorphism, though the cause still remains undiscovered. No. 32 is a fine-a grained yellow sandstone overlaid by more shaly varieties. Above this, even to the summit of the high outlier on the meridian, north of the railroad, comes a succession of arenaceous shales, gray and ferruginous sandstones, weathering yellow, and forming numerous reefs of rocks in the ascent of the hill, and interbedded with these every now and then we find the dark chocolate, coarse sandstone, much harder than that of any other variety, and invariably forming bold combs, while at several horizons are to be found local beds of conglomerate with pebbles, from the size of a walnut down. As we reach the summit of all these outliers, the rocks are naturally more horizontal and across the synclinals are seen the same strata having an opposite dip.

The section taken at the lower cañon of the Yellowstone (Fig. 1, Plate LVI) may also be taken as representative of the coal-bearing Cretaceous strata, though outside of the limit of the field proper, which embraces only such b an area as covers the paying portions of the coal-beds. In this section the coal has been found near the horizon of No. 30, and crosses the river and continues eastward at about the same distance from the limestones of the Jurassic. It is observed that much of the upper portion of this section was covered, but the unfilled spaces are undoubtedly occupied by the arenaceous shales seen in the section of the coal-field proper.

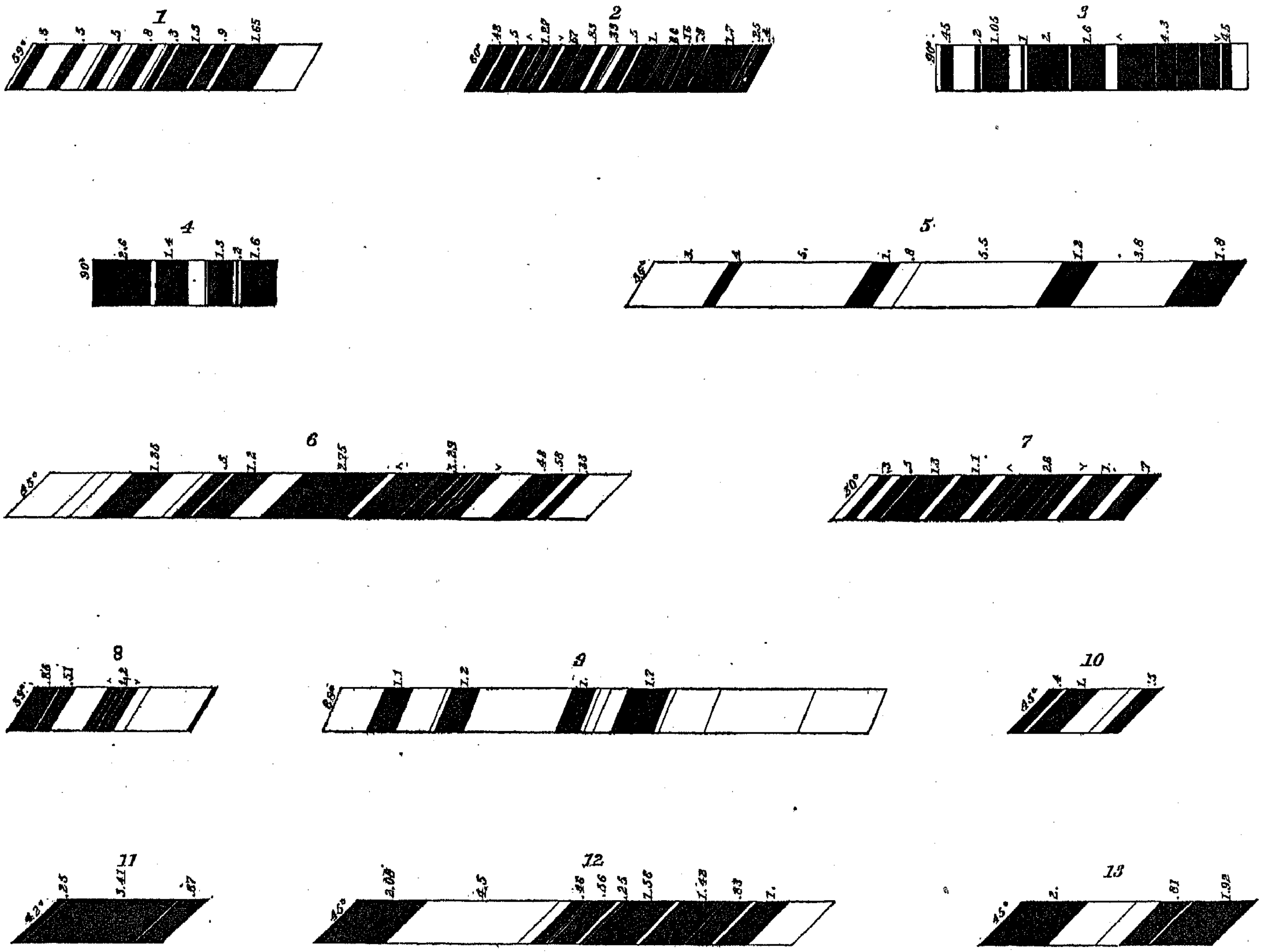
The strata in the vicinity of the Bridger range were too broken to admit of a valuable section being secured toward the determination of the horizon of the coal. In general, the succession and lithological characteristics of the beds were the same as met with in the Bozeman field proper. There are to be found at several points throughout the area covered by the map dikes of eruptive rock, of never more than from one-quarter to one-half a mile in extent and usually under 6 feet in thickness. They have not given rise to any serious displacement, though faults c having a small throw occur at other points, to be noted beyond, but without any accompanying eruptive rock.

The coal-seams.—In the Bozeman field there are three distinct beds of coal of noticeable size, with several insignificant layers of an inch or two, occurring in the midst of a brown argillaceous shale, containing an abundance of impressions of deciduous leaves. Of the more important ones the upper two, styled the A and B seams, will best be considered first, and, as they are separated from each other by only a few feet (from 10 to 15 feet) of interposed rock, they have been indicated on the map by the single continuous line. The outcrop of the seam pursues a very irregular line from the Yellowstone to the East Gallatin, bending around the depressed northern ends of the three anticlinal axes and extending well into the intervening and elevated ends of the two corresponding synclinal basins. Just south of the westernmost synclinal basin, and barely touching the map limits, on the road to the Yellowstone river via Trail creek, the field is continued in a small synclinal remnant of the original deposit, separated from its fellow north of it by reason of the inclination of its own axis in the opposite direction to the one d at the north, and a subsequent erosion of the strata to a depth sufficient to carry away the entire coal-beds for a distance of 3 or 4 miles between the two areas. This second area, which may be called the Trail Creek field, is of too small extent for large enterprises, is much pressed into subordinate folds, and is in a position accessible to a railroad only at the considerable expense always accompanying the overcoming of steep grades. The nature of the coal is precisely that of the Bozeman field, and hence it will be hereafter referred to only casually. In addition to the greater curves of outcrop due to erosion of upturned strata, there are many minor ones, which are the result of actual crumpling of the strata by forces acting laterally, but only in two cases was actual faulting observed. In one of these, on the northeastern dip of the western anticlinal, the throw is between 200 and 300 feet, while in the other, on the eastern side of the middle anticlinal, the throw is but 30 or 40 feet. Generally these subordinate curves are of too small extent to permit of representation on the scale adopted for the map.

e The dip of the beds varies throughout the field. In a general way, east of the range it is from 37° to 45°, and west of the range it varies from 57° to 80°; the folds being more abrupt and frequent. This field has been prospected by pits and tunnels quite extensively, and it is found that while the general dip remains as described, the beds are subject to slight variations in depth in all parts, and, of course, also where the strata contain minor folds caused by gentle lateral thrusts. In these cases, an incline or tunnel, will necessarily take in a portion of the wall—sometimes on one side, sometimes on the other.

There is another most important peculiarity in the behavior of the principal coal-seams, noticed in the eastern portion of the field. The surface of the ground on which the coal-bed was originally laid down is most irregular. For a length of 2 miles at least, and for an undetermined width, but presumably covering quite an area altogether, the surface was covered with gentle undulations in the form of knolls, of varying and irregular dimensions f oftentimes extensive, oftentimes a few feet only either way, with no definite arrangement of the axes. In the hollows of these, overtopping some and only coming up on the sides of others, the material subsequently to be converted into coal was laid down, and finally came the roof of sandstone, capping the whole. These irregularities have furthermore been increased by disturbances in certain parts which have caused both rock and coal to be slickensided and rendered it extremely friable. To both these causes, but in this eastern part of the field especially to the former, is attributed the variation in width of the coal, while in other portions the variation is due more to the latter cause. The topography of the beds underlying the coal hence causes frequent rolls in the foot-wall, and has a most important bearing on the determination of the field. It naturally acts in depth as well as in horizontal extent along the outcrop, causing an ever-changing variation in the width and amount of coal. In fact, it was most satisfactorily proved that wherever such a condition of variation exists along the surface the same variation will be met with in sinking upon the deposits. It is by no means safe to be attracted by a large showing of coal in any

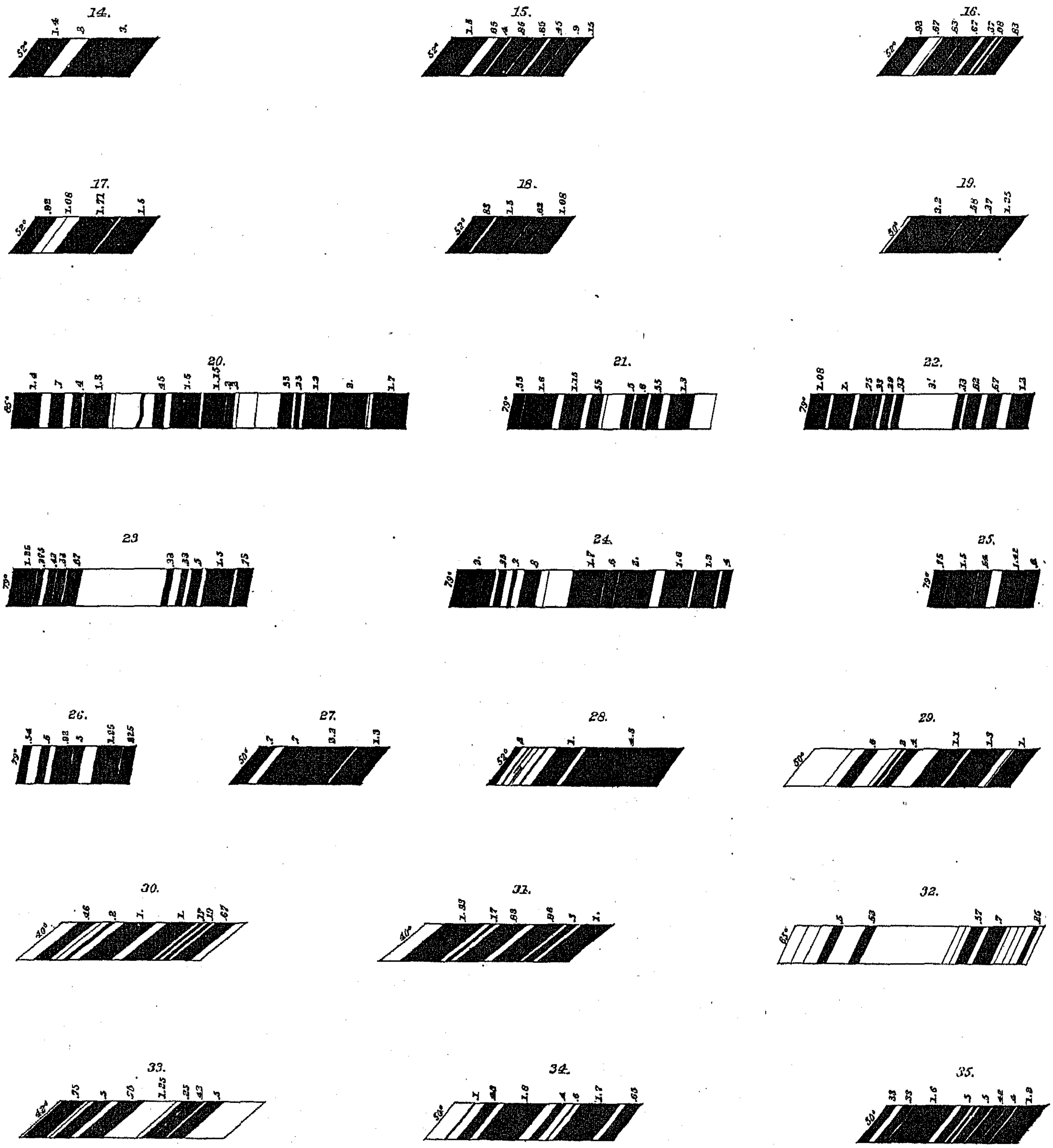
Plate LXIII.



From unpublished MS. material of the Northern Transcontinental Survey.

SECTIONS OF COAL-SEAMS IN THE BOZEMAN COAL-FIELD. By Geo. H. Eldridge.

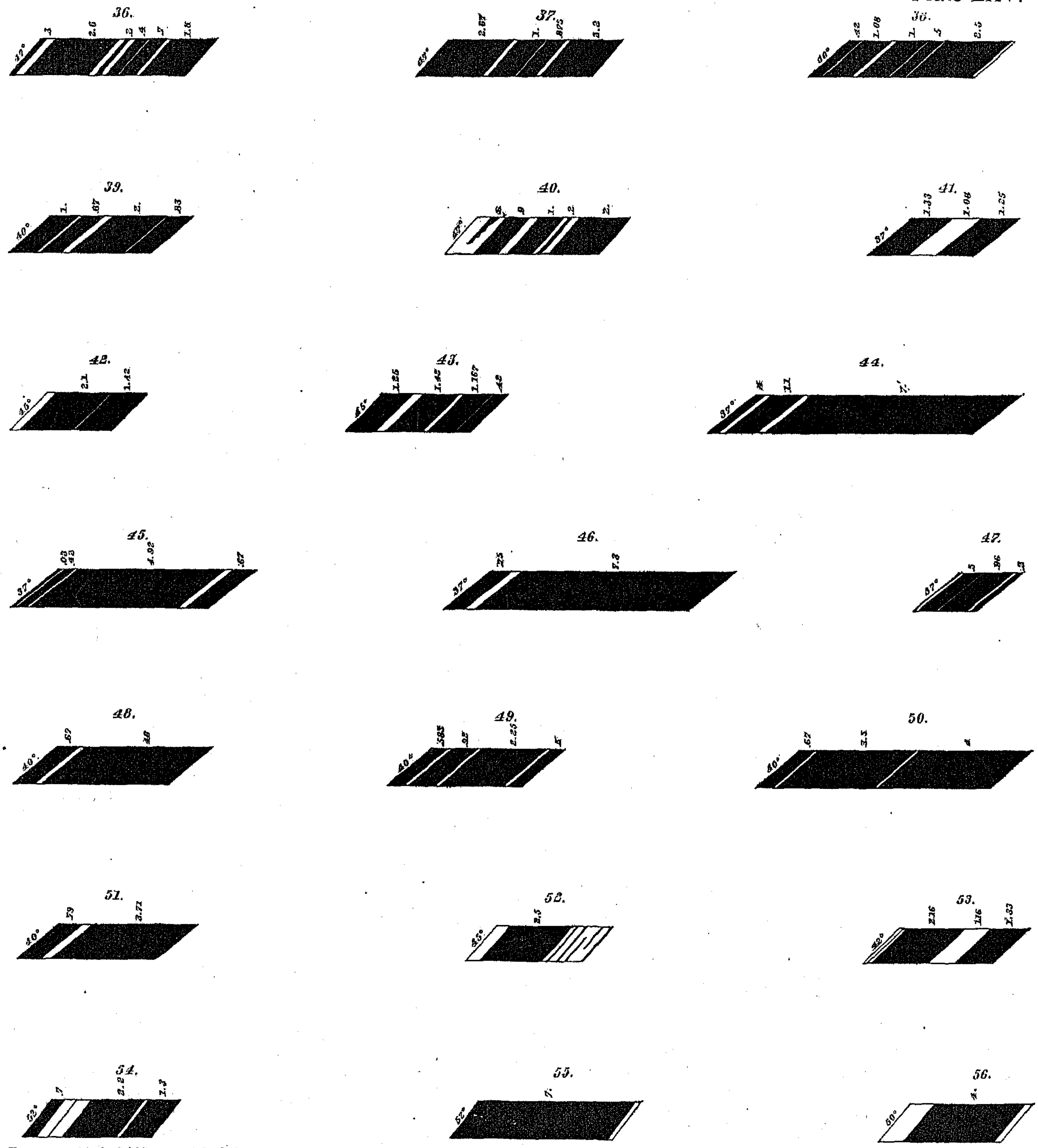
Plate LXIV.



From unpublished MS. material of the Northern Transcontinental Survey.

SECTIONS OF COAL-SEAMS IN THE BOZEMAN COAL-FIELD—Continued.

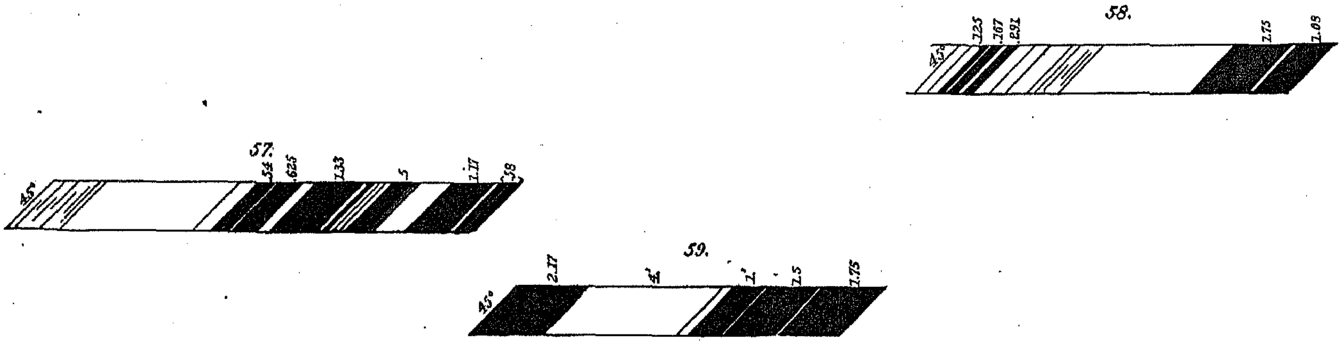
Plate LXV.



From unpublished MS. material of the Northern Transcontinental Survey.

SECTIONS OF COAL-SEAMS IN THE BOZEMAN COAL-FIELD—Continued.

Plate LXVI.



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SECTIONS OF COAL-SEAMS IN THE BOZEMAN COAL-FIELD—Continued.

part of this field without a corresponding knowledge of the surroundings. A most excellent example of this is a given in Figs. 49 and 50 of the Bozeman coal-field sections (Plate LXV), each 148 feet down the incline, the section in Fig. 49 being taken 30 feet east of the point at which 50 was taken. Within 40 feet farther east the coal entirely disappeared, there being in its place nothing but a brown lignitic shale, the ends of the shale and coal being dovetailed in together. In passing down the incline which opens this locality, there are several places where within 20 feet of an excellent thickness of coal there exists either none or only a few inches. In the other portions of the field the thickness of the bed is due to the usual causes effecting the deposition of the material, excepting where the coal is pinched out by a small fault or slip in the inclined bed itself. This frequently happens where slight movements have taken place, and is especially noticeable around the ends of anticlinals. The extent of the barren space is never over 20 or 30 feet, and usually under the former figure. The term "pinched out" is here used b merely to convey an idea of the appearance of the bed, and not as it is used in reference to metallic veins. The constitution of the two important seams of coal is well represented in the sections from different parts of the field. So great is their variation in their component parts that it is in places most difficult to determine which is the A and which the B seam, and it is especially so because where the one is developed to a large extent the other is often apparently of little consequence. Throughout their entire length the beds are composed of strata of coal separated from each other by layers of sandstone and arenaceous clay, which are at times perfectly free from all carbonaceous matter, and at others contain a very large percentage of such material, rendering the stratum jet black in color, but with the texture and appearance of sandstone or clay, as the case may be. Between these two conditions we have every gradation, but between the coaly sandstone or clays and the coal itself there seems to be no gradation c whatever. In other words, the Bozeman coal is remarkably free from what is ordinarily called "bone", and it may be noticed here that this is rather an advantage than otherwise, since should it be deemed desirable at any time to wash the coal, the difference in the specific gravity of the coal and sandstone would probably permit ready separation, which operation would be more difficult were the sandstone and clay replaced by bone and the various gradations between coal and a very coaly sandstone.

Of these bands of sandstone the thicker are of the greater persistency, oftentimes extending for a mile or two, while most of the thinner ones, of from one-eighth to one-half inch thickness, are of much less extent. All these bands vary in their thickness, narrowing and widening from point to point, but never entirely disappearing, for a thin paper-like leaf separating two strata of coal always remains. It must not be understood, however, that the stratification has no regularity whatever. Quite the contrary; for oftentimes the strata continue for several hundred feet with the greatest regularity. In illustration of what has been said in this connection, notice the d series of sections Nos. 14 to 19, inclusive, Plate LXIV, of the Bozeman coal-field sections, taken in a tunnel at the north end of the middle anticlinal, where the dip is 52°.

Fig. 14 is a section of the A seam at the mouth of the tunnel; Fig. 15 is 60 feet in from the mouth; Fig. 16 is 195 feet in from the mouth; Fig. 17 is 220 feet in from the mouth; Fig. 18 is 232 feet in from the mouth; Fig. 19 is from a surface-pit a few hundred feet south of the tunnel.

Again refer to the series Nos. 21 to 24, inclusive (on the same plate), representative of the workable seam on the east side of the middle anticlinal, and about one-half a mile south of the tunnel from which the sections above were taken.

Fig. 21 is a section of the seam at the mouth of the tunnel; Fig. 22 is 200 feet in from the mouth; Fig. 23 is e 300 feet in from the mouth; Fig. 24 is from a surface-pit 600 yards farther south.

This serves to illustrate the persistency, variable in width though they be, of the larger bodies of interbedded sandstone and clay, and the changeability of the smaller strata. Notice the increase in width of the central band of sandstone in section 23 over that in section 22. This would undoubtedly, at a distance farther in, have come down to its normal thickness as shown in section 21, as not only does no trace of its greater width appear in section 24, but also in driving the tunnel just such a change was encountered at a point somewhere about 100 feet back of this one. In that case, however, it was of only 25 feet duration altogether. As an illustration of variation in depth, notice sections 25 and 26, 20 and 33 feet, respectively, below the surface of the ground, at a point half a mile south of the last series of sections. The thin stratum of sandstone next the upper bench of coal has become very important, only 13 feet below, and another equally important one has come in in the meantime. Still another f variation is seen in sections 30 and 31, 30 and 71 feet down an incline in the bend of the synclinal between the eastern and middle anticlinals, where the dip is northward. As a final illustration in variation in the composition of coal-beds, notice sections 44 to 51 (Plate LXV), excluding No. 50, which has already been referred to above. Here the variation in width has confined itself to the coal, and is assignable in a great degree to the original topographical features of the underlying beds; whereas, in the other cases sighted, it has been due to the regular causes ordinarily influencing the thickness of deposition of strata, and which in such cases in this field confines itself apparently to the sandstone and clay partings.

Sections 44 to 51 of the B seam are representative of the deposit about 2½ miles east of the central meridian of the field, at the following depths in the incline sunk for prospecting purposes: Section 44 represents the seam at the surface; section 45, at the depth of 53 feet; section 46, at 60 feet; section 47, at 70 feet; section 48, at 80 feet; section 49, at 148 feet; section 51, at 280 feet.

a Between the depth of 80 and 148 feet, I think, the coal entirely disappeared, as already previously described, and on either side of this deposit, at varying distances of from 5 to 40 feet, for the entire depth of the incline, not a sign of coal existed. This state of affairs, alternate rich and barren portions, probably exists for a distance eastward from a point 1½ miles east of the central meridianal line of 2 or 3 miles at least. On the west of this, from the meridian eastward for 1½ miles, we find the strongest persistency in the width of the coal-beds, as shown in sections 36 to 40 (Plate LXV), which also undoubtedly holds for the depth, as section 37 is at a point 40 feet down an incline of which section 36 was the surface-pit. The same uniformity was observed at a depth of over 70 feet in the same pit.

The few places at which both the A and B seams are exposed are represented as follows: The A seam, in the eastern part of our field, is seen in section 52, the B being the one already discussed. The A seam, near the central
b meridian, is represented by sections 33 and 34 (Plate LXIV), the B being those already referred to, with one or two possible exceptions undeterminable. In the synclinal contour between the middle and eastern anticlinals, the A seam, of very short duration in its horizontal development, is seen in section 54 (Plate LXV); sections 27 to 29 (Plate LXIV) being of the B seam, each about one-half mile from the other. Around the end of the middle anticlinal, the A seam is represented by the sections 12, 13 (Plate LXIII), and 59 (Plate LXVI), the B by sections 56 to 58 (Plates LXV, LXVI).

Sections 1 to 10 (Plate LXIII) were taken along the outcrop on the eastern side of the western anticlinal, sections 6, 7, and 10 being south of the railroad, the others north. A most remarkable change in the bed is noticed in sections 4 and 5, in all probability of the same seam, at points 300 to 400 feet from each other. The coal of this anticlinal
c south of the railroad is rendered less valuable on account of the severe and frequent crumpling it has experienced, while at the north end of the same anticlinal it is of no value whatever, having almost entirely disappeared.

There is a third seam occurring some 300 feet below the two seams already described, which is only now and then of noticeable thickness. It cannot be considered workable as it is variable. Fig. 52 (Plate LXV) would be a fair representation of it where it occurs. The only localities where it has been observed are a quarter of a mile east of the central meridian and on the east side of the western anticlinal. In the synclinal basin between the middle and eastern anticlinals is a thick pocket of coal (section 55, Plate LXV), no trace of which is found 10 feet on either side. The clay overlying it was remarkably abundant in deciduous leaves, which were too tender to bear transportation.

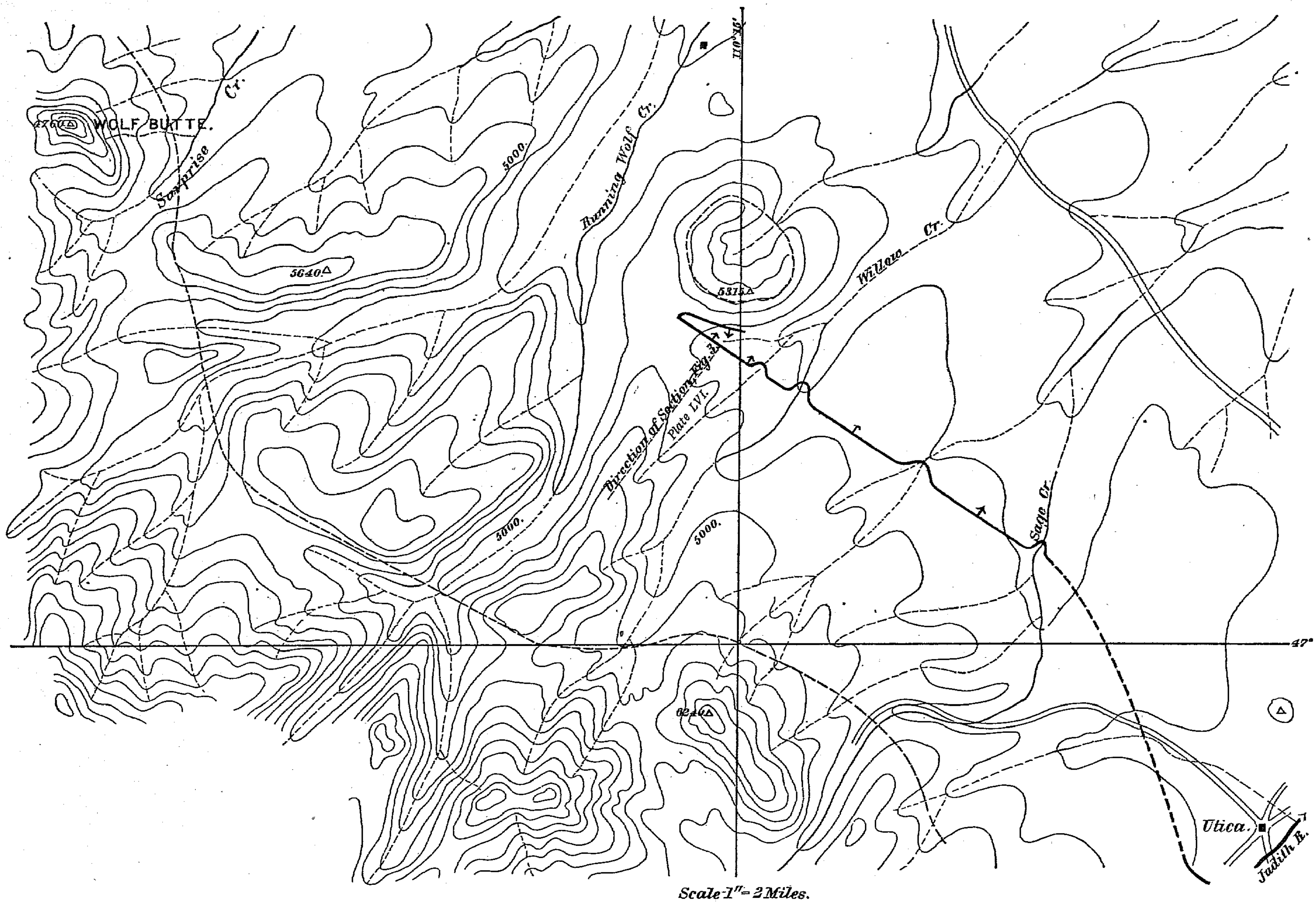
This rather lengthy reference to the various sections in the different parts of the field has been made as the experience gathered from these first explorations on the slopes of the strong upheavals of the Rocky mountains
d proper cannot but be of the utmost advantage in the future to those conducting explorations in other similarly-situated fields.

The physical characteristics of the coal in the Bozeman field divide it into two distinct varieties: a solid block or dicey coal coming down, if necessary, in pieces as large as the width of the seam will allow, and withstanding weather and transportation excellently; and a friable chippy variety coming out in lenticular masses, which, upon being allowed to remain on the dump or upon being transported, crumble into minute fragments an inch or so long by half an inch wide, and of a thickness of about one-eighth of an inch. Examination of these small pieces usually reveals a mass of thin, leafy laminæ of coal, one on the other, their edges overlapping. But at times instead of this we find a piece to be composed of infinitesimal pieces of the dicey variety, and when broken these small particles grit over the hand in the same way as does the ordinary dicey variety.

e The friable variety occurs at times where any sharp fold appears, though the dicey coal may also appear in like position, and also in the eastern part of our field from 2½ miles east of the meridian of 110° 45′ eastward to beyond the Yellowstone river. In this latter part of the field there are numerous slight folds, but it seems impossible that since we find the dicey coal, the usual coal, in positions quite as disturbed as this, this chippy texture should be due alone to disturbances in the inclosing strata.

Both varieties are bituminous and make a fair coke, though perhaps the friable coal gives a more uniformly excellent result. To the eye it appears more fatty, oily, and resinous, and of a more brilliant luster than the dicey variety, and soils the fingers much more. It is not at all uncommon to find short, thin, ⅛-inch streaks of resinous matter in it, scattered about over the face, which is not so uniformly the case with the jointed variety. On exposure to the atmosphere its oily luster gradually disappears. The streak is sometimes black, but usually a decided brown,
f and after a few days exposure much of the coal has taken on a distinct brownish-black color. Here and there, however, it, as an exception, retains its black color, though it loses its oily luster. This is especially the case toward the western limit of its occurrence, in proximity to the coal of a jointed structure. As we go eastward we find the brightness, and oily luster, and black streak giving place to a dead and dirty brown variety.

The dicey coal, of much the same appearance as the ordinary bituminous coal of the east, is met with everywhere west of the divide, or west of the meridian of 110° 45′. It can be mined in excellent shape for transportation, being very hard and solid, and consequently not only coming out in large blocks, but being capable also of easy separation from the sandstone and clay layers already referred to. The luster of the coal is bright and black, and the fracture perfectly regular. The coal throughout the entire field is very uniform in its physical characters, according to which of the two varieties it belongs. Nowhere are the compounds carrying sulphur to be found in any greater visible quantity than a small nodule of pyrite, or a few spangles of gypsum. There is



From unpublished MS. material of the Northern Transcontinental Survey.

MAP OF THE JUDITH COAL-FIELD, MONTANA. By Geo. H. Eldridge.

NOTE.—The heavy line shows the position of the coal outcrop; the heavy dotted line its approximate position.

therefore in this particular a vast difference between this coal and that of every other field in Montana that has a been explored, for elsewhere the sulphur-bearing constituents occur in conspicuous quantities, both in the direction of the lamination and in thin laminæ in the vertical joints and cleavage planes.

Both varieties of coal are most excellent for all blacksmithing purposes, but the dicey alone is superior for locomotive use. Its combustion is rapid and steam is quickly made. In giving the analyses, it may be said that the samples were most carefully taken with reference to both proving the practical value of the coal, and to bringing out any peculiarities likely to develop in the analyses as judged from its physical appearance. As necessity demanded, it was sampled bench by bench, or by the entire seam, excluding, of course, such portions as would be excluded in mining and shipping. By reference to the sections the exact meaning of each sample and analysis will be gathered. b

The northern coal-field.—This field may be considered as composed of two distinct areas, but of identically the same bed of coal throughout, though it has not been proved continuous, nor is it indeed probable that it is between that portion known as the Judith coal-field in the southwestern part of the Judith basin and that lying to the west, between the Missouri river and the Highwood and Little Belt mountains, and comprising the coals of Belt creek, Sand coulée, and Deep creek. The extent of neither field has been proved, consequently what is given beyond is merely the result of superficial exploration, superficial in both geology and topography. Our examinations have always been regarded in the light of preliminary work toward proving the presence or absence of valuable coals in these localities, and the results here presented will serve only as an excellent basis for further examinations in the future. The sketch (Plate LXVII) of the small area covered by our work in the Judith shows in the c southwestern part the northern slopes of the Little Belt mountains, and northward the edge of the far-reaching prairie-lands extending beyond the Missouri river.

The area southwest of the light dotted line, and also the center of the dome, a geological inlier at the western end of our coal field, are occupied by the pre-Cretaceous rocks, the Cretaceous strata occupying the remainder of the sheet. In this part of Montana the pre-Cretaceous rocks consist of Carboniferous limestones and Jurassic strata, without the development to any great extent of the quartzites met with beneath the Bozeman coal-field, the effect of which is to bring the Carboniferous and Jurassic limestones in close succession.

In the Judith basin, at the southwestern edge of the map, there occurs, in addition to the stratified rocks already mentioned, a narrow belt of granite, width undetermined, accompanied by a band of magnetic iron ore, the relations of which to the stratified rocks were, for various good reasons, left undetermined. The ore is steel-gray, strongly magnetic, unless, as in few instances, exposure to atmospheric influences has altered it to limonite. It d outcrops in heavy masses, from one-half ton to 20 tons weight, the outcrop varying in width from 2 feet to what would seem from the float to be at least 15 feet, though perhaps this may be too great a width. The question of width could only be solved by systematic prospecting. The trend of the ore-body is, as nearly as could be determined, about north 70° west. In the vicinity of the head of Wolf creek it was traced by float for 2 miles, but with an intervening space of a mile where it could not be found, owing perhaps to a cover of soil and *débris*. At one point on its course it was traced continuously for 3,000 feet. The guide who was with the party, and in whom every confidence as to truth in this matter can be placed, states that he has traced it for from 3 to 6 miles farther to the westward, or midway between the head of Wolf creek and the Barker mining district, seen on the general maps of the survey. Magnetic iron ore is also reported on good authority in the Barker mining district itself. e

The only other points at which iron ore was observed on the border of the Judith basin were in the Judith mountains, north of the Maiden mining camp, where is found also a limited amount of magnetic iron ore, together with a mass of bog-ore (limonite), resulting from the breaking down of the magnetite, which occurs higher up on the mountain.

The Cretaceous strata underlying the coal in the Judith basin are seen in the accompanying section (Fig. 3, of the geological cross-sections, Plate LVI).

(1) The Jurassic limestones.
(2) A rather coarse basal conglomerate, not over 5 or 6 feet thick.
(3) A thin-bedded yellow sandstone.
(4 and 5) Heavy beds of ferruginous sandstone, weathering a rusty yellow.
(6) A white sandstone, lower portion heavily bedded and forming an outcrop of 20 feet; upper part more shaly. f
(7) Gray and drab limestone, about 10 feet thick.
(8) Gray sandstone.
(9) Thin bed of coarse calcareous sandstone overlaid by red clays forming the top of the knoll; these overlaid at
(10) by a 2-foot bed of limestone.
(11) Sandstone, thin laminated, fine-grained, weathering brown.
(12) A white calcareous sandstone overlaid at
(13) by a heavy bed of yellow sandstone, weathering in huge blocks, and succeeded by a gray limy sandstone.
(14) The coal.

As already stated, the limestone (No. 10) with the thin bed of underlying red clays forms the most characteristic feature of this section, and in a general way this section remains the same, with perhaps local developments of interstratified clays toward the top, both in the Judith and Belt Creek areas.

a This section is referred to the Dakota on the ground of the unmistakable Colorado overlying it, but no fossils were found occurring in it in any part of our area of exploration. Furthermore, it is composed of the strata usually going to make up this group in the west, a basal conglomerate and heavy beds of ferruginous sandstone.

The line of outcrop of coal in the Judith basin is represented by the heavy black line. It lies out on the prairie at least a mile or two from the foot-hills of the Little Belt mountains. The portion of the outcrop traced, represented by the solid line, has a strike of north 56° west, the coal dipping to the northeast about 10°; but from the probability of the coal-opening on the Judith river being on the same seam, the outcrop evidently bends around with the mountains and takes about the direction of the broken line, with a corresponding dip to the east-northeast. At the western end of the line of outcrop, owing to the local upheaval of the small dome in that vicinity, the outcrop bends around
b this inlier to the eastward, with a corresponding dip to the southwestward, and the basin therefore receives its limit at the west by this disturbance. The prairies to the northward were not explored, owing to the lateness of the season, the press of still other field-work before the snows came finally, and the fact that it would not be well then to take any definite steps for the further development of a field which promised so brightly in the future. But from the large size of the coal deposit, from its general appearance of permanence, from its topographical position on the prairies away from the more disturbed regions of the mountains, from its continuance farther westward in the region of Belt creek and Sand coulée, there is every reason to expect at this point a coal deposit of at least fair extent. That the coal-bed suffers variation in its thickness, there is no doubt, as is shown by reference to sections 2 and 3 (Plate LXVIII), the former taken at the eastern end of the solid line, on Sage creek, the
c latter at the western end of the outcrop, near Wolf creek. This much knowledge, therefore, of the behavior of the bed guides us as to our expectations regarding the unexplored portions. From its slight dip the field can be most easily prospected, and the limits of its available coal well defined by drilling. The bed apparently thins out to the eastward, as is indicated from the outcrop on the Judith, given in Fig. 1, of the section of the northern coal-fields (Plate LXVIII).

The partings in the seam in this locality are much the same in general characters as those in the Bozeman field, but they contain much more argillaceous material. Where in the former field the partings, especially the larger ones, were composed of sandy constituents, producing a genuine sandstone, here the argillaceous materials largely predominate, forming a genuine slate, usually rather thinly laminated. The coal of this field also is bituminous.

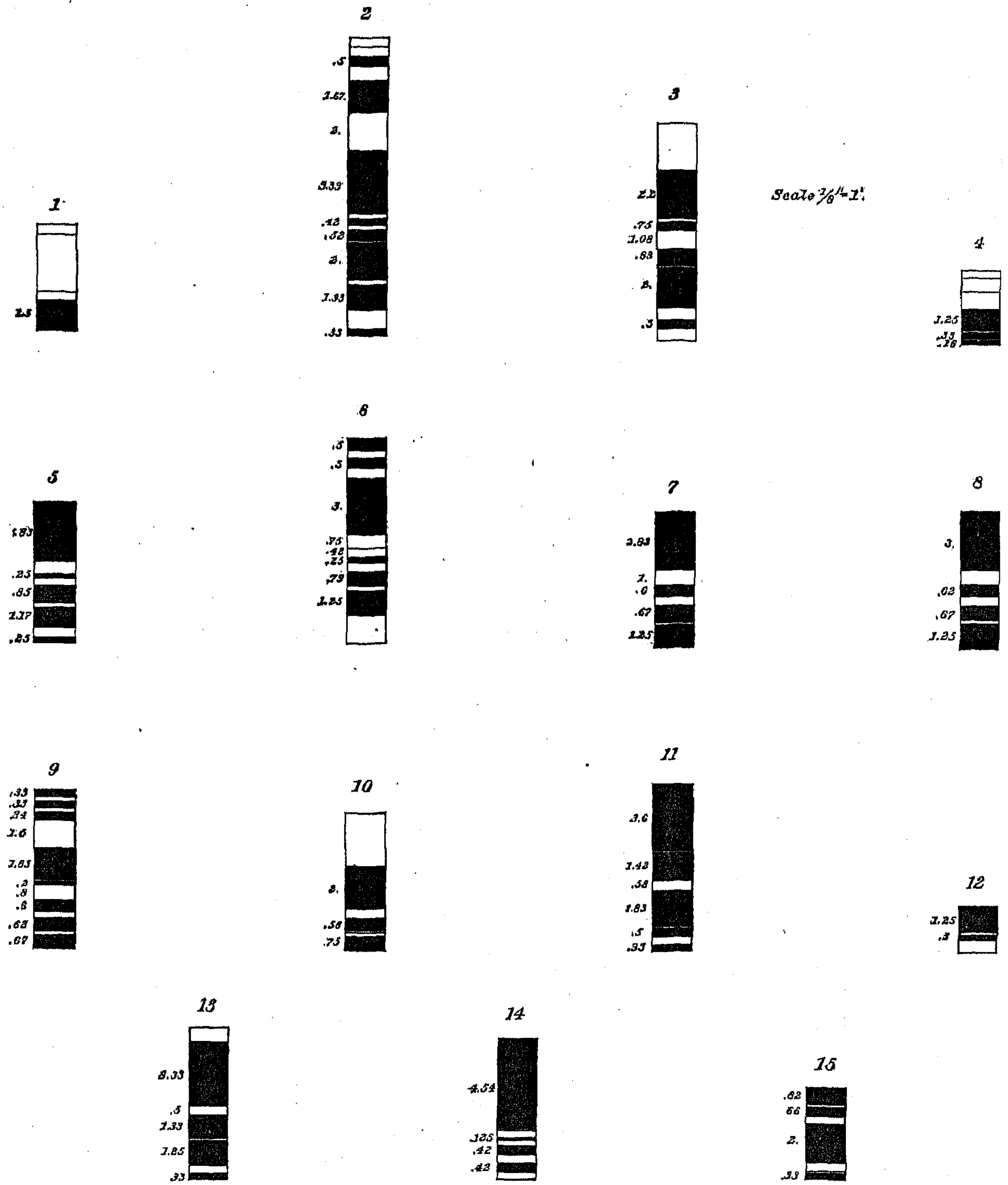
The one variety of *jointed* coal alone appears, the friable, chippy variety, noticed in the Bozeman field, being nowhere found either in this or in the Belt Creek field. The jointed coal of the Judith is of a bright, jet-black luster,
d oftentimes oily in appearance, having usually a brown streak, sometimes iridescent in spots or in layers, with a decided tendency to lamination, the laminæ being of variable thickness, but none over 1½ inch, the thinner laminæ having a fibrous structure, the thicker being more compact and homogeneous in texture, and having a very prominent conchoidal fracture, and generally occurring in a certain part of the bench, with coal of the fibrous kind both above and below it in the same bench. There is met with in this area, in the section from Sage creek (Fig. 2, Plate LXVIII), near the bottom of the seam, in the next to the lowest band of coal, opposite the figures 1.33, and constituting the lower 4 inches of it, a peculiar substance resembling a muddy coal, having a leaden or bluish color, cutting like graphite somewhat, *i. e.*, sectile, and decidedly heavier than the other coal of the bed. The analyses show it to contain from 10 to 25 per cent. more of ash than the other coal of this locality, the ash running from 22 to 37 per cent. The sample giving the latter figure (37 per cent.) was an extreme one, while that giving
e the former (22 per cent.) was in appearance much nearer the ordinary coal, and only had a slight bluish color on being freshly cut, and, furthermore, was not nearly as sectile as the other specimen. This peculiarity was again met with at the Ellis pit, near Mann's ranch, on Otter creek, of which Fig. 4 (same plate) is a section. The coal at this pit was of no value. The coal of the Judith gave no evidence of coking qualities upon analysis, but this may have been due to the fact that the samples were really surface samples, being nowhere taken at a depth beneath the surface of over 10 feet.

The sampling in this field was conducted on the same plan as that already pursued in the Bozeman field, and, indeed, in all the fields examined.

It may be remarked here in passing that besides the coal-field just described in the southwest corner of the Judith basin there are found wholly unimportant beds of coal in the eastern part, near the Judith and Snowy
f mountains, and in the high and much disturbed country connecting the two ranges; also on the eastern flanks of the Judith mountains.

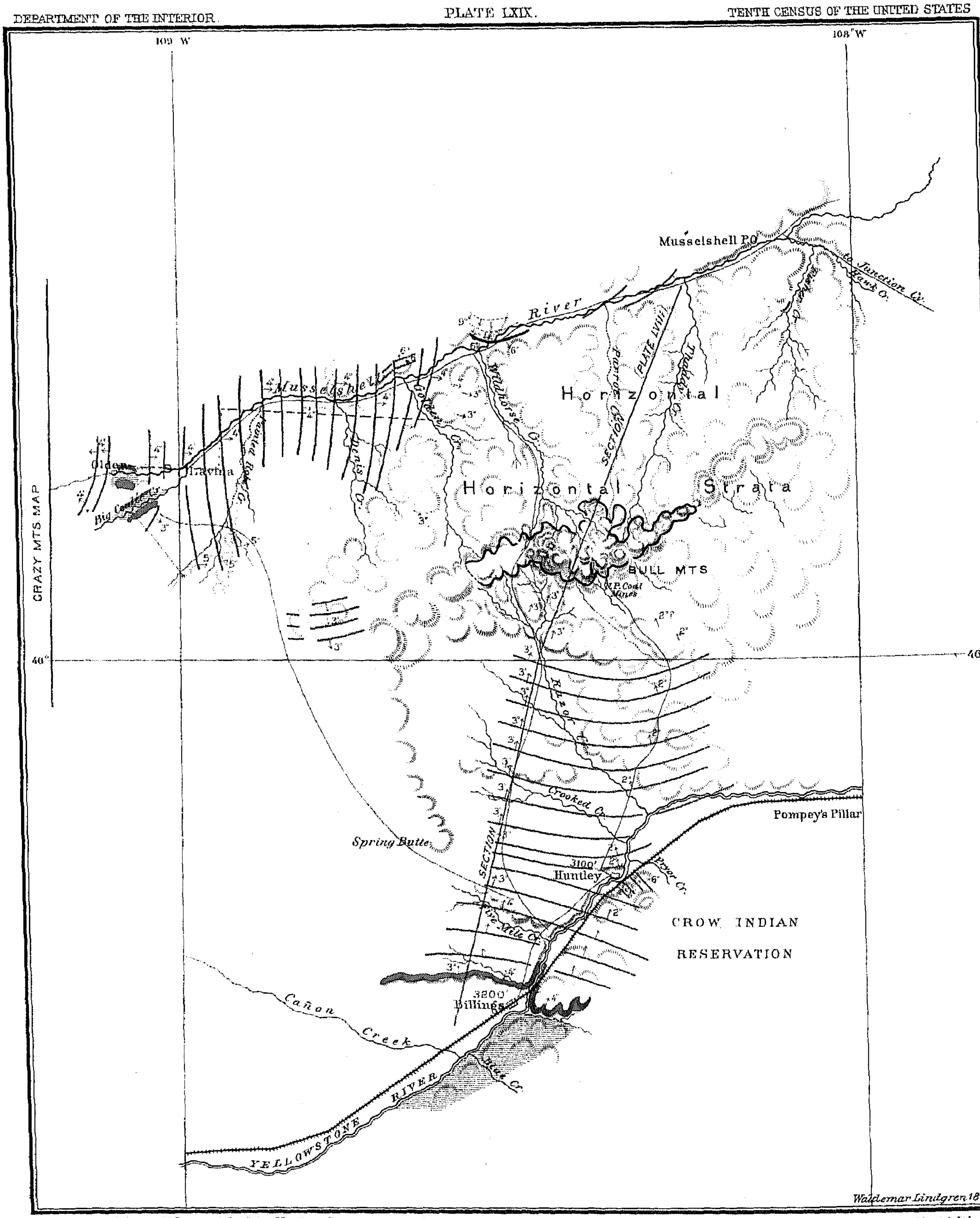
The general geology of the region of Belt creek, Sand couleé, and Deep creek has already been noticed in a casual way. The coal is at the same horizon as that just discussed, underlaid by much the same succession of strata, and overlaid by the strata represented in Fig. 6 of the geological cross-sections (Plate LVI), and given in detail on page 742. As in the Judith field, the coal lies on the prairie, a little farther out perhaps from the region of upheaved strata, and overlaid at a distance still more remote from the mountains by the dark shales of the Colorado group; but there has also been preserved, immediately overlying the coal on Belt creek, a landmark of erosion extending some 1,300 feet up into the Colorado.

The outcrop of coal has a general east and west course, with a northern dip, and skirts the edge of the prairies to the Missouri river, though at a point not determined, between Deep creek and the river, it probably runs nearer



From unpublished MS. material of the Northern Transcontinental Survey.

SECTIONS OF COAL-SEAMS IN THE JUDITH COAL-FIELD. By Geo. H. Eldridge.



From unpublished M.S. material of the Northern Transcontinental Survey. Julius Bien & Co. Lith.

BULL MOUNTAINS AND ADJACENT TERRITORY

Ft Pierre | Fox Hills s.st. | Lower Laramie | Lowest s.stone in Bull Mts series | Bull Mts series | Lignite

Scale 10 miles to the inch.

the mountains, until finally, south of Ulidia, at the Chestnut ferry, it partakes of their disturbances and loses much a of its economic value. The entire length of its outcrop cannot be far from 25 miles.

The seam is constituted much like that of the Judith. In fact, the remarks made concerning the composition of the bed and the physical characteristics of the coal in one locality are equally applicable to that of the other. The quantity of coal, perhaps, remains persistent over a larger area in this last region than in the Judith, and, perhaps also, there are generally fewer partings. It is certain that the coal lies more compactly in the Belt Creek field than in the Judith, the wide parting of slate in the latter being much reduced in the former, and the relative thickness of the upper and under benches has changed.

The bed has been much more extensively opened in the Belt Creek area, one or two mines here having supplied Fort Benton, on the Missouri, with coal for domestic and blacksmithing purposes for several years. The two lower benches, below the widest parting, in the immediate vicinity of Belt creek, are said to be especially good for b the latter purpose, and also yield a very fine coke. The universal opinion in Fort Benton is that this coal excels the Fort McLeod coal in British America, some of which finds its way into the Benton market by the return freight teams from that northern post.

In noticing the sections of these coals, Figs. 5 to 15 (Plate LXVIII, it should be observed that No. 12 is probably a section of a different seam from the large one here discussed, and overlies it. It is possibly only a local development, and of no value.

The amount of sulphur compounds appearing to the eye in the coals in this northern field is much in excess of that in the Bozeman field, and very much less than that of the Bull Mountain coal. In the Judith basin proper it is especially abundant in the unimportant seams occurring near the eastern edge, notably in the coals on Big Spring creek, where by far the largest amount observed in the coals of Montana was noticed. c

THE BULL MOUNTAIN COAL-FIELD.

Most unfortunately, the exhaustive explorations being conducted in the Bull mountains were brought to an untimely end by circumstances over which our survey had no control. Two months more in the field would have sufficed to complete the data for a valuable report on a valuable field of coal. As it is, however, the most northwestern extension of the field was left unsurveyed, though carefully examined, and the topographical and geological map of the entire field has been left uncompleted, owing to the disbandment of the survey. For reference and aid a small general map (Plate LXIX) has been constructed, which will, of necessity, have to answer our purposes. The geology of the Bull mountains has already been fully given under the description of the Upper Laramie in d Mr. Lindgren's notes. These additional notes on the topography of the mountains and adjoining country by the same gentleman may also be here inserted:

> The district examined is situated in central Montana, between the parallels of 45° 30′ and 46° 30′ north, and the meridians of 108° and 109° west.
>
> The Musselshell and Yellowstone rivers here for some distance flow nearly parallel, at a distance of about 40 miles. The valley of the Yellowstone is bordered by bluffs from 100 to 200 feet high. For miles northward the country stretches, a gently rising, hilly, dry plateau, only to be used for grazing purposes. The creeks carry running water in the spring only. About 24 miles north of Billings on the Yellowstone, the appearance of the country changes. It rises more rapidly, is cut up in high bluffs, deep gulches, or dry creeks; the ground is covered with thick grass and a quite abundant vegetation of pines; still it is very dry; the water-supply during the summer and fall is limited to a few springs. e
>
> This part of the country coincides very closely with the geological extension of the highest series in the Laramie, the Bull Mountain series. The center of this district, situated about 30 miles north of Billings, and 15 miles south of the Musselshell river, is occupied by a deeply eroded and cut mesa, the Bull mountains rising to 5,000 feet above the sea, or about 2,000 feet above the Yellowstone river at Billings. Westward, the divide between the Yellowstone and Musselshell has a southwesterly trend, and is yet for a distance of 30 miles from the Bull mountains covered with pine vegetation; from there, however, it lowers, and the bleak and barren plateau stretches between the two rivers. Eastward a narrow plateau, about 4,000 feet above the sea, extends for 10 miles; from there the country lowers considerably, but is still for a long distance occupied by the Bull Mountain series. The Bull mountains proper, that is, the highest 800 feet of the series, extend only about 10 miles east and west, and 5 or 6 miles north and south, and form, as already mentioned, a very much eroded and cut up mesa, separated on the outskirts into several square or pointed buttes.
>
> They are the last remnant of the enormous sheet of Laramie formation once covering the country. The erosion is going on rapidly. Deep, narrow gulches, square buttes, and horizontal, far-extending benches of heavy sandstone give a peculiar aspect to the country. These heavy beds of sandstone are not so easily attacked by erosion as the softer layers, and remain near the central mesa as horizontal benches, forming veritable natural contour-lines. Sometimes a local burning out of a lignite seam has hardened the overlying soft sandstones and imparted to them a deep red or yellow color. f

There exist in the Bull mountains many lignite seams, but the smaller ones having a development sufficient to be of economic value only here and there over the area, and the limits of their workable portions not having been determined, it is best to pass them over without further notice, and proceed at once to the examination of the only seam of large size existing in the region—the "Mammoth seam", as it has been called by way of designation. Furthermore, in view of the great thickness and uniform persistency of the Mammoth seam, the smaller beds of lignite, even where locally developed to a workable size, will not be touched for many years to come. The outcrop of the "Mammoth" bed has been traced every few feet for the entire circumference of the mountains, and but very few of its irregularities are now unknown to our party. On the general map it is marked by the heavy black line

a in the center, which is approximately the shape of the field, excepting that on Wildhorse creek it extends farther down (northward) than indicated, by some 3 or 4 miles, underlying the upper part of the divide between Wildhorse and Parrot creeks.

The coal lies nearly horizontally, but still, by close examination and comparison of the strata over wide areas, it is proved to occupy an exceedingly shallow synclinal basin, the shape of which is not positively determined, but it seems to have its center somewhere near the center of the mountains themselves, the strata dipping inward from the periphery, but never over 2° 30′. In other words, the Bull mountains constitute a geological outlier.

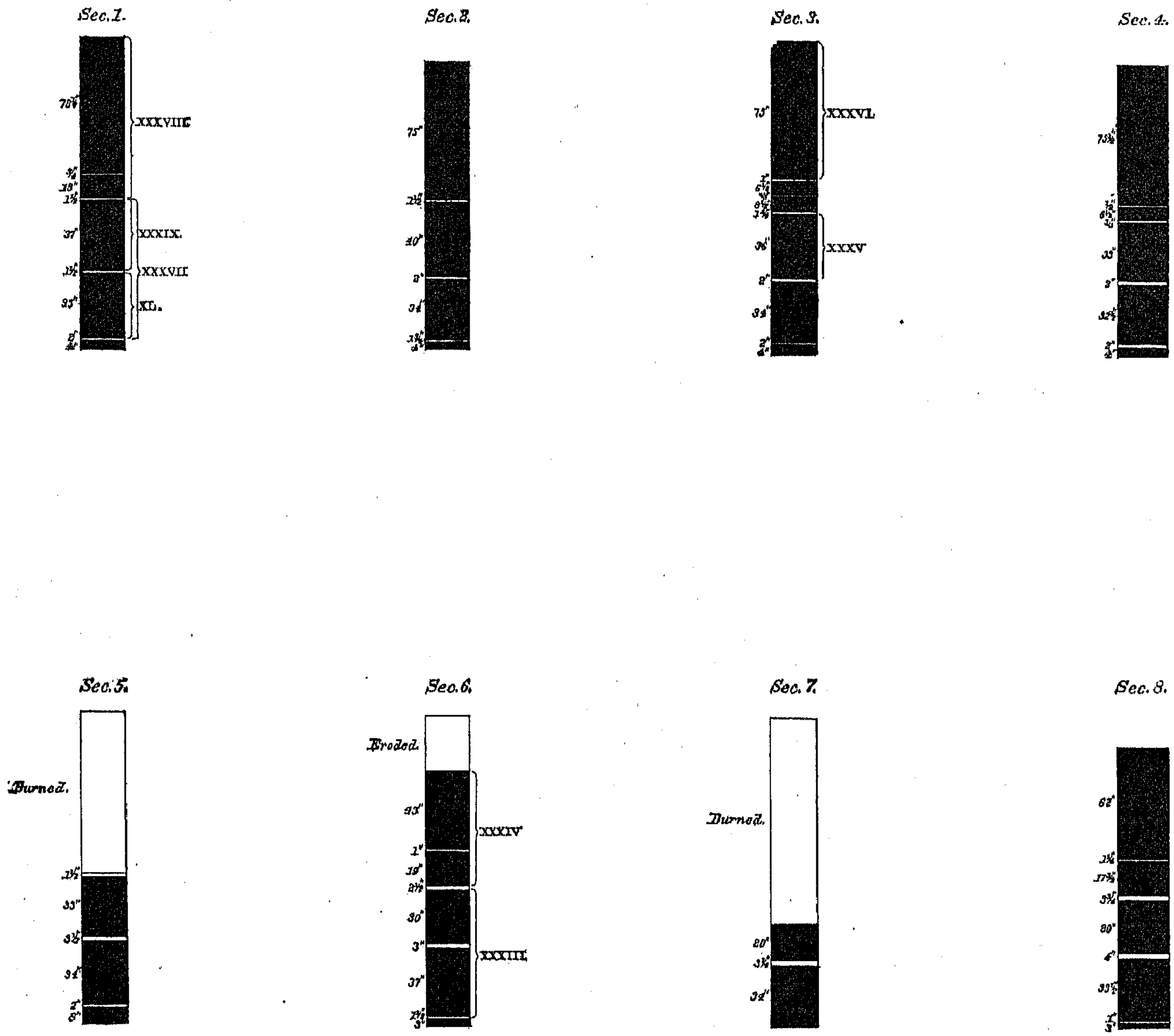
The composition of the bed will be best understood from the sections, following them in their order around the mountain. Taking as our initial point that designated on the general map as the locality of the mines of the **b** Northern Pacific Coal Company, we have, first, Figs. 1 to 4, inclusive (Plate LXX), covering a distance of a little over a mile along the southern front of the mountain. Following the bed to the eastward a mile and a half farther, Figs. 5 to 8 (Plate LXX), inclusive, the same general composition prevails. From our initial point *westward* for from 3 to 4 miles, Figs. 47 to 54 (Plate LXXIV), inclusive, but little difference in the number of benches and the width of the partings exists, though, indeed, the thickness of each bench of coal, especially those above the third bench from the floor (including the little 6-inch bottom bench), varies somewhat, the variation in the large upper bench making a difference in different localities of several thousand tons per acre. Thus, for a distance of from 6 to 7 miles along the central portion of the southern face of the mountains, we find a great regularity occurring in the composition of the bed. Returning to our easternmost point mentioned thus far, some 2½ miles east of the **c** location of the Northern Pacific Coal Company, at the section represented by Fig. 9 (Plate LXXI), we find the beginning of a marked change in the character of the bed. The central parting, heretofore from 2 to 6 inches wide, is on the point of a constant and rapid increase, until at the easternmost point of the coal deposit, and also of the mountains, Fig. 21 (Plate LXXII), it has attained the thickness of 50 feet, separating the bed, as shown, into two workable seams, averaging roughly 6 feet each.

Along the northern side of the mountains, passing westward from this point, this central parting decreases, until at a point directly across the mountains from the point of the commencement of its increase on the southern side, on one of the eastern branches at the head of Thaddy creek, it has again attained its normal conditions, the two sections of the bed being here separated by only from 2 to 4 inches of slate. For a mile and a half to the westward along the face of the mountains it now continues without any important change, when, in passing **d** northward and westward around the northern portion of the central part of the range, Figs. 27 to 32, inclusive, (Plate LXXII), this latter section being on the head of Parrot creek, and at least 3 miles in a direct line from the former, the same parting has again attained a thickness of at least 20 feet to again decrease, Fig. 36 (Plate LXXIII), several miles down the divide between Parrot and Wildhorse creeks, but still on the slopes of Parrot creek. For the remainder of the distance on this side, Figs. 36 to 39 (Plate LXXIII), inclusive, we have again the usual characteristic outcrop, excepting that the little 6-inch bench at the bottom has again disappeared, as is often the case on the north side of the mountains. On the opposite side of this divide, Fig. 40 (Plate LXXIII), *et. seq.*, in the gulches of Wildhorse, we find the seam considerably decreased in thickness, which condition seems to prevail in the low western spur putting out from the main body of the mountains, *i. e.*, on the head of the western branches of Razor and Wildhorse creeks. This decrease seems to be attributable to the absence or diminution in size of the **e** upper members of the Mammoth bed. This brings us around to the sections already noted, 47 to 50, and completes the contour of the coal.

Generalizing the preceding: The Bull Mountain plateau near its summit may be divided into a northern and a southern portion, the latter much the larger. The southern part lies on the divide between the Yellowstone and Musselshell rivers, and extends east and west several miles. The northern or smaller part lies between the heads of Thaddy and Wildhorse creeks, with a long spur running to the northward between Parrot and Wildhorse creeks. Under the high plateau in the center of the southern part, an area of perhaps 20 square miles, the bed attains its greatest thickness, and is most compact, the partings being of a minimum thickness; here the entire thickness can be worked at once. East of this, comprising an area of perhaps 12 square miles, the seam is split into two members, an upper and a lower, each of which must be worked separately. Westward from the central high plateau of the southern portion, for at least 3½ or 4 miles, and comprising an area of at least 12 square miles, the bed is undivided, **f** but has by no means its normal thickness as under the main mass of the mountains. Under the high plateau constituting the northern part of the Bull mountains, for at least one-half of its entire area of 12 square miles, the bed would have to be worked in two portions, by reason of the increase in thickness of its middle parting. The northern spur of this plateau, between Wildhorse and Parrot creeks, may in part be worked from one opening, and in part must be worked from two; these portions are about equally divided, and comprise about 10 square miles. It is estimated that this field contains at least 400,000,000 tons of available coal. In connection with this estimate, and what has been said of the areas, it must be observed that the figures are only roughly calculated, and that should time ever permit the plotting of the map of this coal-field they will be revised and corrected, since the data exist for a very close estimate; but the tonnage given is rather an under- than an over-estimate.

The physical characteristics of the Bull Mountain coals are the same for all the workable seams, that is the "Mammoth" and such parts of the two or three others as are of available thickness. The coal much resembles in

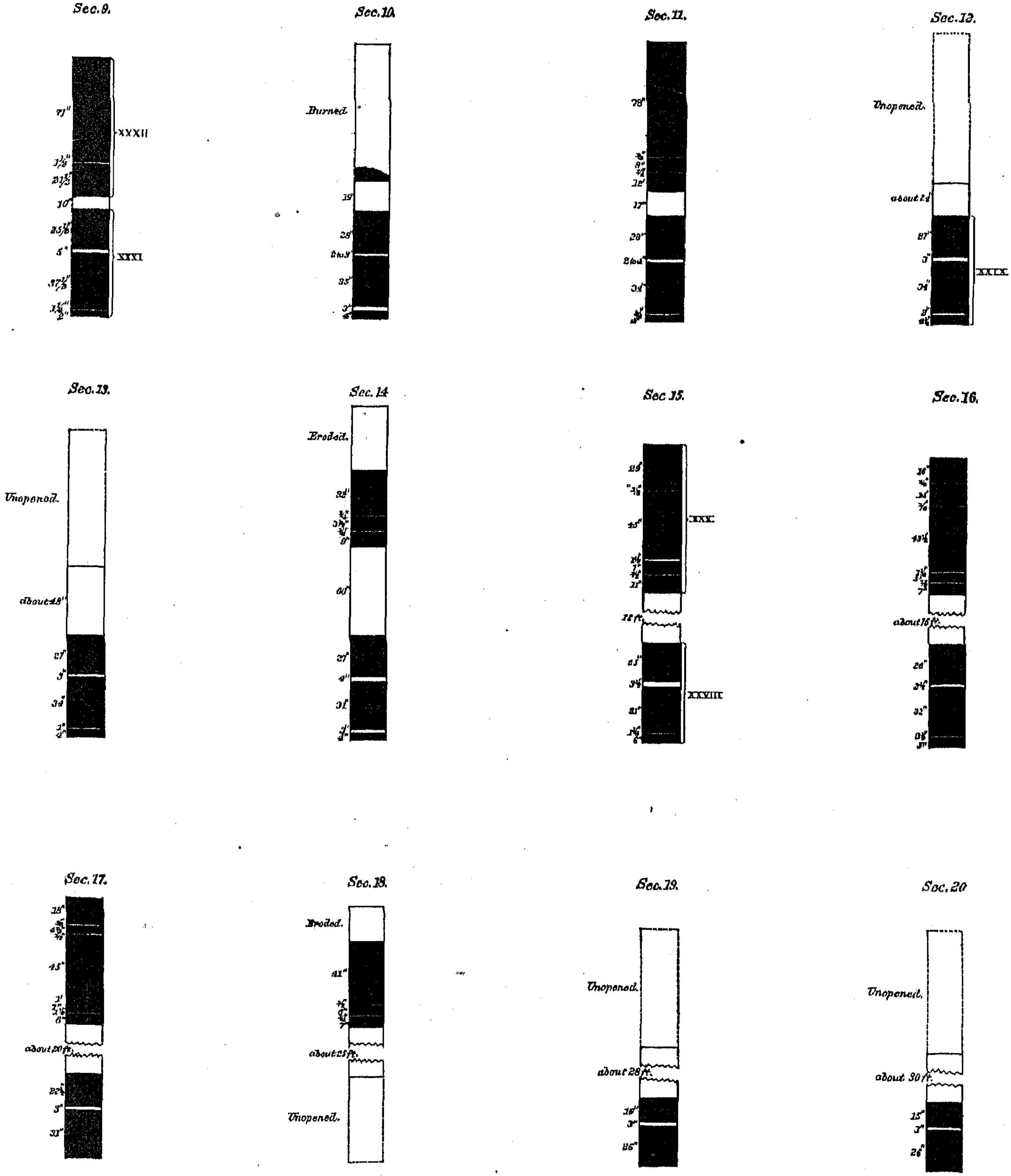
Plate LXX.



From unpublished MS. material of the Northern Transcontinental Survey.

SECTIONS OF THE MAMMOTH COAL-SEAM, BULL MOUNTAIN. By Geo. H. Eldridge.

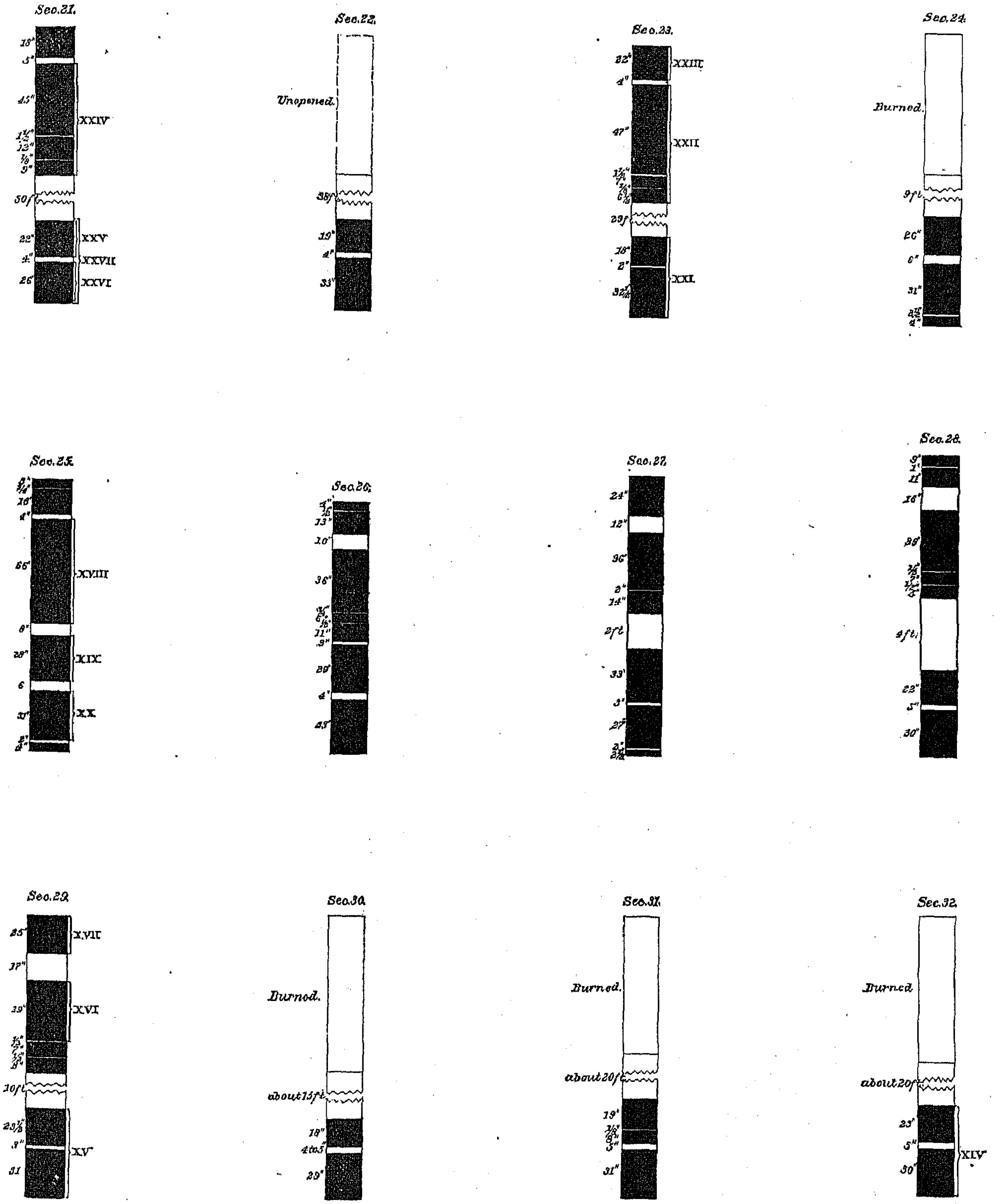
Plate LXXI.



From unpublished MS. material of the Northern Transcontinental Survey.

SECTIONS OF THE MAMMOTH COAL-SEAM, BULL MOUNTAIN—Continued.

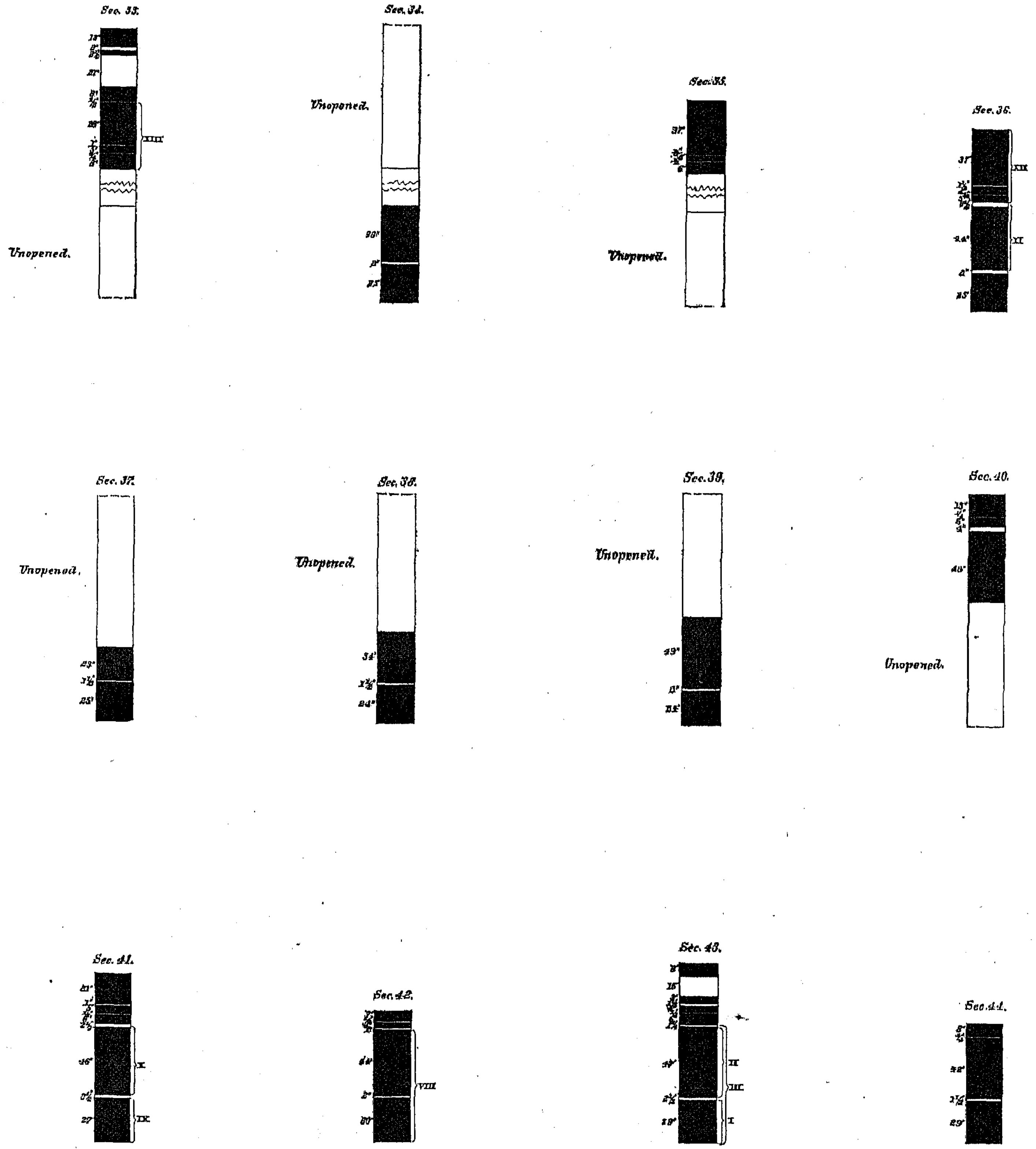
Plate LXXII.



From unpublished MS. material of the Northern Transcontinental Survey.

SECTIONS OF THE MAMMOTH COAL-SEAM, BULL MOUNTAIN—Continued.

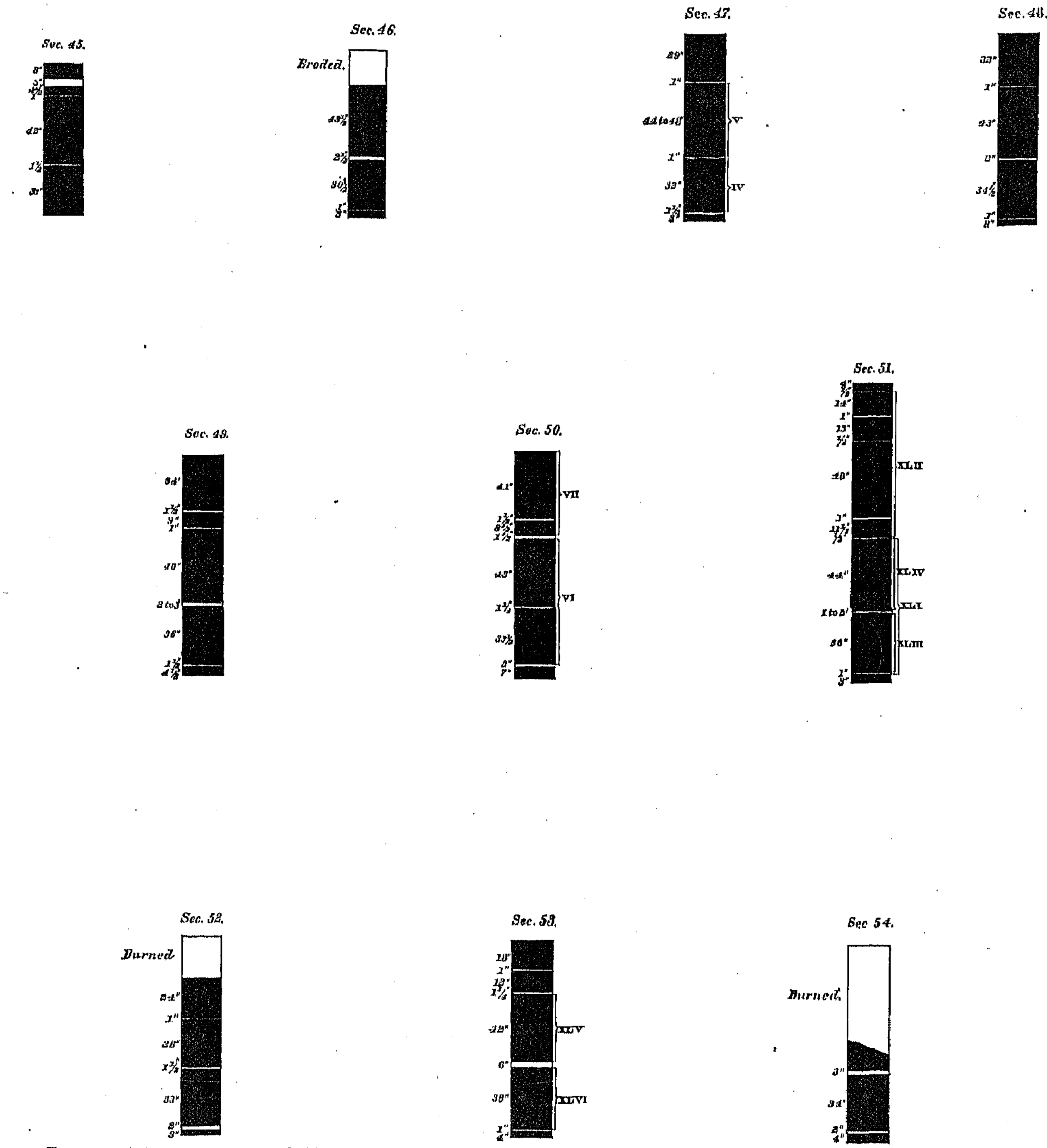
Plate LXXIII.



From unpublished MS. material of the Northern Transcontinental Survey.

SECTIONS OF THE MAMMOTH COAL-SEAM, BULL MOUNTAIN—Continued.

Plate LXXIV.



From unpublished MS. material of the Northern Transcontinental Survey.

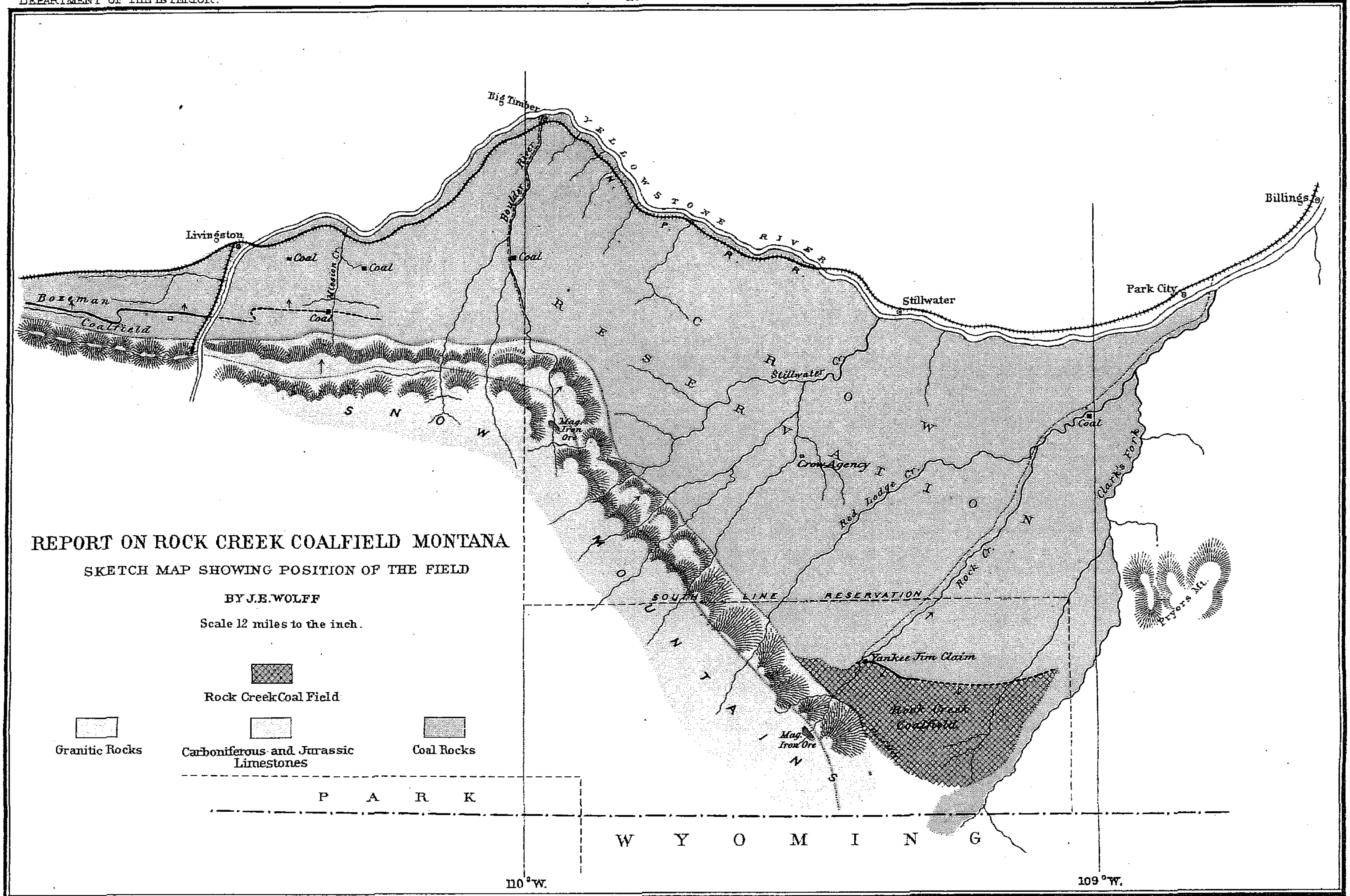
SECTIONS OF THE MAMMOTH COAL-SEAM, BULL MOUNTAIN—Continued.

REPORT ON ROCK CREEK COALFIELD MONTANA

SKETCH MAP SHOWING POSITION OF THE FIELD

BY J.E. WOLFF

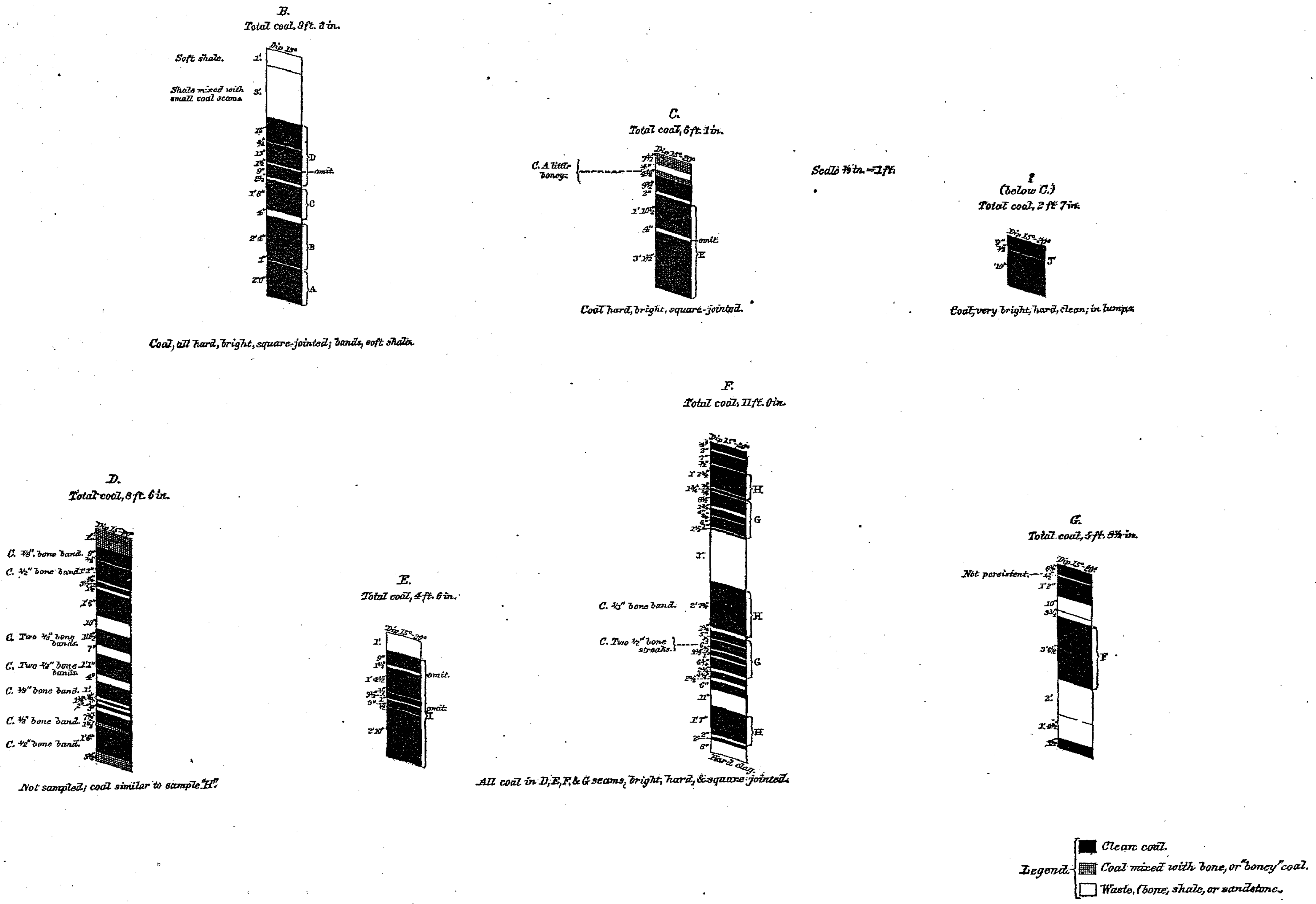
Scale 12 miles to the inch.



From unpublished MS. materiel of the Northern Transcontinental Survey.

Julius Bien & Co. Lith.

Plate LXXVI.

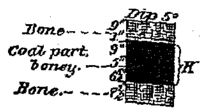


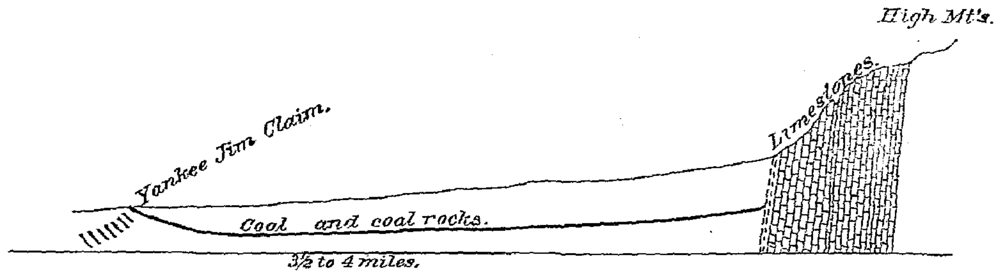
From unpublished MS. material of the Northern Transcontinental Survey.

SECTIONS AT THE YANKEE JIM CLAIM, ROCK CREEK COAL-FIELD, MONTANA. By J. E. Wolff.

Plate LXXVII.

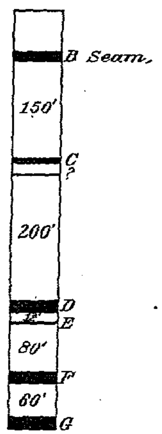
Section Coal found on Rock Cr. 16 miles from Park City.



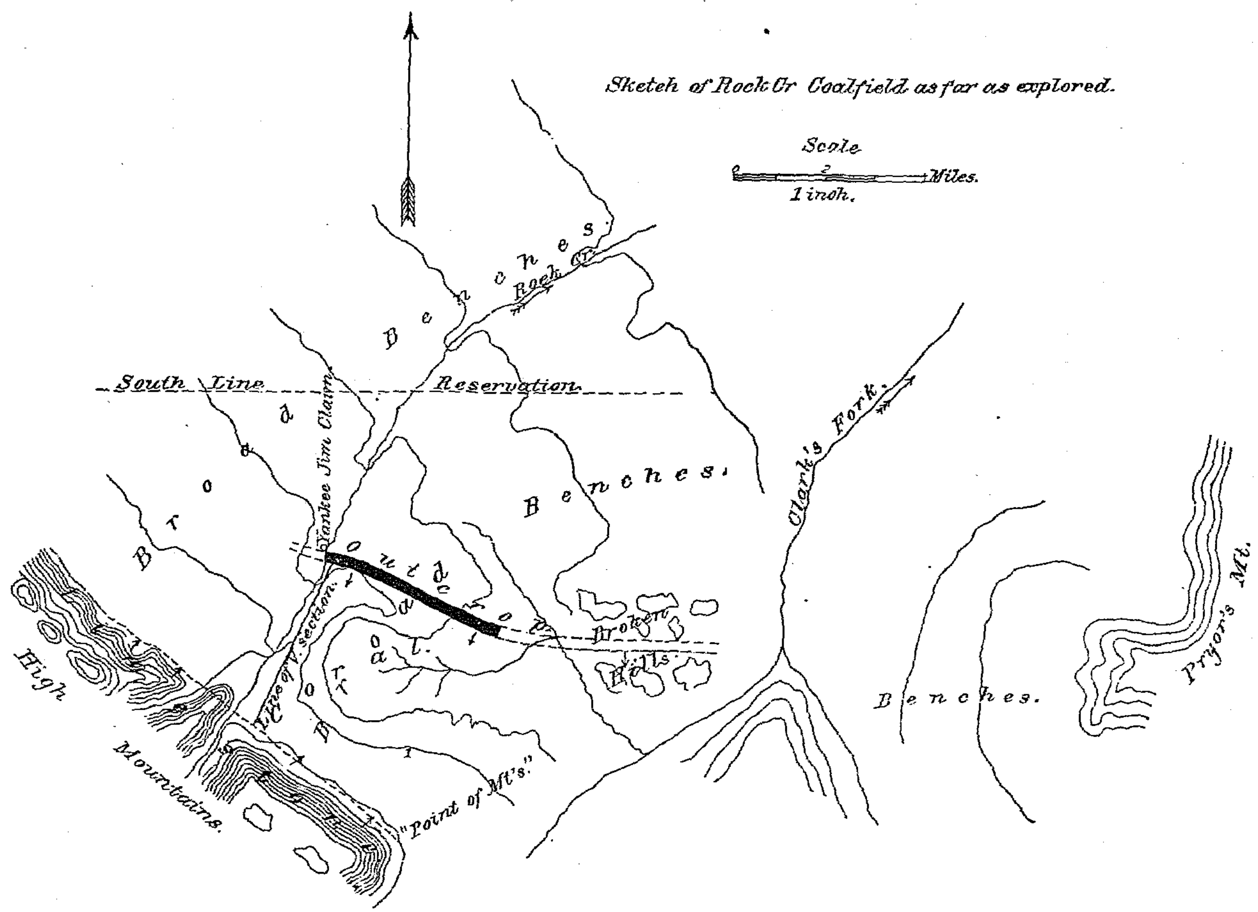


Vertical section across Rock Cr. Coalfield from Outcrop of Coal to Limestones.

Relative position of seams.



Sketch of Rock Cr Coalfield as far as explored.



From unpublished MS. material of the Northern Transcontinental Survey.

SKETCHES OF THE ROCK CREEK COAL-FIELD, MONTANA. By J. E. Wolff.

structure that of the Judith basin, but is, however, a decided lignite. It has a jet-black luster, at times dry, a
especially in the fibrous and more thinly laminated variety, at times oily, as in the more heavily laminated kinds which break with an irregular and distinct conchoidal fracture. Its streak is brown, its structure jointed. In mining it comes down in large blocks, which, on exposure to the atmosphere for three or four weeks, are easily reduced to small fragments by handling. It has, however, sufficient resistance to weathering to permit of its transportation over roads to remote points, and is in every way much superior to the lignites farther east. It is brittle and contains compounds carrying sulphur in large quantities, disseminated through the coal in lenticular masses and balls of pyrite, and in the vertical joints and between the laminæ, in thin laminæ of pyrite and spangles of gypsum. On weathering, the coal is very rusty from the oxidation of the pyrite, and white from the deposits of gypsum, which occur both in the crystalline form and also in a fine powder. On being burned, the sulphur-fumes are very strong and readily perceived. The vertical laminæ of pyrite occupying the joints of the b
coal are often very beautifully arranged, showing a network of layers crossing each other at sharp angles. They are generally very thin and often cut coal and slate alike, passing even into the bench of coal lying beneath the parting. Besides the pyrite and gypsum met with, thin laminæ of "mother-of-coal" are everywhere to be seen.

In passing over the field there is frequently brought to one's notice the numerous places in which the bed has been on fire, and in which it is at present on fire. When burning it is usually detected by the odor of smoke and sulphurous fumes pervading the air in the vicinity, and, upon examination, it shows the gradual breaking down and falling in of the roof, the brilliant red, yellow, orange, and brown stains from the oxidation of its pyrite striping the face, where exposed to view, most beautifully. Adjoining these brilliant colors, or occurring where they do not, we find an abundance of sooty matter, of a dirty-brown color, resulting from the burning of the coal itself, and often containing particles of coal which have not been completely burned; and it is worthy of note in passing that, at c
places, all that is left of 10 or 12 feet of compact benches of coal is from 6 to 8 inches of soot. As the support for the roof is thus gradually removed the sandstone and other overlying matter settles down in massive blocks, oftentimes large depressions occurring, which are quite *sui generis* and easily recognized from valleys of erosion. Nowhere have the fires extended over areas greater than a few thousand square feet, and usually they have not reached that extent. In some cases the fires are the result of spontaneous combustion, in others they undoubtedly caught from burning grass or stumps, which latter cause has been observed on the Musselshell during the present season.

The partings of the coal are usually slate, but the prominent middle parting, on increasing to its great width in the eastern and northern parts of the field, becomes a heavy-bedded, coarse-grained, white sandstone, weathering in rounded forms. d

The sampling of the coal was done in part by the writer, but chiefly by the assistant of the party, Mr. J. R. Williston, and was carried out in the same careful manner as was that in the other coal-fields in Montana. The samples are representative of the coal from the periphery of the entire field, and were taken in every case from a solid portion of the seam, at a distance from the surface beyond all influences of weathering, pits having been dug for the purpose.

The Rock Creek coal-field.—This field was explored and largely discovered by Mr. J. E. Wolff, assistant geologist of this division of the survey, and such parts of his report as are of general scientific value are here given:

The field lies at the base of the Snow mountains, the high range that extends 100 miles southeasterly from the Yellowstone cañon, near Livingston, and is about 30 or 35 miles due south from Stillwater, the nearest station on the Northern Pacific railroad. Its elevation above sea-level is about 5,700 feet, and above the Yellowstone river at Stillwater about 2,300 feet.

At what is known as the "Yankee Jim claim", on what we have designated as the B seam, the coal crops out in a bluff that rises e
about 100 feet above the creek-level. This seam was found partially opened at about 80 feet above the creek, but the other seams we ourselves discovered and opened in the bluff lower down. All are easy of access for working. There were found in all seven seams containing workable coal, in addition to several other smaller ones containing a foot or so of coal. In the sketches, Plates LXXVI and LXXVII, will be found sections of these seams. All of the coal is hard, bright, square-jointed, in appearance similar to the best coal of the Bozeman field, while none is of the soft, "chippy" variety there observed. The total thickness of coal in these seams is 46 feet 6½ inches, of which about 46 feet may be said to be ultimately available for mining, if it were desirable to work the coal in every seam. The largest single bench of clean coal (seam G) is 3 feet 6½ inches thick, but, as will be seen from seam B, a much larger amount of coal (9 feet 2 inches) can be mined from one opening with perfect ease and economy. The dip is low, from 15° to 20°, and within a few hundred yards from the outcrop toward the mountains becomes flat. Anywhere between this point and the mountains the coal would be found within a distance of perhaps 300 feet from the surface. The seven seams are contained in about 500 feet of measures.

All samples were taken under cover, but yet not far enough in to obtain the coal at its best, especially for coking tests. Sample J, in physical qualities, was the best coal I have seen in Montana. The D seam was not sampled, but the coal seemed similar to that in the f
F seam (sample H). Sample G was taken to test the value of the mixture of coal and bone represented in the F seam by that sample, which could not be separated in mining.

Circumstances allowed but a limited time for exploration of the area of this field. From the "Yankee Jim" claim the coal was traced 4 miles, nearly to the Clark's Fork bottom (Plate LXXV), and could be seen by the "lay" of the rocks to extend an unknown distance farther. Coal-croppings are found in these 4 miles, in a band nearly one-quarter of a mile wide, showing that a large number of seams extend this direction. Some natural exposures of the seams are found in the gulches, in one place about 3 feet of coal showing in one solid bench. These facts indicate, therefore, that the coal maintains its thickness and quality from Rock creek toward Clark's fork. Near the outcrop the coal dips toward the mountains, but it gradually loses its dip until at a distance of some hundreds of yards from the exposures it becomes flat, and so continues to the southwest border of the field, where it is terminated by a fault, bringing up the limestones (see sketch-map and vertical section, Plates LXXVI and LXXVII). By estimate the distance from the coal outcrop to the limestones varies from 3 to 4 miles, and therefore the approximate area of the coal-field, *so far as explored*, would be 12 square miles. If the whole area of coal, a lying flat, was worked, this would give, with 46 feet of coal, about 388,000,000 tons; or, saying that on an average half that thickness of coal were found, 194,000,000 tons of coal. This rough estimate gives some idea of the value of this field should it prove up as the prospects indicate.

A few words may be said as to the probable extent of this field and its connection with other coal-fields. It is the direct continuation of the Bozeman field, distant about 100 miles. The continuation of the Bozeman coal was found as far as Missouri creek, southeast from Livingston (see Plate LXXV). It is reported to crop again on the banks of Boulder creek, and from there runs down to Rock creek, following along the edge of the limestones. In short, the region from the base of the Snow mountains to the Yellowstone river, all the way along the range, is underlaid by coal at a moderate depth from the surface, the measures lying flat except where upheaved locally, and in general along the immediate base of the mountains. Constant discoveries of coal, therefore, are likely to be made along this range in the future. From the "Yankee Jim" claim, the coal, therefore, extends northwest toward the Bozeman field. Coal, rather "bony", was also found lower down on Rock creek, about 16 miles from the railroad. A section is given in Plate LXXVII. This is probably the same coal as that
b found at the "Yankee Jim" claim, in which case the other seams could be reached here only by boring. The good quality of the Rock Creek coal, its freedom from dirt, the number of seams, thickness of coal, thickness of single benches of clean coal, and flat position favorable to easy working, will probably place this field among the best, if not itself the best, yet discovered in Montana.

The last field of importance in Montana lies on the Upper Yellowstone, near the Yellowstone National Park, and was also examined by Mr. Wolff, with the following results, taken from his notes:

The Gardiner River coal-field (Plate LXXVIII).—This field is situated on the Upper Yellowstone, about 60 miles above Livingston and the Bozeman coal-field, and extends from the mouth of Gardiner river down the Yellowstone on both sides to within 2 miles of Cinnabar mountain. The river here flows in a general northwesterly direction, Bear Gulch creek flowing into it from the north and Gardiner river from the southeast, together with smaller creeks shown on the accompanying sketch-map.

The north line of the Yellowstone National Park runs from the top of Electric peak east through the mouth of Gardiner river, and
c the Coal Measures are found in the area bounded by Electric peak, Cinnabar mountain, Mount Evarts (in the Park), and the base of the mountains rising from the river on the northeast side, opposite Electric peak.

The coal, as traced by Mr. Eldridge a year ago, runs from Electric peak in a high spur of this mountain to Cinnabar mountain, but was not found to be of any value in that distance, the seams being small, none having over 1 foot 10 inches of available coal. The coal varies from a dip of 30° near Electric peak to almost vertical near Cinnabar mountain. South of the latter mountain it is opened in two or three places in the hills at the foot of the higher peaks and spurs. All the coal found in these low hills west of the river, between Reese's creek, Cinnabar mountain, and the spur of Electric peak is worthless for any extensive mining, for the formation is badly broken up by one extensive fault and several smaller ones, and dips in many ways, rising suddenly from a flat position to one almost perpendicular, etc. Sections 1 and 2 of the "Gardiner coal-field" (Plate LXXIX) are representative of the bed at the two principal openings on this side of the river, viz, at Major Horr's and Reese's, respectively. On the opposite or east side of the river is situated the only portion of this field that present developments indicate to be of value. Opposite Reese's ferry, a little back from the river, the coal croppings are found, one pit having been opened, affording the section given in Fig. 3 (Plate LXXIX). There are probably at least four seams of coal here, two close together, then about 150 feet of rock, then two more close together. The coal is of good quality, but just here worthless, for the
d reason that within a hundred feet or so the Coal Measures and coal are cut off by granite forming the base of the high mountains rising from the river, as shown in Fig. 6. About a mile up the river Messrs. Gourley & Gillis have opened the coal to a slight extent, their pit affording the section represented in Fig. 4. This shows some good benches of coal, which is also of a good quality.

Over a mile farther up the river, at Eagle creek, the croppings are found again, and continue for half or three-quarters of a mile until the coal crosses into the Park. Fig. 5 is a section taken from this locality, on the east bank of the Yellowstone, opposite the mouth of Gardiner.

The only valuable portion of this field (as far as present developments show) extends from a little below Gourley & Gillis' pit to the Park line, a distance of from 2 to 2¼ miles. Above and below Gourley's pit the outcrop is covered by trap-flows and travertine, and from Eagle creek to the Park line it is continuous. The Coal Measures, however, form only a narrow strip extending from the river back a short distance, probably not over three-quarters of a mile in greatest width, and generally much less. Except at the immediate outcrop the Coal Measures are covered by trap and travertine, and are probably cut off by a great trap-dike extending from opposite Cinnabar mountain to Bear gulch; hence even this portion of the field is of uncertain value, for it seems difficult to foretell how far the coal can be
e followed down from the outcrop before being cut off by trap. Nearly all the seams furnish coal of excellent quality, black, hard, and square-jointed, giving evidences of coking qualities, and the pits on the portion east of the river show a thickness which, though not large, could probably be profitably worked.

This coal all occurs above the Colorado.

Another totally unimportant coal area occurs 9 miles east of Gallatin city, at the confluence of the three rivers forming the head of the Missouri. The coal lies in a narrow trough, the greatest width of any seam being about 18 inches. It is, furthermore, of the soft, friable, and "chippy" variety already noticed in the eastern part of the Bozeman field. This area is of no consequence whatever from an economic point of view. From the scientific side it merely adds another locality to the numerous Cretaceous coal areas of Montana.

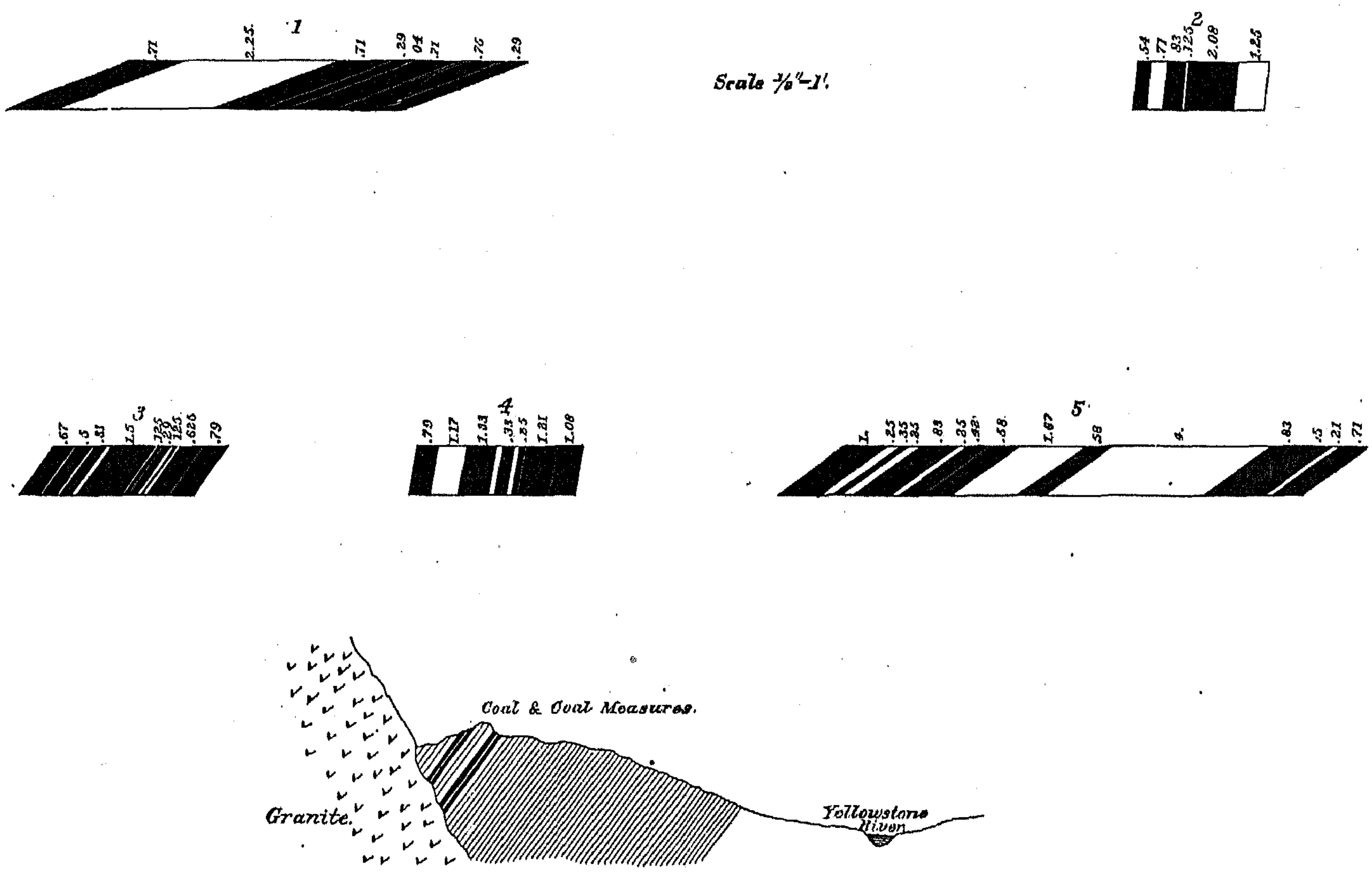
THE MOUSE RIVER COAL-FIELD OF DAKOTA.

f

By reference to our general map (Plate LV), the area comprising the coal in this locality lies from 80 to 150 miles or more north or north-northwest from Bismarck.

The coteaus of the Missouri of an average width of 35 miles are seen having a northwest trend. Eastward they blend by a gentle slope with the broad expanse of level prairie, relieved only in its monotony of landscape by a low hill rising here and there abruptly for a few hundred feet. The surface of the prairies have a gradual fall eastward, as indicated by the flow of the rivers. Small lakes, both wet and dry, and still smaller ponds, lie scattered over the area. The sharply eroded valleys of the Mouse, Cheyenne, and James rivers cut the prairie to depths of from 75 to 150 feet, their former broad channels now constituting the rich bottom-lands, cut in turn by the meandering narrow streams of the present day. Along the Mouse river there is a special feature of topography in the long line of low sand dunes rising on both sides the river near its great bend and eastward.

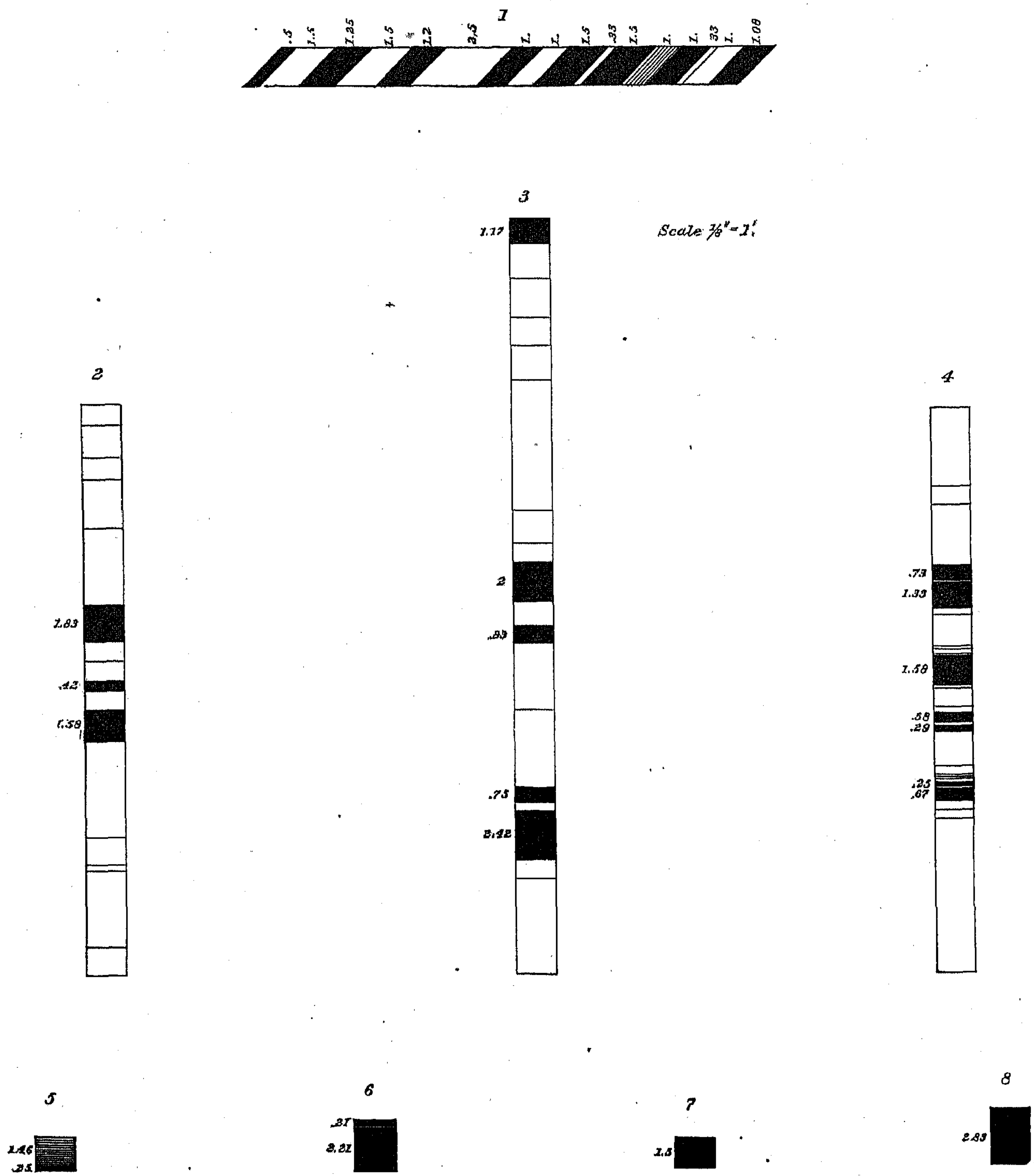
Plate LXXIX.



From unpublished MS. material of the Northern Transcontinental Survey.

SECTIONS OF COAL-SEAMS IN THE GARDINER COAL-FIELD. By J. E. Wolff.

Plate LXXX.



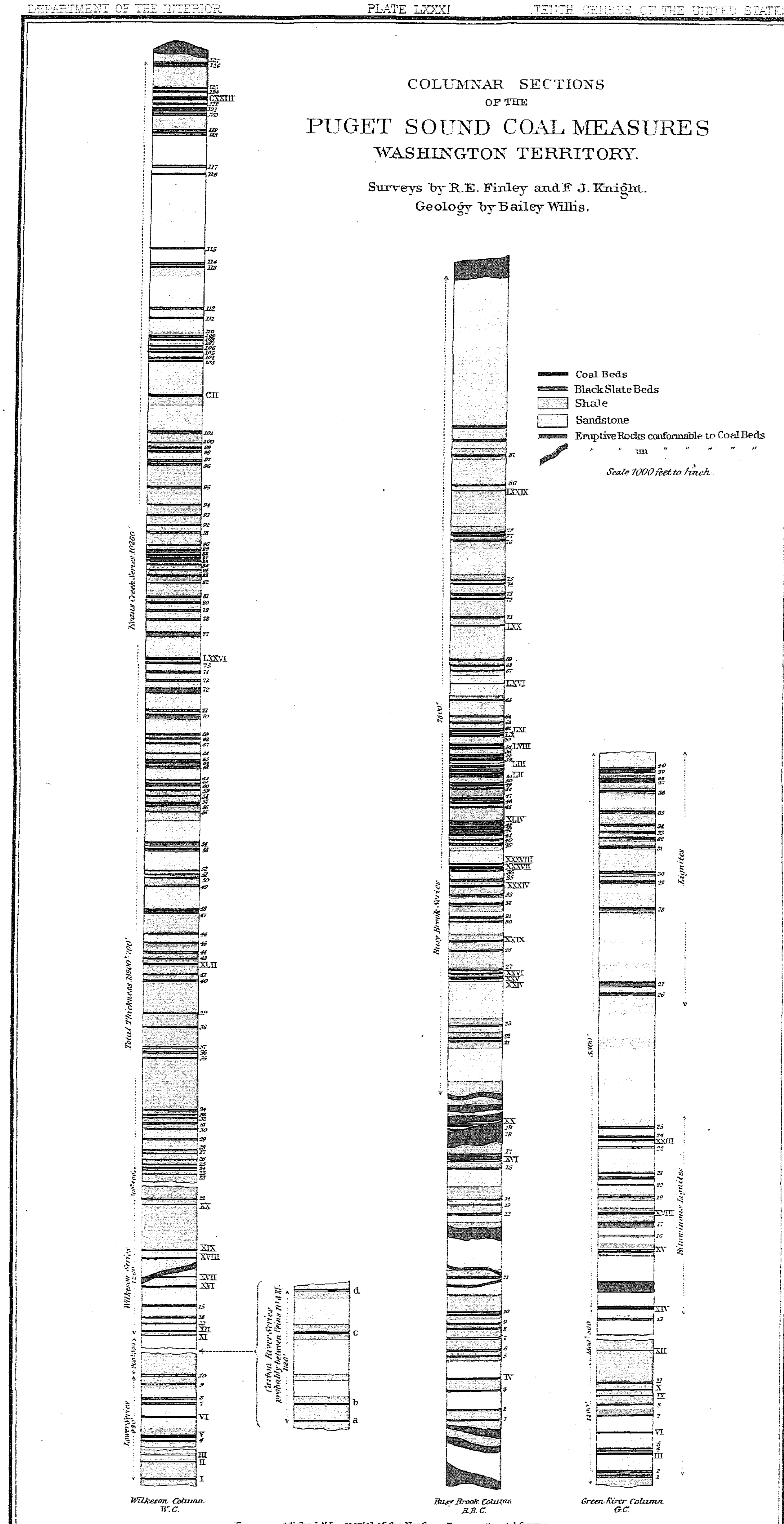
From unpublished MS. material of the Northern Transcontinental Survey.

MISCELLANEOUS SECTIONS OF COAL-SEAMS. By Geo. H. Eldridge.

The strata carrying the coals of this region may all be referred to the lower part of the Laramie group, upon **a** both lithological and palæontological evidence. They consist, in ascending order, of heavily-bedded, coarse-grained sandstones, of gray color, and often ferruginous, containing thin, paper-like seams of lignite, the whole weathering easily. These are overlaid by other gray and yellow sandstones intercalated with clays, the former somewhat argillaceous, the latter arenaceous. Above these last come other purer drab clays, with some beds of sandstone, the latter being very variable in texture and their ability to withstand the weather. Many of the strata have a strong tendency to a concretionary structure. In the uppermost series of strata, just mentioned, the coal-seams are larger and the underlying clays thicker, and invariably of a leaden-gray color, except where, here and there, they are tinged chocolate from the lignitic matter contained in them. All the clays form bold and steep bluffs, and are a noticeable feature of the landscape where they occur.

The Lower Laramie of this region contains only comparatively unimportant lignite-beds, the more important **b** ones occurring higher up in the series and to the southwest of our area of exploration, on the Missouri river, near Fort Stevenson and elsewhere, there being a dip of very slight amount toward a common center at Fort Union, forming there a great but very shallow synclinal basin.

The localities of the exposures of lignite are: 8 miles below the "Big bend" of Mouse river (Fig. 5 of the Miscellaneous sections, Plate LXXX); 25 miles above the Big bend, where the lignite is of comparatively fair quality, taken with the other lignite-beds of this locality (Fig. 6); another exposure of this seam a mile farther up the river (Fig. 7); 1 mile below the mouth of Lake river, a 6-inch seam, not figured; on Lake river, 40 miles above its entrance into Mouse river, a 30-inch and a 36-inch seam, the former very dirty, the latter much cleaner (the latter represented in Fig. 8 of the sections); with numerous thin seams of an inch or two scattered all along through the series. While, therefore, we have many seams of lignite, from one-half inch to 8 inches thick, **c** outcropping along the bluffs between the Big bend of Mouse river and the source of Lake river, and also two of a thickness of 2+ feet, but one workable bed of 3 feet was met with. The coal of this bed exhibits the usual characteristics of the poorer class of lignites, layers of the fibrous structure being intercalated with those of a homogeneous appearance and conchoidal fracture and a jetty luster. The entire seam contains much gypsum in the crystalline and powdered forms. The coal is by far the poorest observed during our explorations, and has no resistance whatever to the influences of weathering. It will, therefore, in all probability, never be used for other than domestic purposes by the future settlers of this river. Owing to the lay of the country, boring is the only means of determining the extent of any of the beds of lignite.


COLUMNAR SECTIONS
OF THE
PUGET SOUND COAL MEASURES
WASHINGTON TERRITORY.
Surveys by R.E. Finley and F. J. Knight.
Geology by Bailey Willis.
Coal Beds
Black Slate Beds
Shale
Sandstone
Eruptive Rocks conformable to Coal Beds
Scale 1000 feet to 1 inch
Evans Creek Series 10260'
Total Thickness 13900'-700'
Wilkeson Series 1260'
Lower Series 930'
Carbon River Series probably between Veins II & III
Bucy Brook Series
Lignites
Bituminous Lignites
Wilkeson Column W.C.
Bucy Brook Column B.B.C.
Green River Column G.C.
From unpublished MS. material of the Northern Transcontinental Survey.

REPORT ON THE COAL-FIELDS OF WASHINGTON TERRITORY.

By Bailey Willis.

GENERAL GEOLOGY.

The Coal Measures of the Puget Sound basin consist of alternating beds of yellow and gray fine-grained sandstones and very fine gray arenaceous shales interstratified with many beds of carbonaceous shale and coal; the individual strata of sandstone and shale, from 20 to 200 feet thick, maintain the same general character wherever observed, and no well-defined horizon has been found which might serve as an index to correlate the widely-separated exposures. Leaf impressions occur in both shales and sandstones associated with unios. Collections made by the Northern Transcontinental Survey have been submitted to Professor J. S. Newberry, who considers them the equivalent of the Laramie east of the Rocky mountains, and of greater antiquity than the Tertiaries of Bridge creek and John Day's valley in eastern Oregon; these collections relate, however, principally to the lower measures of the Wilkeson field of bituminous coal, and it remains to be seen whether further evidence, now being gathered, will sustain the inference, drawn from stratigraphical relations, that the lignites and bituminous coals belong to one age.

The thickness of the Laramie group, as determined by Mr. George H. Eldridge in Montana, is about 8,500 feet in the Bull mountains, and very much less near the old shore-lines. On the Pacific coast it greatly exceeds the above maximum, but it is not possible without further study to state even an approximate total, on account of the uncertain relations of the much-disturbed strata, obscured by volcanic flows, recent drift, and a dense forest.

The best sections are those obtained in the Wilkeson and Green River fields, and described in detail in their proper connection, though even they are incomplete; of these one gives a minimum of 13,200 feet, with a probable maximum of 14,500 feet; a second, still less complete, measures 7,700 feet; and the third, on Green river, lies between 6,200 and 8,200 feet; and these sections do not in either case reach the limits of the Coal Measures, as the base of each is an anticlinal axis and the top the highest exposure, geologically speaking, beneath the volcanic flows or drift-beds. Such figures challenge confirmation, but they are the result of accurate surveys and careful observation, and are only invalidated by the possibility of undiscovered faults, of which the sections have yielded no proof under close examination.

The fossils indicate the maintenance of fresh- and brackish-water conditions through this long period of deposition, implying that the general rate of this profound subsidence was the same as that of accumulation of sediments.

The circumstances of deposition were subject to frequent and probably often local changes; the preponderance of layers of fine sandstone, apparently derived from granite, suggests clear currents and pools, existing cotemporaneously with shallow waters and marshes, in which muddy sediment and peat accumulated; and the succession of sandstones, shales, and coal-veins in the column of strata indicate as many changes of depth and current over the same locality. In the first of the above-mentioned sections there are 127 carbonaceous beds, of which 17 are workable coal-veins 3 to 15 feet thick.

Outcrops of older rocks in the vicinity of these Coal Measures are usually of granite or crystalline schists, either serpentine or chloritic; in the San Juan archipelago there are evidences of Cretaceous strata, and a hint of their existence is found in some indistinct agatized casts, of oval cross-section and about 2 inches long, which were brought from a conglomerate on the upper Skookumchuck southeast of Tenino; they were unfortunately lost, but were apparently casts of baculites. These would seem to be the edges of a Cretaceous deposit, hidden beneath the more extensive later rocks. But one contact of the Coal Measures with underlying schists has been observed, and that is of uncertain character; its two interpretations are given in the accompanying diagram (Plate LXXXII). The first shows a plane of unconformable deposition tilted to a dip of 45°; the other presents the alternative of a fault.

a I was unable from the contact exposed to determine which view is correct, and I had no opportunity to trace it out. It is probable that the first coal-bearing rocks were laid down upon a surface composed of areas of granite, schist, and Cretaceous conglomerate.

The region over which this deposition occurred has since been the scene of mountain-making upheaval, of stupendous volcanic eruptions and enormous erosion, both glacial and subaërial. The definition of its boundaries and extent is a correspondingly difficult, perhaps in some directions impossible task.

Looking at the Puget Sound basin as a whole, the Coal Measures extend from beyond the British boundary south almost to the Columbia, and from the Pacific ocean eastward up onto the Cascade range to elevations varying from 800 to 5,000 feet above the sea; but buried on the one hand beneath recent gravel-beds, and overflowed on the other by erupted masses, the visible part of the formation appears as an interrupted belt along the base of the
b Cascades and encircling the Olympic mountains.

The Bellingham Bay lignite mines, which were known in 1851, and shipped 20,500 tons to San Francisco in 1869, but were shut down in 1878, are opened on an isolated outcrop surrounded by a region of forest-covered drift-beds. Their nearest associated coals are to the west, on Vancouver's island, and southeast at the "Coal mine", on the Skagit river, 40 miles from its mouth. The latter covers a small area south of the Skagit. It is bounded on the east by a contact with crystalline schists, which extend far northwest of Mount Baker; on the west and south by drift-beds, and on the north the coal is lost beneath the swamp-lands along the river. This coal is of bituminous character, and quite different in chemical composition from the inferior lignites which crop out on both branches of the Stilaguamish river.

From the latter, southward, there is a region little known geologically, over which the drift-beds extend up to
c the outliers of the Cascades, and the Coal Measures appear, if at all, only as a very narrow strip, until they are exposed in the cañon of Green river. Within this stretch, however, are the disconnected outcrops on which the Newcastle and Renton mines are sunk, 15 miles southeast of Seattle. Both of these mines produce an excellent lignite, which does not air-slack. Between them and the Green River field is the outcrop of a vein, called the McAllister, on Cedar river.

Green river cuts through the Coal Measures from east to west for about 9 miles, in a straight line, but much farther by the river, giving a section from the contact with eruptive rocks on the east to the drift-beds on the west. This section includes coals generally called bituminous, which produce a fragile coke, but have a lignitic luster, and very poor typical lignites, the latter overlying the former in the western portion of the section. The field is bounded north, west, and south by overlying drift, which extends 20 miles in the latter direction, to the most northern
d outcrops of the Wilkeson coal. This is a soft, coking, highly bituminous coal, jet black, and of cubical fracture, which produces a strong, close-grained, sonorous coke. Its general character is maintained throughout the field from Wilkeson south to the Nisqually river, about 24 miles, except where it is locally altered to semi-anthracite or columnar coke by the action of intruded rocks. The field is from 1 to 6 miles wide, and is limited on the east by the volcanic rocks of Mount Rainier and its lesser craters, and on the west by eruptive rocks, which 30 miles west of Mount Rainier form an unnamed group of mountains 5,000 feet high.

Still west of these little known heights, and south of Puget Sound, is the most extensive lignite area in Washington territory. It reaches from Castle Rock station, on the Northern Pacific railroad, north to the Sciatco mines on the Skookumchuck river, and northwest to the Olympic range, along the Upper Satsop river. Its eastern boundary is where the lignite measures join the volcanic rocks which separate them from the coking coal of the
e Wilkeson field, but the lignite remains unaltered up to the contact. The proximity of this field to the line of the railroad has led to its being carefully prospected. Wherever the veins have been opened they produce a bright, clean lignite, which air-slacks and possesses a low heating power.

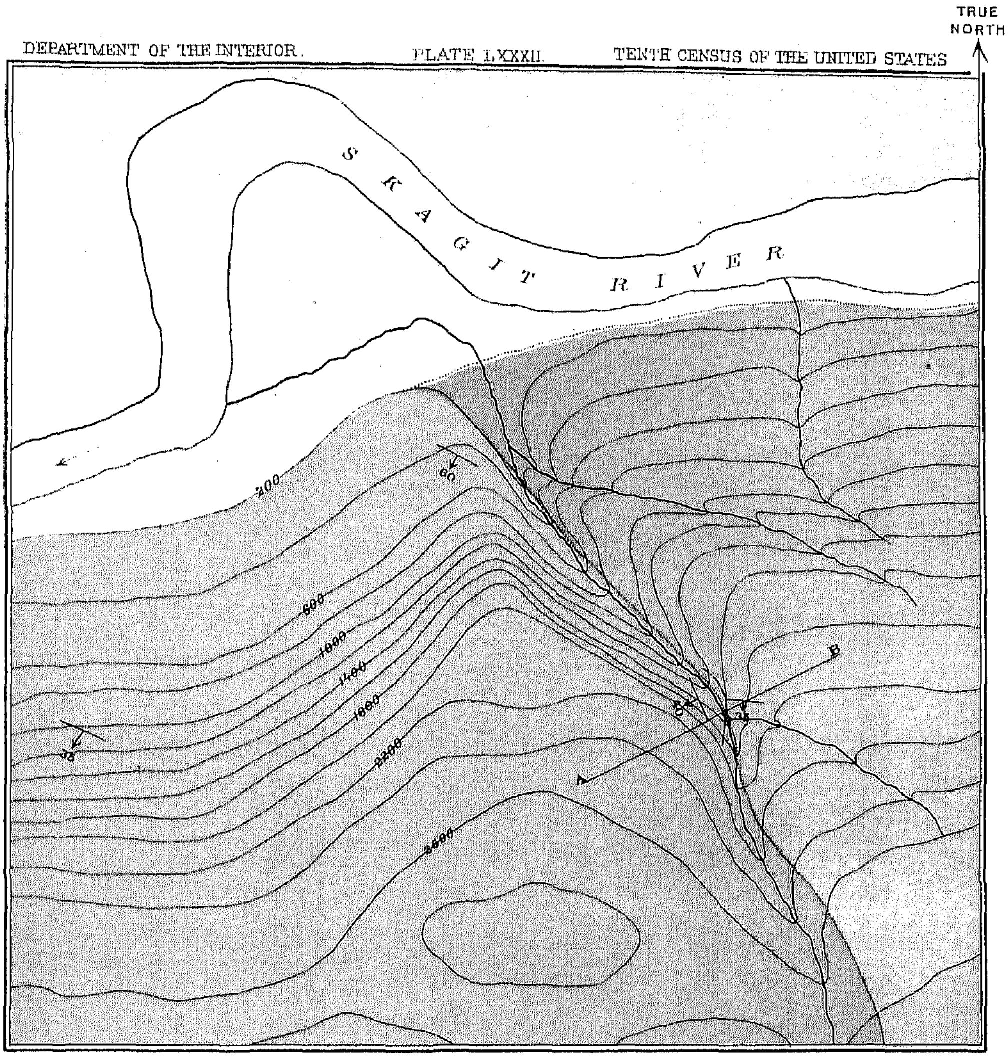
The Olympic range, composed of granite, crystalline schists, and volcanic rocks girt by recent drift, has been so little explored it is not possible to define the limits of the Coal Measures on its slopes; but besides the localities mentioned on the south and southwest, they occur on Clallam and Pysche rivers on the north, and probably at other points about the foot-hills.

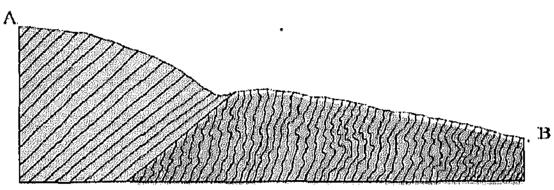
The geological section of the Puget Sound basin as developed in the exploration of these coal-fields may be provisionally stated as follows:

(1) Present surface of humus, accumulating from the beds of *Hypnum splendens* and the contributions of ferns,
f shrubs, and evergreens of the damp, luxuriant forest; average thickness probably 4 inches, though frequently wanting, where fires have occurred within two centuries.

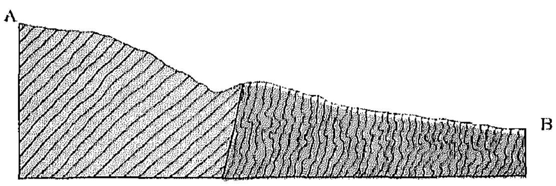
(2) Beds of coarse and fine gravel, sand, and clay, intimately mingled and distributed by swift currents; composed almost wholly of hard volcanic material, highly polished, and sometimes striated. These drift-beds fill the deeply-eroded valleys of all the rivers entering the sound to an unknown depth; they form well-defined terraces at Wilkeson, 1,600 feet above the sea, with a known thickness above the solid rock of 300 feet, and occur in terraces at an elevation of 2,000 feet on the western slope from the Natchez pass.

(3) Tertiary volcanic rocks, which form the highest peaks of the Cascade range (Mount Rainier, 14,300 feet), and detached mountain masses and ridges. They occur as intrusive dikes in the Coal Measures, often with an appearance of conformability, and as flows beneath which the coal-rocks disappear.





UNCONFORMABLE DEPOSITION



FAULT

Drift.

Coal Measures

Schist.

Scale: 2" = 1 mile.

Topography by R.C. Templeman. Geology by Bailey Willis.

CONTACT OF COAL MEASURES AND SCHISTS NEAR SKAGIT COAL MINES, WASH. TER.

From unpublished M.S. material of the Northern Transcontinental Survey.

Julius Bien & Co. Lith.

(4) The lignitic and bituminous Coal Measures, sandstones, and shales probably exceeding 13,000 (?) feet in thickness; Laramie? a

(5) Cretaceous strata of the San Juan islands and conglomerate? of the Skookumchuck.

(6) Serpentine or chloritic schists associated with limestones and marble beds, containing segregated auriferous quartz veins, and on the Skagit silicious specular iron ore. These highly metamorphosed strata form with granite the mass of the Cascade range, and are similar in association to the same rocks in northern Washington territory and those of western Idaho; they are pre-Cretaceous and possibly Paleozoic.

Granite covers a large area west of the crystalline schists of the Skagit, reaching beyond Lake Chelan to the Okinakane and eastward to the Colville region, though sometimes hidden beneath more recent material.

Turning to the eastern slopes of the cascades there appears a small development of Coal Measures similar to b those of the Puget Sound basin near the head of the Yakima river and on the Wenatchie river; they crop out near Lake Kitchelas, Lake Klealim, and on Schwak creek, a small tributary of the Yakima from the north; they are of limited extent and probably not more than 1,000 feet thick. They rest conformably (?) upon 7,000 or 8,000 feet of coarse sandstone containing thin layers of conglomerate, at the base of which is a bed of coarse conglomerate 300 to 400 feet thick; the best exposures of these rocks are south of the Wenatchie on the spur of the Cascades, called the Peshastan range which divides that river from the Yakima. The same sandstone and conglomerate beds occur at the head of the Munastash creek, 25 miles west of Ellensburg, at an elevation of 5,500 feet on the main Cascade range. The probability that these strata east of the range correspond to the Coal Measures west of it is suggested in the following comparison of sections: c

West of the Cascades.	East of the Cascades.
(1) Wide-spread glacial drift.	(1) Limited glacial drift. Lake beds of the Yakima and Columbia rivers.
(2) Tertiary volcanic rocks.	(2) Tertiary volcanic rocks.
(3) Lignitic and bituminous Coal Measures, characterized by angiospermous leaf impressions throughout the entire thickness, 13,000 feet or more.	(3) Coal Measures of limited extent, 1,000 feet ±. Coarse sandstone with thin conglomerate beds, 7,000 to 8,000 feet.
(4) Cretaceous strata and conglomerate of the Skookumchuck.	(4) Conglomerate, 300 to 400 feet thick.
(5) Serpentinic or chloritic schists, associated with limestone and resting on granite; common to both sides of the range.	

d

The extent of the Cretaceous strata requires further study, but the existence of Laramie (?) sandstones upturned high upon the mountains places their upheaval at the close of that period.

TABLE 45.—*Analyses of representative samples of Washington territory coals and lignites.*

	LIGNITES.					BITUMINOUS LIGNITES.						
			Green River field, Washington territory.									
	Miles City, Dakota.	Newcastle, Washington territory.	Vein (?) G. R. C.	Vein 33 G. R. C.	Vein (?) (G. R. C.).	Vein XVIII G. R. C.	Vein IX G. R. C.	Vein VI G. R. C.	Vein III G. R. C.	Upper Yakima river, Washington territory.	Carbon Station, Wyoming territory.	Rock Springs, Wyoming territory.
Original sample number	70	24	50	50	50	27	42	43	45	....	....	....
Moisture	14.10	4.16	7.27	9.98	8.08	2.50	4.82	3.34	3.24	0.80	8.10	7.00
Volatile hydro-carbons	36.95	44.84	36.02	40.63	35.90	45.71	42.02	39.39	39.52	40.87	34.70	36.81
Fixed carbon	35.76	43.86	28.48	41.07	47.07	48.37	37.12	41.40	48.30	46.30	51.65	54.46
Ash	13.10	7.14	28.23	8.32	8.95	3.42	16.04	15.78	9.85	11.04	5.55	1.73
F. C. / V. H. C.	0.97	0.98	0.79	1.01	1.31	1.06	0.88	1.05	1.22	1.13	1.48	1.48
Coke	None.	None.	None.	None.	None.	Poor.	None. (a)	None. (a)	Worthless	Fair.	....	....

c

TABLE 45.—*Analyses of representative samples of Washington territory coals and lignites*—Continued.

	BITUMINOUS COALS.										
	Wilkeson field, Washington territory.								Skagit river, Washington territory.	Raton, New Mexico.	El Moro, New Mexico.
							Altered by intrusive rocks.				
	Wingate vein, carbonado.	Vein CXXIII W. C.	Vein XVIII W. C.	Vein V W. C.	Vein I W. C.	Vein LVIII B. B. C.	Vein XLIV B. B. C.	Vein d, Carbon river W. C.			
Original sample number	12	125	17	64	37	136	135	68	76	....	....
Moisture	1.80	3.98	1.33	1.16	1.54	0.61	0.44	2.56	1.17	2.0	1.66
Volatile hydro-carbons	42.27	28.64	25.88	29.09	28.17	29.58	5.84	8.43	14.40	37.1	34.48
Fixed carbon	52.11	54.10	60.67	60.38	59.70	56.18	73.98	83.27	64.56	51.6	60.08
Ash	3.82	13.28	12.12	9.37	10.59	13.63	19.74	5.74	19.87	9.3	3.78
$\frac{F. C.}{V. H. C.}$	1.23	1.88	2.34	2.07	2.12	1.89	12.67	9.87	4.48	1.39	1.74
Coke	Very good.	None?(*b*)	Excellent.	Excellent.	Poor?(*b*).	Black and friable.	None.	None.	Rather poor.	Good.	Good.

a Produced fragile coke in field test. *b* Produced first-class coke in field test.

NOTE.—G. R. C., Green River column; W. C., Wilkeson column; B. B. C., Busy Brook column. See columnar sections of Coal Measures. Analyses of coal from Carbon Station, Rock Springs, Raton, and El Moro taken from *Mineral Resources of the United States*, by Albert Williams, jr., United States Geological Survey, 1883.

Sample 79, taken from outcrop of typical lignite-bed on Sunday creek, near Miles City, Dakota. Sample 24, taken from end of gangway, 400 feet below the surface, represents cross-section of vein 12 feet thick. Samples 59, 56, and 50, taken from the outcrop. Sample 27, McKay vein, 5 feet thick, taken from prospect tunnel, 20 feet below the surface. Samples 42, 43, 45, average samples from outcrops faced down. Sample 12, average sample from end of gangway, 150± feet below the surface. Samples 125, 17, 37, 136, 135, average samples from outcrops faced down. Sample 64, average sample from tunnel, 30 feet below the surface. Sample 68, picked sample from outcrop. Sample 76, picked sample from Prospect tunnel, 10 feet below the surface.

The coals of Washington territory range in quality all the way from lignite, which still retains a woody structure, to anthracite. In the above table a number of representative analyses are given, and those of some similar coals of Wyoming and New Mexico are added for comparison. The "lignites", "bituminous lignites," and "bituminous coals" grade into each other, but they may here be defined to mean—

Lignite, a coal of brilliant luster, conchoidal fracture, brown streak, homogeneous or woody structure, which cracks into small, irregular fragments when exposed to changes of temperature and moisture, and which does not coke.

Bituminous lignite, a coal of lignitic luster and streak, homogeneous structure, irregular, slightly conchoidal fracture, which does not air-slack, and forms a more or less fragile coke.

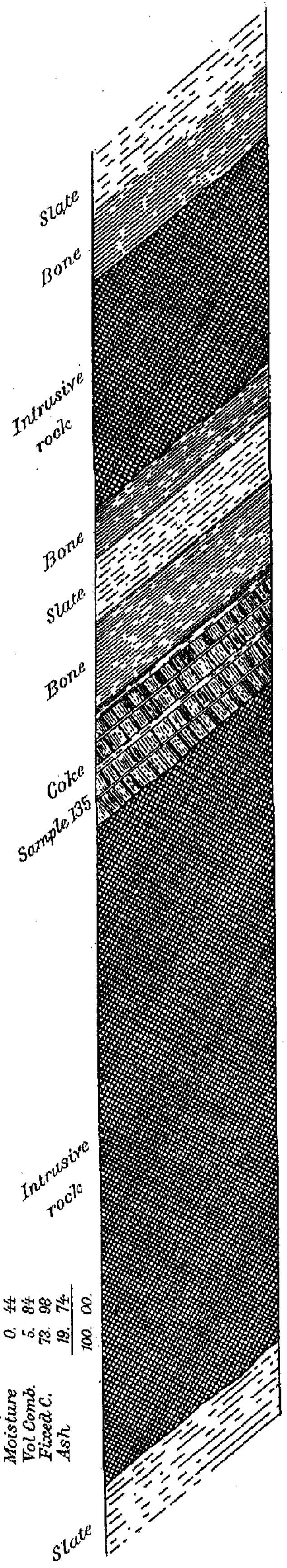
The Newcastle, Washington territory, lignite is intermediate between these two classes. It does not air-slack, but, on the other hand, it does not coke, and it is known in the Pacific coast markets as a high-grade lignite.

Bituminous coals have a black streak, more or less cubical fracture, and coke strongly, forming a sonorous, close-grained coke.

The coking quality of a coal is of practical importance in relation to the value of the fine material, particularly when, as is the case in the Wilkeson field, the coal is soft, and it gives a means of determining, in the course of primary exploration, the probable chemical character of the beds discovered. I have calculated the ratio $\frac{F. C.}{V. H. C.}$, suggested by Professor Frazer, in Vol. MM, *Second Geological Survey of Pennsylvania*, as a basis for classification, in order to show the relations of the bituminous coals and their altered products to the eastern coals. Professor Frazer's classification is:

	$\frac{F. C.}{V. H. C.}$
Hard, dry anthracite	100 to 12.
Semi-anthracite	12 to 8.
Semi-bituminous	8 to 5.
Bituminous	5 to a fraction.

No. 68 is therefore a semi-anthracite; and No. 135 corresponds to hard, dry anthracite, but it is more truly a natural coke, since it has a somewhat cellular structure and occurs in polygonal columns 3 or 4 inches long and ¼ to ½ inch diameter, which lie at right-angles to the heating-surface of intrusive rock. Both of these are purely local results.



ANALYSIS OF COKE SAMPLE 135.

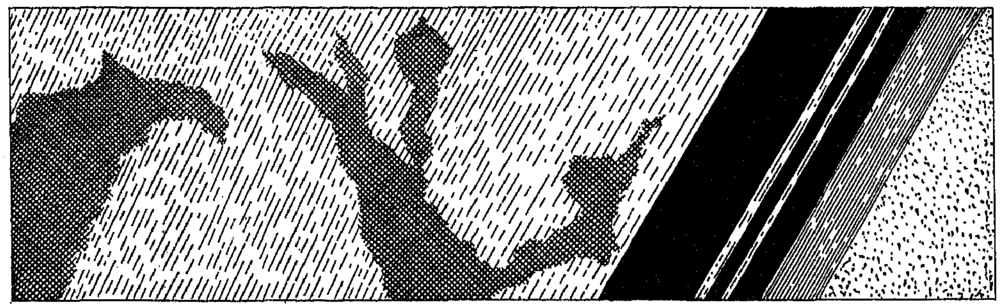
Moisture	0.44
Vol Comb.	5.84
Fixed C.	73.98
Ash	19.74
	100.00

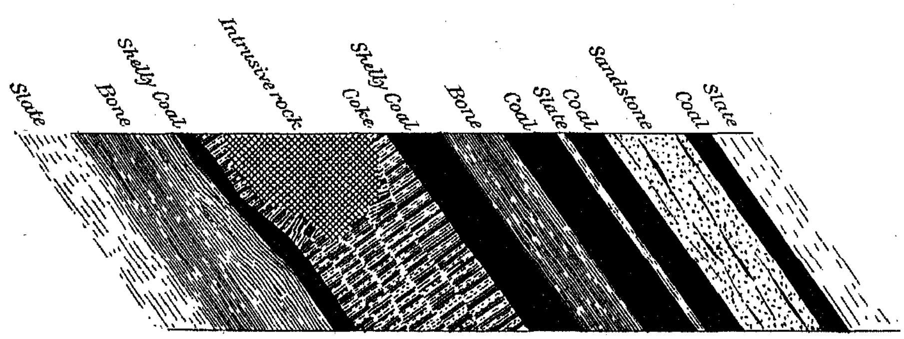
WILKESON COALFIELD.

Vein 44 Busy Brook
Coal altered to columnar coke by intrusive rock conformable to the bedding. Scale 1/60. Drawn on observed dip.

GREEN RIVER COALFIELD.
Washington Ter.

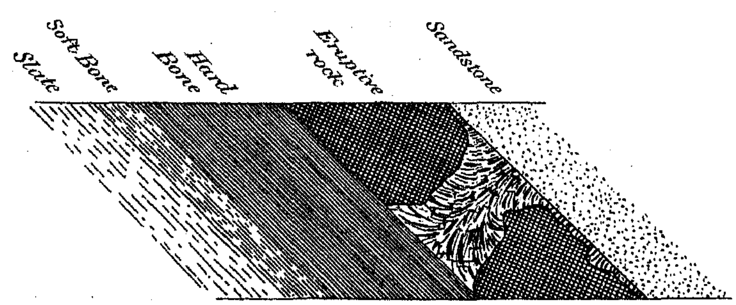
Intrusive dyke and coal bed observed near the eastern limit of the field
Scale 1/120 Drawn on observed Dip.





WILKESON COALFIELD.

Vein XXIX Busy Brook
Coal altered to columnar coke by intrusive rock
Scale 1/60 Drawn on observed dip.



WILKESON COALFIELD.

Vein 47 Busy Brook
Coal bed replaced by eruptive rock which encloses a mass of columnar coke
Scale 1/60. Drawn on observed dip.

Bailey Willis, del.

From unpublished MS. material of the Northern Transcontinental Survey. Julius Bien & Co. Lith.

It will be noticed that the above ratio affords no criterion for distinguishing between lignites and more a bituminous varieties of coal, since the classes overlap each other; in stages of alteration bordering on lignite the percentage of combined and hygroscopic water is of more importance than the relation of hydrocarbons to the fixed carbon of the coal.

The differences of character of the Washington territory coals are ascribed to three principal causes: differences of age, the influence of volcanic rocks, and the metamorphic action incident to the crumpling of the strata.

The fields which have been wholly or partially modified by these causes are the Wilkeson, the Green river, and the Skagit; separated from each other and from the lignite areas by broad stretches of drift and by volcanic flows, they afford no data from which their relations might be deduced, except the lithological characteristics and fossils of their strata.

The similarity of composition and interbedding of the sandstones and shales, wherever they have been b observed, points, so far as it goes, to identity of age, and considering the great thickness of the sections measured in the different fields, it is difficult to believe that they can be superimposed to the extent necessary to account for the varieties of coal. The fossils, so far as they have been examined, belong to one period.

The great thickness of strata in the Green River and Wilkeson fields justifies us in expecting differences between the upper and lower coals in either section; and the expectation is apparently borne out in the former field, where the upper veins are of typical and rather inferior lignite, and the lower are bituminous lignites. But the poorer lignites are at the same time confined to the least-disturbed portion of the field, and the more bituminous beds are very similar in composition throughout the lower 3,000 feet of the series, which have suffered a uniform faulting and folding. This evidence applies equally, therefore, to supposed differences of age or the differences of metamorphism. c

The same is true of the Skagit coal, which may on the one hand be the lowest portion of the Coal Measures known in close contact with the schists, upon which it was deposited, or, on the other hand, a bed belonging anywhere in the coal series, modified by proximity to a very extensive fault.

The thickness of the strata measured in the Wilkeson field is double that of the Green river, and the differences of composition between the upper and lower coals should be correspondingly greater. They are indicated in samples 125, 17, 64, and 37, from the highest, intermediate, and lowest beds, and they are practically *nil*. The identity of character points to the conclusion that some stronger influence has destroyed differences we might justly expect in coals separated by such intervals of deposition.

Volcanic rocks occur in contact with the Coal Measures as flows and as intrusive dikes. They have modified the character of the coal by pressure and heat, and the influence of a superficial flow would, in both these respects, be d less than that of the molten rock before extrusion. Coal-beds altered by dikes in their immediate vicinity are frequent in the Wilkeson field, but in every such case the alteration is confined to a few hundred feet on either side of the contact. Thus, sample 68 represents a vein cropping out in close proximity to the great fracture which bounds the Wilkeson field on the west, south of Carbonado. The dike is known to be a mile wide, and it joins other flows and dikes to the westward. But this same bed of coal, here altered to semi-anthracite of brilliant luster and anthracitic fracture, produces coking coal of the character common to the whole field less than a quarter of a mile from this outcrop, and "Bed C, Carbon river, W. C.", separated from it by but 500 feet of shale and sandstone, is unaltered. Sample 135 was taken from between walls of volcanic rock within 750 feet of the bed represented by Sample 136.

A cause so local in its action, under the most favorable conditions, could not have produced the widespread e and uniform differences between the Wilkeson, Green river, and lignitic coals.

Great differences of age being improbable, and the influence of volcanic rocks being purely local, we may justly compare the modern lignite and its concentrated products with the Carboniferous coals of Ohio and their modifications in the Pennsylvania and Rhode Island anthracites. Thus the lignites are usually horizontal, and where they are disturbed the flexures are broad, even where the dips are considerable. In the Green River field the bituminous lignites are sharply flexed and faulted and the dips are frequently vertical, but within the veins themselves there is little evidence of movement. The Wilkeson bituminous coal-field is folded into long narrow troughs of great depth, with dips ranging from 50° to 90°; small throws and large faults, slicken-sides, and balls of crushed coal, bear witness to the mechanical pressure the Measures have been subjected to. The concentration of the coal is throughout in proportion to the degree of flexure and evidence of movement in the Coal Measures, and the relation between f the chemical character of the coal and the complexity of the structural geology justifies the conclusion that they are the common result of that force, which closed the lignitic period with the elevation of the Cascade range.

THE WILKESON COAL-FIELD.

Position and boundaries.—This field, as now known, is an isolated strip of Coal Measure strata, extending north from the Nisqually river, in township 15 north to township 19 north, and within range 6 east of the Willamette meridian. Wilkeson, the place of first discovery of the coal, and the end of the branch road built by the Northern Pacific Railroad Company to the coal-mines, is near the northern end of the field, 31 miles by rail southeast of Tacoma a on Puget sound. Carbonado, the town erected at the mines of the Central Pacific Railroad Company, is about 3 miles southwest of Wilkeson on the edge of Carbon River cañon, and near the western border of the coal-field. South Prairie creek, 2 miles north of Wilkeson, and on which the South Prairie mines are opened, may be considered the northern boundary of the field, since it disappears to the northward under the drift of the White River plain and valley, which is only interrupted by a few outcrops of volcanic rock. Thus defined the Wilkeson coal-field is about 27 miles long north and south, and from 1 to 6 miles wide east and west, with an area of approximately 100 square miles, of which perhaps one-fifth can be developed and made profitably productive. As stated, the northern boundary is somewhat indefinite, but its eastern, southern, and western limits are absolute contacts with erupted mountain masses, in which this slender strip of sedimentary rocks has been almost engulfed. These contacts are nevertheless seldom to be observed since glacial deposits and forest growth bury all solid rock below 5,000 feet b under a covering that only patient work with axe, pick, and shovel can penetrate. Only in the bold walls of the lower cañons of Carbon river, of the Puyallup and Mishall creek, and on the high summits of the volcanic peaks are there any outcrops. I have therefore not attempted to give absolute boundaries on the geological map, although the coloring is a close approximation to exactness.

Topography.—The topography of the Wilkeson field is the result of several volcanic uplifts, of subsequent glacial conditions and subaerial erosion, working in material of widely different degrees of hardness; its character may be justly described as extremely mountainous; slopes are steep, valleys narrow, and elevations that rise 1,000 to 3,000 feet above them, the rule within the Coal Measure area.

On its eastern border is mount Rainier, towering to an elevation of 14,300 feet; 7,000 feet above the crest of the adjacent Cascade range, and 8,000 to 9,000 feet above the mountains on the northwest and south. From the c flanks of this grand mountain a chaotic chain of lesser volcanic peaks extends a little west of north about 20 miles, falling away toward Wilkeson, and drained mainly by South Prairie creek. Another spur reaches out from Rainier to the southwest, between the Cowlitz and Nisqually rivers, and the whole volcanic range forms at once the eastern and southern geological and topographical boundary of the coal-field. This uplift, which probably was among the earliest manifestations of Tertiary eruptive force in the region, determined the northward course of White river, the flow of the several branches of the Puyallup and of the Nisqually toward the west, and of the Cowlitz to the southwest. Of these, the Puyallup and Nisqually now drain the coal-field, their main streams and principal tributaries cutting across it from east to west at right-angles to the general trend of the anticlinal and synclinal axes. In their descent from Rainier to the sound, the Nisqually, the Puyallup, and Carbon river (formerly called the North fork of the Puyallup), each passes through three valley phases. There is on each an upper valley, beginning d with the terminal moraines of the glaciers on Rainier, and extending 20 to 35 miles down stream; hemmed in between dark precipices near the mountain, these valleys widen to 300 yards on Carbon river, and to 1 to 2 miles on the Puyallup and Nisqually; where narrow, the river-bed is but a strip of gray boulders between steep, densely-timbered mountain sides; where wider, the bottom-lands are forest clad, and the slopes of the mountains are contoured by terraces. From these upper valleys the rivers plunge into narrow cañons, with vertical or overhanging walls of sedimentary and eruptive rock; the cañon of Carbon river is 2½ miles long, with a greatest depth near its lower end of about 250 feet; it is often but 40 to 50 feet wide, and through part of its course exposes an interesting section of recent volcanic rock, underlying the Coal Measure strata it has upheaved, but at that point not broken through. The cañons of the Puyallup and Nisqually are similar, but deeper and longer; lying far outside the valuable coal region, they were not closely studied. These cañons are cut through a probably volcanic uplift e later than that of Rainier; the uplift itself may have obliterated the former river-courses and have forced the cutting of the new channels, or the diversion of the rivers which resulted in these cañons may have been the effect of stoppage of former courses by drift of the much later glacial period.

The region of maximum activity of this secondary uplift appears to have been west of the Nisqually, where a group of mountains reaches a height of 5,000 to 6,000 feet; they have never been mapped, but the western slope is drained by the Deschutes, Newaukum, Skookumchuck, and Tilton creek.

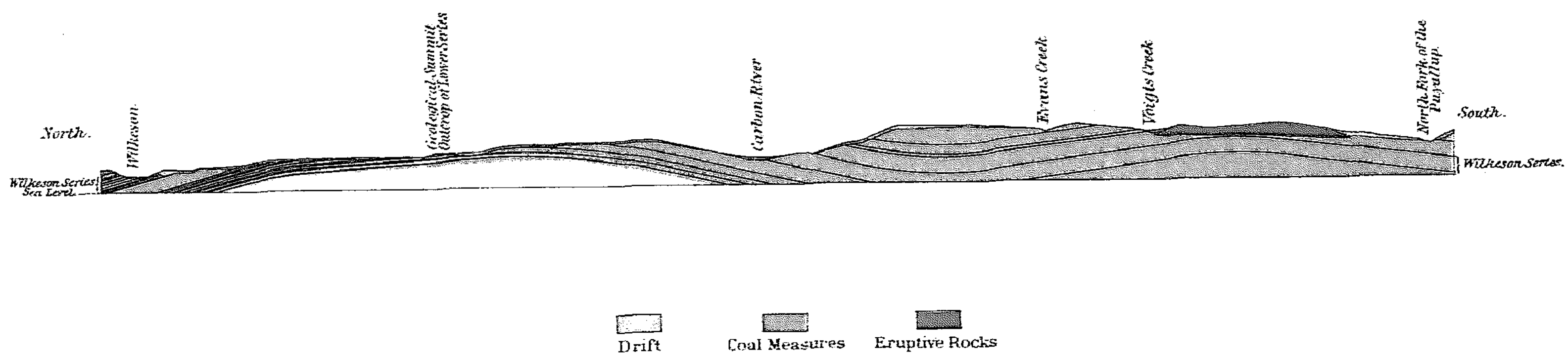
The third phase of these river cañons is that of their lower valleys; level bottom-lands, 1 to 3 miles wide, bounded by terraced hills of drift which lead down to the deltas, forming very rapidly where tide and river meet. The great depth to which these valleys have formerly been excavated, as evidenced in the depth of the Sound basin, is proof of elevation probably of much later date than those disturbances that produced the structure of the f Wilkeson coal-field.

The glacial period has added its chapter of great interest to that of the volcanic phenomena. Drift is almost the universal superficial deposit; it forms the shores of the sound and fills the valleys to their present levels; it reaches far up on the slopes of the Cascades and of Rainier and merges with the terminal moraines of the diminished glaciers. Its presence in the area of the coal-field results in gently-sloping plateaus and abrupt terraces. From the several terraces above Wilkeson a gentle ascent extends southward to the steep descent into the Upper Carbon River valley, and beyond it a continuation of apparently the same rising plateau reaches south to the ridge above Evans creek to an elevation of about 3,000 feet. This whole surface, composed entirely of drift, was probably continuous with the general sheet which reaches out to the north and west and is interrupted by Flett's creek and South

IDEAL SECTION OF THE WILKESON COALFIELD.
FROM WILKESON TO THE PUYALLUP RIVER 14 MILES ALONG THE GREAT ANTICLINAL AXIS, SHOWING THE PITCH.

By Bailey Willis Northern Transcontinental Survey.

Scale: 2 Miles = 1 Inch.



From unpublished M.S. material of the Northern Transcontinental Survey.

Julius Bien & Co. Lith.

Prairie creek, but which, farther north, sinks far beneath the excavation of present drainage lines. The glacier **a** which made this widespread deposit has left its marks on the rocks of Tolmies peak and the highest slopes of Rainier. In the terraces above Wilkeson the drift has a depth of 300 feet, as proved by tunnels, and on the plateau, 3 miles south, shafts were sunk 50 to 70 feet before reaching bed-rock. South of Evans creek drift is strikingly absent until, on descending into the valley of the Puyallup, we pass down over four terraces to the river, along which it is a prominent feature. Leaving the Puyallup and crossing into the Mishall basin it disappears altogether and only reappears as we descend into the upper valley of the Nisqually. Its presence and its absence are both significant of the topography of the region during the ice period and bear upon the question of general glaciation west of the Cascades.

Leaving on one side, as not pertinent to the present purpose, the historical relations of these various surface features, the topography of the field has a very important connection with the economic value of its several **b** divisions; of these four are determined by topographical features, fixing the possible conditions of mining and transportation. The first may be designated the Wilkeson area, all that portion of the coal-field north and east of Carbon river, including Carbonado and South Prairie; the second is the Evans Creek area, drained by Evans and Voigts creeks and extending from Carbon river to the flow, beneath which the Coal Measures disappear south of Voigts creek; the third is the Puyallup area, that portion drained by the upper branches of the Puyallup proper; the fourth is the Nisqually area, including the Mishall basin and the Nisqually valley. The first and last are the more valuable coal-fields and the easier of access. The Wilkeson area is already tapped by a branch of the Northern Pacific, which reaches its three mining points, South Prairie, Wilkeson, and Carbonado. The Evans creek area is isolated by streams, whose valleys cut it off from the adjacent coal-areas, yet afford no practicable approach for **c** lines of transportation. Carbon river cañon forbids the extension of the railroad beyond Carbonado, and Voigts creek, with a fall of 2,200 feet in 13 miles, offers a route that is but little more satisfactory, even were the area as rich in good coal-veins as that north of Carbon river, which is, however, not the case. The Puyallup area is similarly difficult of access, and its development as a mining region is like that of Evans creek, a doubtful question of an indefinite future. The southern end of the field includes the broad upper valley of the Nisqually, with a general elevation of 1,700 feet; a railroad line passing over the region of dry lakes at the head of Muck creek into this upper valley was surveyed some years ago and proved practicable, and the existence of coal in the adjacent mountains will sooner or later lead to its construction. The coal of the Mishall basin must be looked upon as a reserve for the future, to be mined from the Nisqually valley, the wild cañon of the Mishall being impracticable for a railroad line and there being no other outlet to the area.

Structural geology.—The study of the geological structure of a much-disturbed series of sandstones, shales, **d** and coal-veins, which presents no one well-defined horizon, and which is buried beneath a dense forest and heavy drift-beds, is a matter of much difficulty. The general facts here given and the structure deduced from them are the result of three years' careful examination, during which over 700 coal-veins were discovered by digging down through the superficial deposits, and their relations traced by considering all the facts of dip, strike, detailed cross-section, and horizontal and vertical position, as determined by accurate surveys.

Of the four topographical divisions of the coal-field, the Wilkeson and Evans creek areas are geologically one with a connection that may be definitely traced, and they are no doubt represented in the southern portion of the field, although the relation is difficult to establish.

The principal feature of the northern district is an anticlinal axis extending from Voigts creek northward through Wilkeson to South Prairie creek, and beyond; its strike is a little west of north, its pitch sometimes north **e** and sometimes south. Three miles south of Wilkeson this axis reaches its geological summit in the vicinity of the secondary volcanic upheaval; here the lowest known coal-veins are exposed with the structure of a long crumpled dome; from this point the main axis pitches northward toward Wilkeson and southward toward Carbon river. A subordinate anticlinal axis pitches toward the northeast, producing a trough between it and the main or Wilkeson axis; this trough may be called the eastern Wilkeson basin. A second or western basin lies between Wilkeson and Carbonado; it is recognizable near Wilkeson, but lost farther south under the drift plateau.

Carbonado itself is a region of great disturbance, well exposed in the cañon and developed in the mines, but unsurveyed and not yet understood.

Southeastward from the geological summit of the main axis there is a small synclinal, apparently corresponding with the eastern Wilkeson basin, but it fades away by a rapid southern pitch, and in the section measured on **f** Voigts creek the dip is simple. Southwest from the same summit Carbon river exposes a section through several minor folds, which pitch southward.

It is upon the study of this geological center and its radiating troughs and arches that the Wilkeson columnar section is based.

The section measured on Voigts creek consists of 10,260 feet of strata, containing little coal but a great number of bony beds, which are recognized on upper Fletts creek, east of the lowest beds exposed, and may be called the upper bony measures. The interposition of the Wilkeson series, as measured on either side of the Wilkeson axis by surface section and diamond-drill, between this bony series and the lower beds, rests on the comparative pitch of the great axis and the character of the coal-beds. The position of the beds worked at Carbonado is very difficult to determine and they cannot be placed with any certainty, but I am inclined to believe they lie between the Wilkeson

a and the lowest known beds. The column thus constructed consists of 3,000 feet of productive measures underlying 10,000 feet of comparatively barren measures. Where the proportion of valuable property to worthless mountains is so small, the importance of knowing the geology before investing is apparent.

Aside from this, the geological structure has a most important bearing on the development of the mines. Thus at Carbonado the Coal Measures are crumpled into four or more anticlinal folds, with narrow intermediate troughs, cut by faults at an angle to the axes, which pitch northward. Carbon river exposes these folds in a cañon about 400 feet deep, having a crooked, northwest course. South of the coal-mines, and within 200 yards of the southernmost openings, the river-channel is cut down into the volcanic rock of the secondary upheaval. Of a number of gangways started southward from the river, all but two have been abandoned, and these two, being the farthest west, are farthest removed from the intrusive rock; they may continue to be profitably worked for some time. The ground **b** north of the river has been developed by gangways run in on the veins from the river, and by a rock tunnel which started near the western edge of the original property and runs eastward. This tunnel crosses the same succession of faulted anticlinals cut by the cañon. Gangways driven southward from it would open upon the cañon, if not interrupted by faults; gangways driven northward from it encounter the descending anticlinals in a comparatively short distance, and in one case at least a gangway has been driven on the vein around the axis, returning to the cross-cut tunnel. This tunnel is, however, progressing eastward toward the western basin, which lies between Wilkeson and Carbonado, and is penetrating into lower beds. Were good mining surveys and facts determinable by surface prospecting accessible, the extent of this basin and the ultimate value of this tunnel might be estimated. Had the facts of the geology been understood before the mines were begun, a different plan, involving less outlay, **c** and securing more profitable results would probably have been adopted.

The difficulty of mining on a descending pitch, which results in a lift that decreases in each vein from a maximum to nothing between the beginning of a gangway and its intersection with the axis, and in a proportionately large amount of rock work, is not to be encountered at Wilkeson.

Where Fletts creek passes from its narrow gorge into the little valley up which the railroad has been built, a short section of the measures, containing three coal-veins on a western dip of 80° to 90°, is exposed. These three beds are also known on the eastern dip of 53° on the other side of the northward-pitching main axis. A dike of volcanic rock, which forms low cliffs on Fletts creek, near the top of the arch and on the eastern side, is the visible surface evidence of disturbed measures, proved by small faults in the gangways on both sides of it, and expensively explored by a large slope, sunk 300 feet, on the western dip. The southern extension of the three beds had, however, **d** been early proved—on the eastern dip for 2½ miles, on the western for 1½ mile—and the existence of under- and over-lying beds has since been determined. Gangways driven on these veins with an increasing lift will ultimately concentrate at Wilkeson the coal of the eastern and part of the western basin, and render the product of the lower series accessible by cross-cut tunnels.

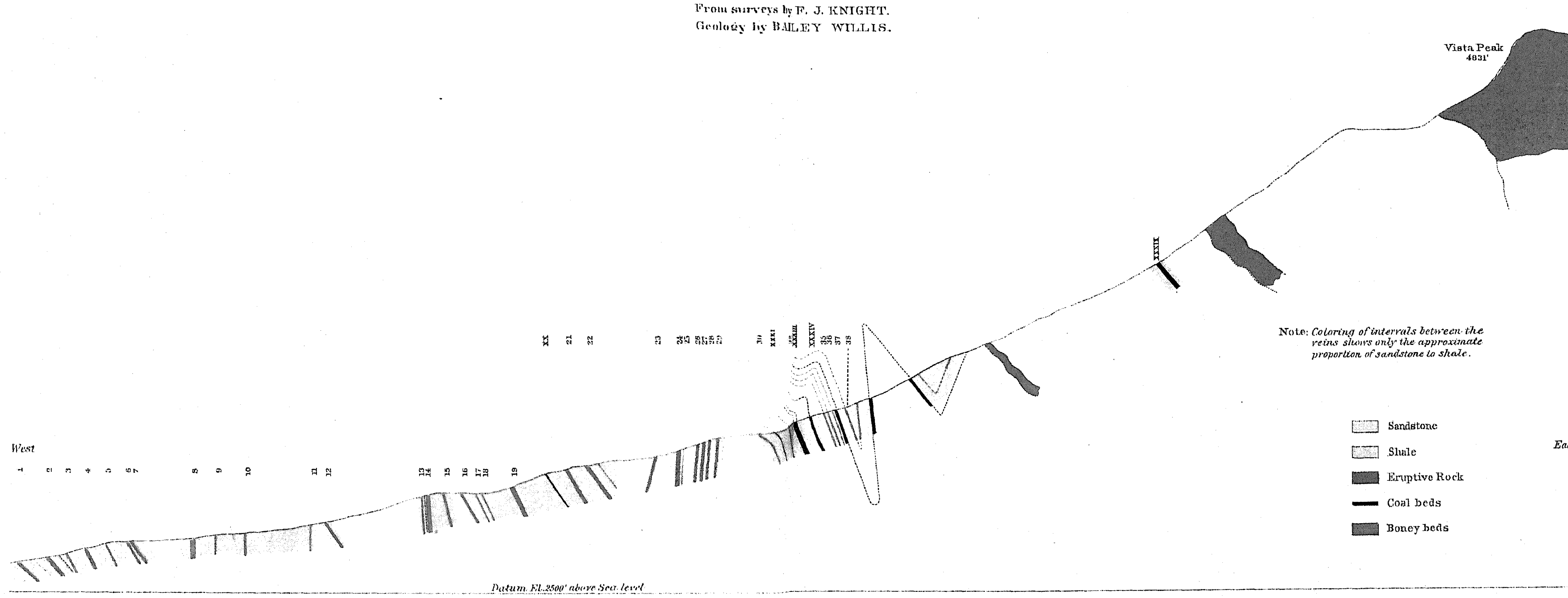
The structure of the southern portion of the field, so far as it is known, is sufficiently indicated in the accompanying sections of the Mishall basin (Plate LXXXIX), as measured near the Narrowgauge and on Busy brook. The region west of Vista peak is evidently one of great disturbance and of very extensive faulting. On Busy brook these faults, though of less extent, are apparent in the presence of dikes, some of which have altered the coal of adjacent veins to coke.

The examination of this remote part of the field, only accessible after the construction of a mountain trail over **e** a pass of 4,000 feet elevation, was interrupted before the extension of good veins into the Nisqually valley had been determined. Upon a satisfactory answer to this uncertainty rests the probable value of the Nisqually area.

Character of the coal.—As stated in the general discussion of the Washington Territory coals, the Wilkeson field produces black, highly bituminous, coking coal, unlike any other known on the Pacific coast south of Alaska. Its chemical qualities are sufficiently shown in the many analyses which accompany this report; and the sections of the beds indicate their structure. The analyses are of full cross-section samples, taken to show the quality of coal which could be shipped on a commercial scale. It should be said, however, that these analyses show a lower ash percentage than has been hitherto obtained in mining. The coal throughout the field is soft and makes much fine coal. If carefully mined, screened, and hand-picked, good clean lump-coal can be produced, the subsequent crushing of which, in transportation, will not affect its value for many purposes. The finer screenings can also be **f** cleaned and utilized, since the coking character of the coal makes even the finest material available, when clean. It has, however, been the custom at Carbonado, as well as in the small shipments from Wilkeson, to ship unscreened coal as it comes from the mine, except for the removal of large pieces of bone by hand-picking of coarse and fine coal mixed. The reputation of the mines is, therefore, not a good one in the Pacific Coast markets; but it is, for the same reason, capable of great improvement.

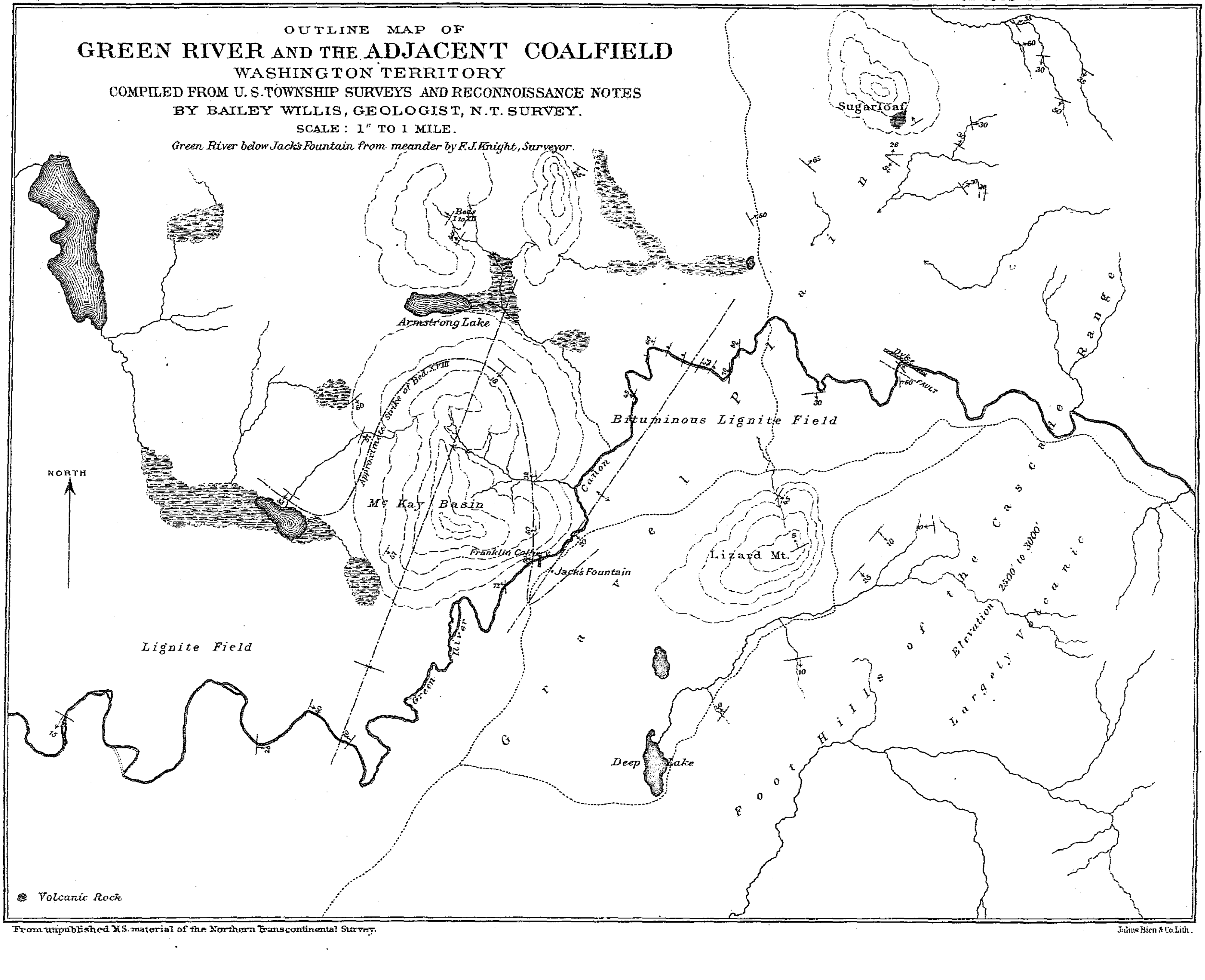
I would, in this connection, call attention to the analyses of coke given on Plate XCII, with the detailed sections of the beds from which the coke was made. The analyses represent average samples of about a ton of coke from each bed; the very low percentage of ash, as compared with that of the corresponding coal samples, is due: (1) To the partial removal of thin layers of bone from the purer coal, by the weathering of the coal, which was mined in short prospect tunnels in December, and lay exposed to snow and rain till April, when it was burned in heaps on

GEOLOGICAL SECTION OF THE MISHALL BASIN, WILKESON COALFIELD NEAR THE NARROWGAUGE.
SHOWING THE FAULTED MEASURES WEST OF VISTA PEAK.
Scale 500 feet 1 inch.
From surveys by F. J. KNIGHT.
Geology by BAILEY WILLIS.



From unpublished MS. material of the Northern Transcontinental Survey.

Julius Bien & Co. Lith.


OUTLINE MAP OF
GREEN RIVER AND THE ADJACENT COALFIELD
WASHINGTON TERRITORY
COMPILED FROM U. S. TOWNSHIP SURVEYS AND RECONNOISSANCE NOTES
BY BAILEY WILLIS, GEOLOGIST, N. T. SURVEY.
SCALE: 1″ TO 1 MILE.
Green River below Jack's Fountain from meander by F. J. Knight, Surveyor.
Sugarloaf
Armstrong Lake
Bituminous Lignite Field
Mc Kay Basin
Franklin Coll.
Jack's Fountain
Cañon
Lizard Mt.
Lignite Field
Green River
Deep Lake
Gravel Plain
Foot Hills of the Cascade Range
Elevation 2500′ to 3000′
Largely Volcanic
Dyke
FAULT
NORTH
Volcanic Rock

the ground. (2) To the fact that the bone associated with the coal does not produce marketable coke, and was, a therefore, rejected as not a legitimate part of the merchantable product. The proportion of coke obtainable from any coal-bed of the Wilkeson field depends directly upon the amount of ash the market will buy. By careful mining and subsequent treatment of the coal very excellent coke can be produced.

THE GREEN RIVER COAL-FIELD.

Position and boundaries.—The Green River coal-field takes its name from the clear mountain stream which cuts a deep east and west section into the Coal Measures 30 miles northeast of Tacoma, and about the same distance southeast of Seattle. This exposure is the first appearance of sedimentary rocks north of Wilkeson. A few low b hills near Green river, within what may be called the coal-field, several pinnacles of volcanic rock near White river, and the lignite outcrops on Cedar river are the only breaks in the great drift plain traversed by the streams which flow into Elliot bay.

As may be inferred, the limits of the coal-field on the northwest and south are simply the disappearance of the strata under the all-obscuring gravel sheet. The eastern border is a much more definite contact with the bold outliers of the Cascade range, composed of volcanic breccia.

The area of so indefinite a coal-field can only be stated approximately at 50 square miles, of which but a small part is likely to be profitably productive.

Topography.—The low round hills and terraces of the Green River field are in strong contrast to the mountainous character of the Wilkeson region. Green river issues from its narrow gorge in the western slope of the Cascades, c up which the proposed line of the Northern Pacific railroad is located, into the nearly level drift plain, at an elevation of about 900 feet. Flowing for 2 miles between low banks, it descends into the cañon which it has cut, 200 feet below the general surface of the adjacent plain. Now it dashes in little rapids through the narrow gateways, formed by massive sandstone strata highly inclined, now it eddies in the intervening pools, where soft shales and coal-beds allow it to widen its bed. On the southeast of this cañon the spurs of the Cascades sweep round toward the west in a quarter circle, mount Enem Claugh rising abruptly in a bold cliff from the rolling drift surface. Between these volcanic foot-hills and the river is an isolated hill, several hundred feet high, called Lizard mountain. It consists of nearly horizontal Coal Measures severed by erosion from the steeply-dipping strata on the north. Northward the terraced plain stretches to the Swak range beyond Cedar river, and to the southwest it reaches, without interruption, across White river. But on the west, north of Green River cañon, and about 6 d miles from its eastern boundary, the level is broken by a group of low hills, which cover an area of 3 or 4 square miles, the most valuable portion of the coal-field, the McKay basin.

Geology.—Geologic study of the Green River field has been confined to the notes of Professor E. W. Hilgard, to my occasional observations, beginning in the autumn of 1881, and to the survey by Mr. F. J. Knight of the cañon west of Jack's Fountain. With the aid of topographic surveys of the northwest part of the field, made by the Transcontinental Survey, and Mr. Knight's work, it is possible to construct the columnar section of the Coal Measures of the McKay basin (Plate LXXXI); but all the eastern and southeastern area remains known only through reconnaissance work.

Viewed broadly the Green River coal-field may be looked upon as a flexed and correspondingly metamorphosed corner of the extensive lignite field, into which it passes on the west and north. Inasmuch as those qualities e which give the coal a greater value than lignite are dependent on the degree of this flexure, the worth of lands beyond its visible boundaries is doubtful, and a hint of the limits thus set to the valuable coal area is to be found in the presence of lignites a mile west of the Franklin colliery and on Cedar river.

Looked at in detail the bituminous-lignite area varies considerably in the steepness of dips. The broad synclinal of the McKay basin, so well developed by six openings on bed XVIII G. R. is succeeded on the east by much sharper folds, and in the extreme northeast, close to the foot-hills of the Cascades, there is evidence of much faulting. In the southeastern portion of the field, on the contrary, is a flat anticlinal, which exposes in Lizard mountain and vicinity beds that probably lie below the lowest known in the McKay basin. If this view be correct, the outcrop of bed XVIII G. R. trends back southward in an irregular curve under the gravel plain around Deep lake, and the workable series, of which it is the principal vein, is not to be found in the eastern half of the field. f

While the data at hand do not justify further general conclusions, there are certain details worthy of note. The section of the McKay basin gives a continuous column of 5,300 feet, and I have placed below it a series of twelve beds observed near Armstrong lake. On Green river, where it makes its northern cut across the anticlinal that bounds the McKay basin on the east, a number of large bony beds are exposed with dips of 45° to 80°; these beds very probably lie between XII and 13 of the columnar section.

In Lizard mountain, presumably below No. 1 of the column, is a bed of carbonaceous shale with many earthy partings, which aggregates 125 feet in thickness and contains 15 feet of fair coal in two benches. There are also several workable beds in the vicinity of the Sugarloaf, but while their dips indicate one or several extensive faults, the facts are not definite enough to determine their relations.

a The eruptive rocks of this field form the great mass of volcanic breccia of which the adjacent foot-hills are composed, and occur as dikes in the sedimentary strata. One of the latter, exposed by the river, is the apparent cause of a fault of 30 feet horizontal throw near by, and penetrates the slate in the curious ramifications of the accompanying section on Plate XXXIII.

Another dike (or flow?) 70 feet thick occurs in the McKay basin, between beds XIV and XV. It is exactly conformable to the sedimentary beds, and when traced south to the anticlinal it appears to follow the strike around the axis and forms the core of a ridge above Jack's Fountain, the trend of which coincides with the strike of the southern dip. That an intrusive dike should thus conform to the folds of the strata is very improbable, and the evidence of this single instance is therefore in favor of volcanic activity during the formation of the coal series.

b An interesting occurrence is that of veins of realgar and orpiment, associated with quartz, in the black slates that form the cliff of Realgar point, on Green river.

Character of the coal.—The bituminous lignite of Green river is a hard, brilliant coal, of moderate heating power. It differs essentially from the Wilkeson coal in that it is harder and does not make a serviceable coke. It will find a ready market in all cases where the demand for cleanliness and cheerfulness overrules the economy of the greater heating power of the more highly bituminous coals.

DETAILED CROSS-SECTIONS OF THE COAL-BEDS OF THE WILKESON AND GREEN RIVER COAL-FIELDS, WASHINGTON TERRITORY.(*a*)

c

[Arranged in order of position in the columnar sections, beginning at the bottom of each column.]

The general course of the geologic axes is north and south, and the sections are all drawn looking north on the dip observed in each individual case in the field. The least thickness defined in the sections is one inch. Each analysis belongs to the bed immediately above it.

In the absence of all other data for determining the relative horizons of different parts of the same coal-field the identification of coal-beds became a most important problem in developing the structural geology; and this identification, restricted always to small areas, depended necessarily on the cross-sections of the beds in different test-pits. While no definite rules can be laid down for such comparisons, the following factors have been considered in the order here given:

(1) The presence of one or several well-defined benches of coal, considered characteristic in proportion to d thickness and purity; thus the 5-foot bench of pure coal in vein V W. C. (Plate XCII), identifies it in the third and fourth sections given although the mixed upper benches have passed into brown shale.

(2) The presence of a strong parting of pure sandstone or shale, associated with similar benches of coal; thus vein XVIII W. C. is identified by the sandstone parting near the top with its adjacent beds of good coal, although the lower part of the bed varies between brown slate and inferior coal.

(3) The probability of transition of a bed of inferior coal into one of bone, and of bone into carbonaceous shale.

(4) The tendency of conditions governing the purity or impurity of a sediment to be constant for a considerable period for any one locality, so that if a bed of inferior coal in one opening corresponds to a bed of bone in another, a bony bench in the first will probably be represented by a layer of shale in the second; this is illustrated in the sections of vein VI W. C., Plate XCII. The third section of that bed represents a locality where the sediments were e heavier and more earthy during its entire formation than over adjacent areas of contemporaneous deposition; the identity of the bed would be lost but for its relation to others.

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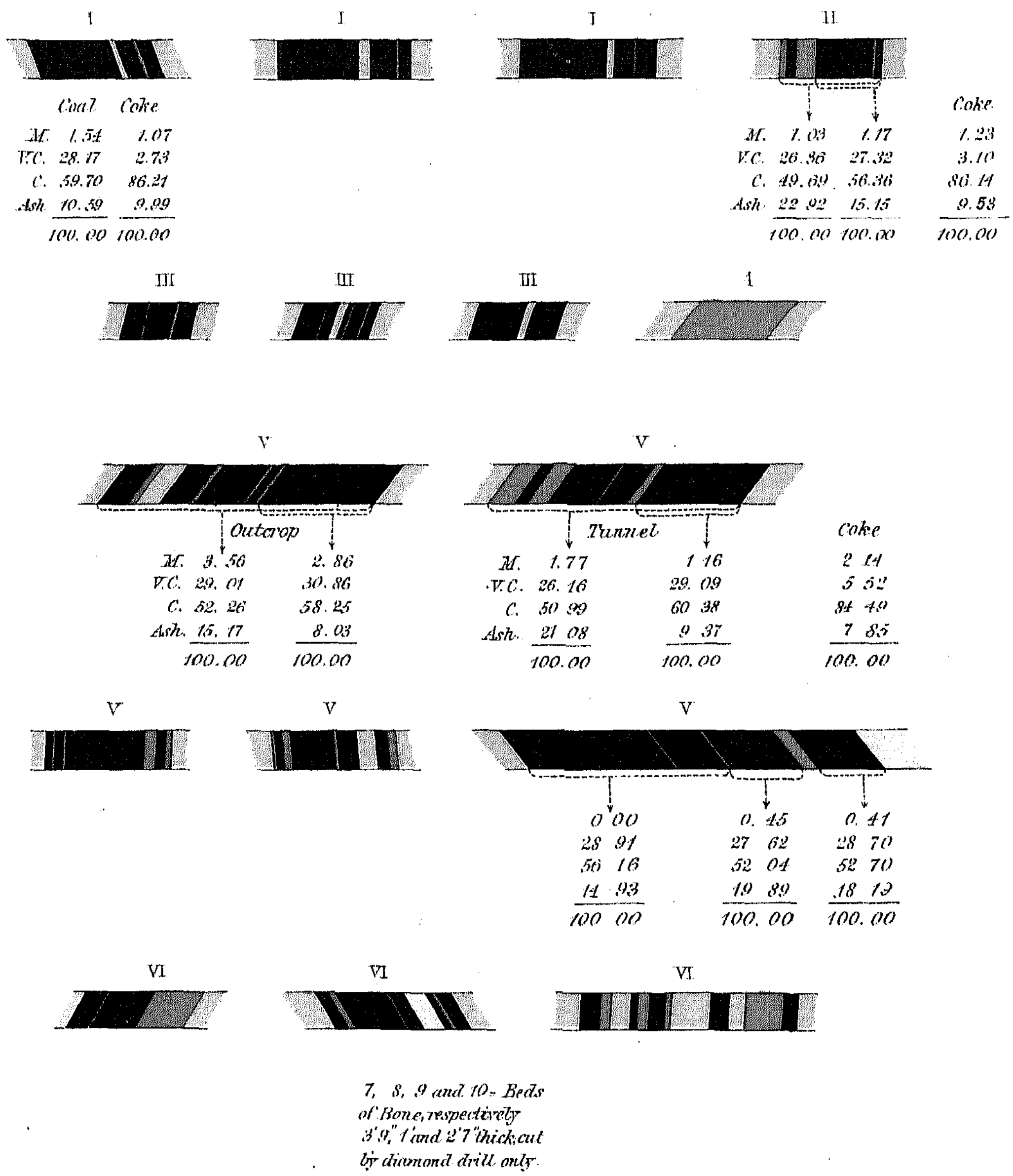
a Definition of terms.—Coal: Lignitic or bituminous material, recognized when hard by the ordinary characteristics of lignite or bituminous coal; when decomposed, at the outcrop, by the shape of minute particles, with or without luster, by not cohering when pressed in the hand, and by rough ash determination; ash not to exceed 25 per cent., and qualified as inferior or bony coal where it is above 18 per cent. Bone: Material ranging from inferior coal to black slate; recognized when not weathered by its hardness, lamination, and earthy streak; when softened, by cohering when pressed, and by the flatness of small pieces. Slate: Argillaceous beds; light-gray (and often slightly arenaceous) to dark-brown carbonaceous shales.



Scale 10 feet to 1 inch.

From unpublished MS. material of the Northern Transcontinental Survey.

Julius Bien & Co. Lith.

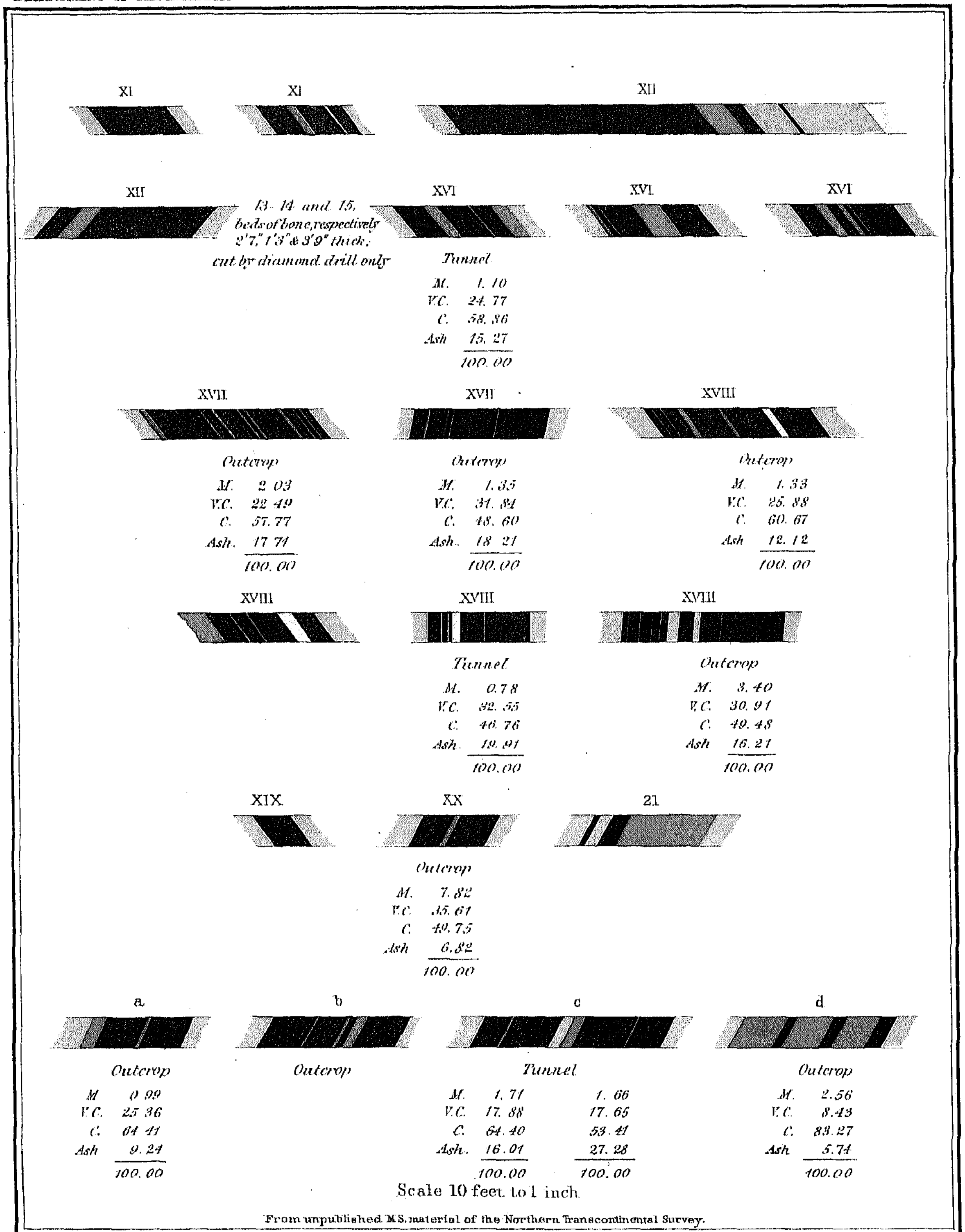
WILKESON COALFIELD

BEDS OF THE LOWER SERIES W. C.

W. C. = Wilkeson Column

Coal	Bone	Slate	Sandstone

Observed and sampled by Bailey Willis, Geologist.



Julius Bien & Co. Lith.

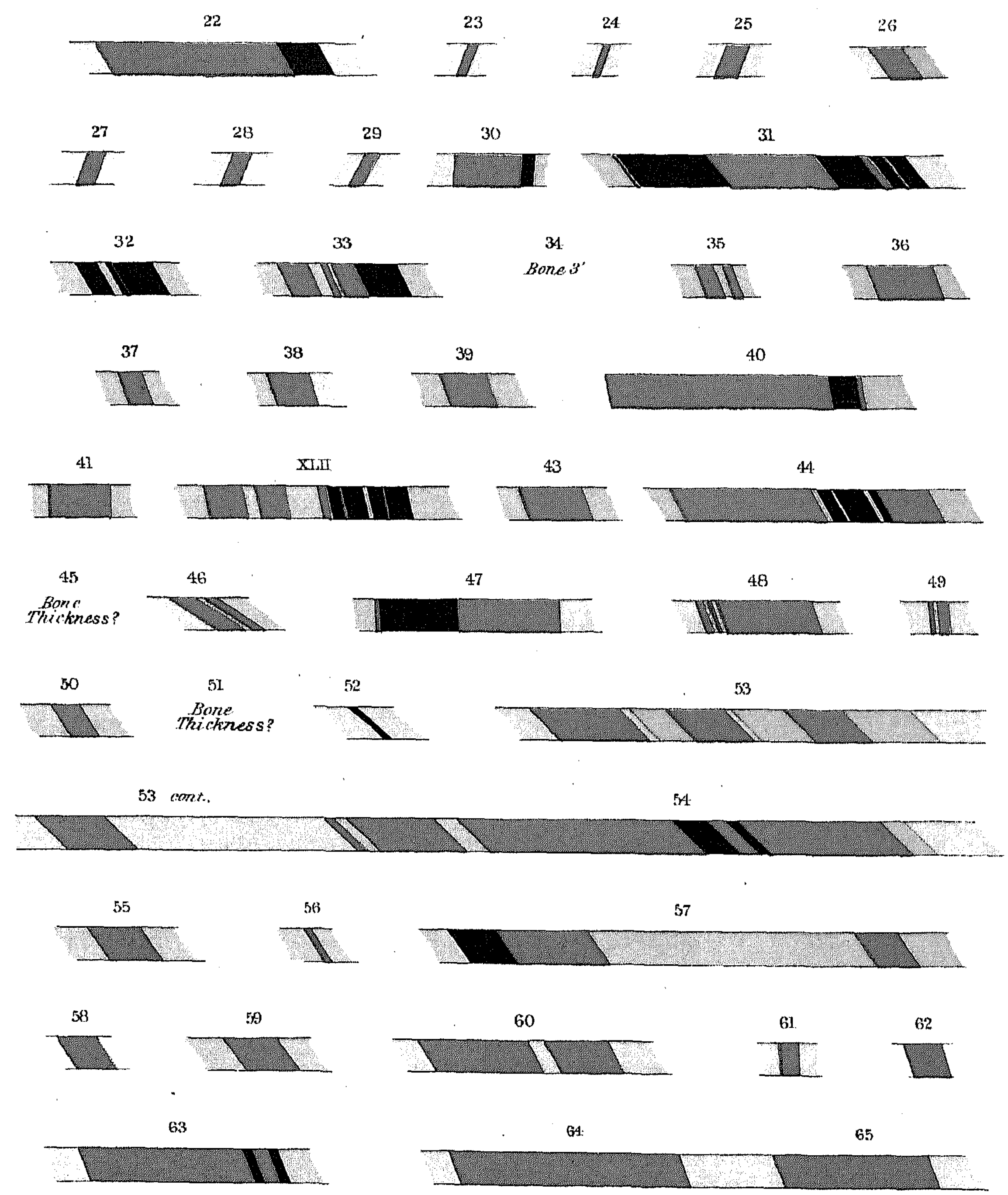
WILKESON COALFIELD

BEDS OF THE WILKESON SERIES W. C.

W.C = Wilkeson Column

Coal Bone Slate Sandstone

Observed and sampled by Bailey Willis, Geologist



Scale 10 feet to 1 inch

From unpublished M.S. material of the Northern Transcontinental Survey.

Julius Bien & Co. Lith.

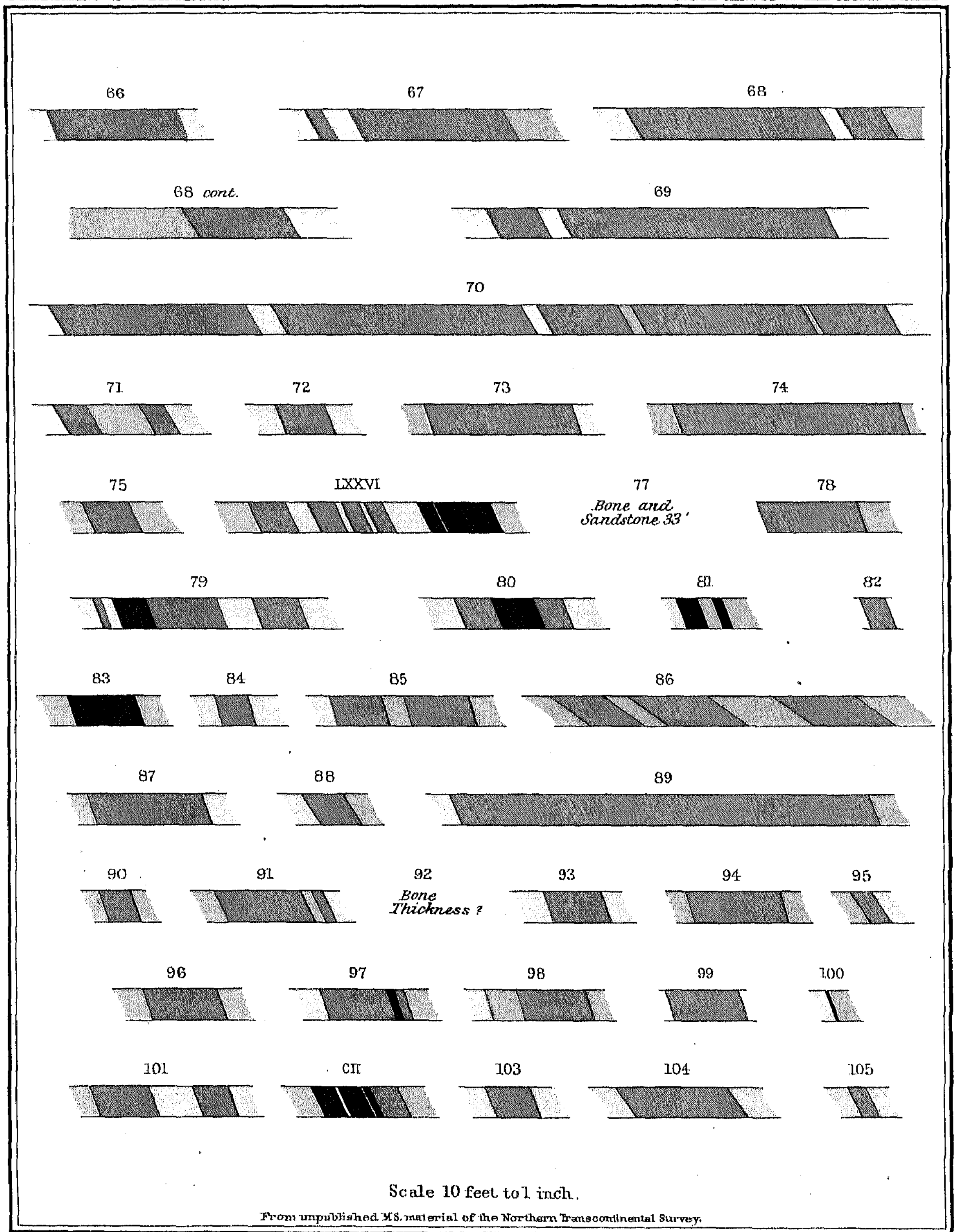
WILKESON COALFIELD

BEDS OF THE EVANS CREEK SERIES W. C

W. C. = Wilkeson Column

Coal Bone Slate Sandstone

Observed and sampled by Bailey Willis, Geologist



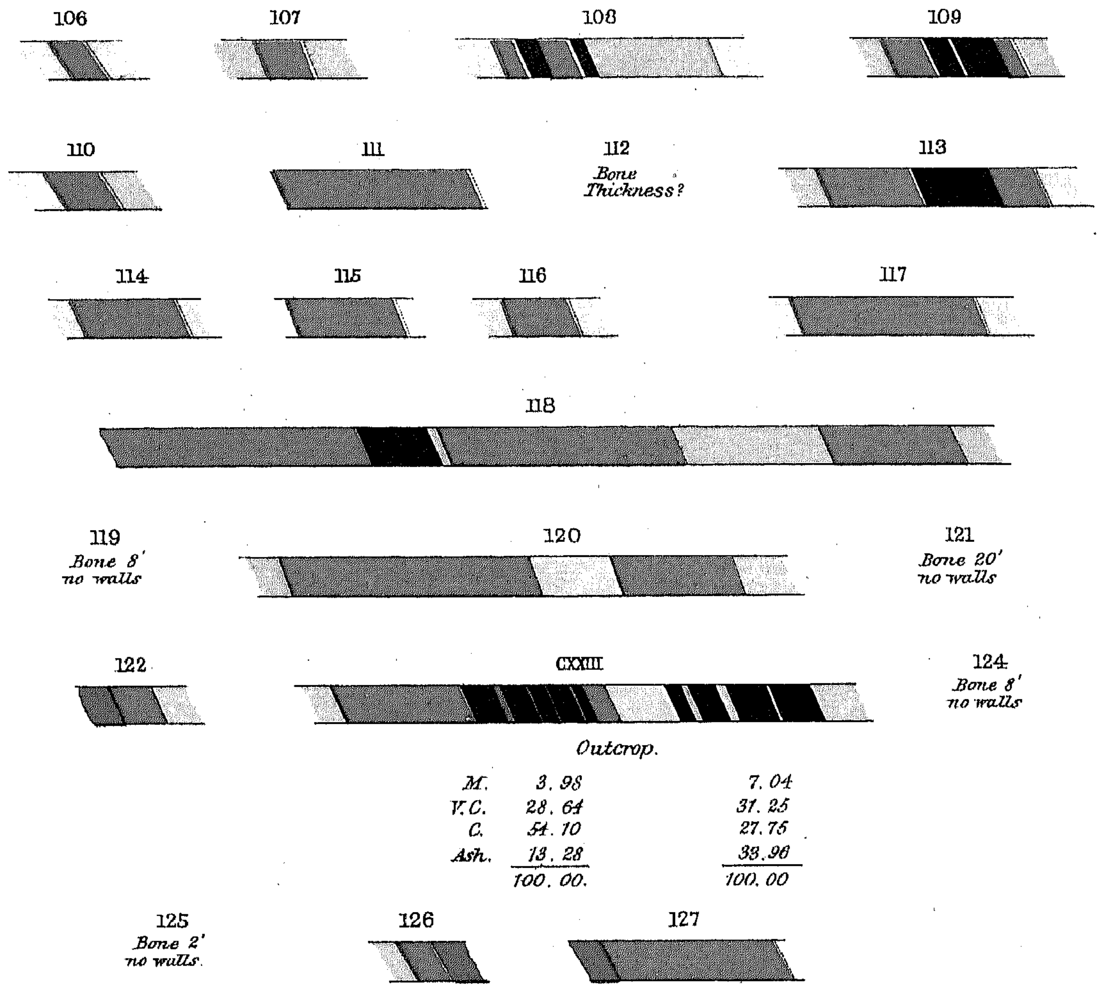
Julius Bien & Co. Lith.

WILKESON COALFIELD

BEDS OF THE EVANS CREEK SERIES. W. C.

W. C. - Wilkeson Column

Observed and sampled by Bailey Willis, Geologist



Outcrop.

M.	*3. 98*	*7. 04*
V.C.	*28. 64*	*31. 25*
C.	*54. 10*	*27. 75*
Ash.	*13. 28*	*33. 96*
	100. 00.	*100. 00*

Scale 10 feet to 1 inch.

From unpublished MS. material of the Northern Transcontinental Survey.

Julius Bien & Co. Lith.

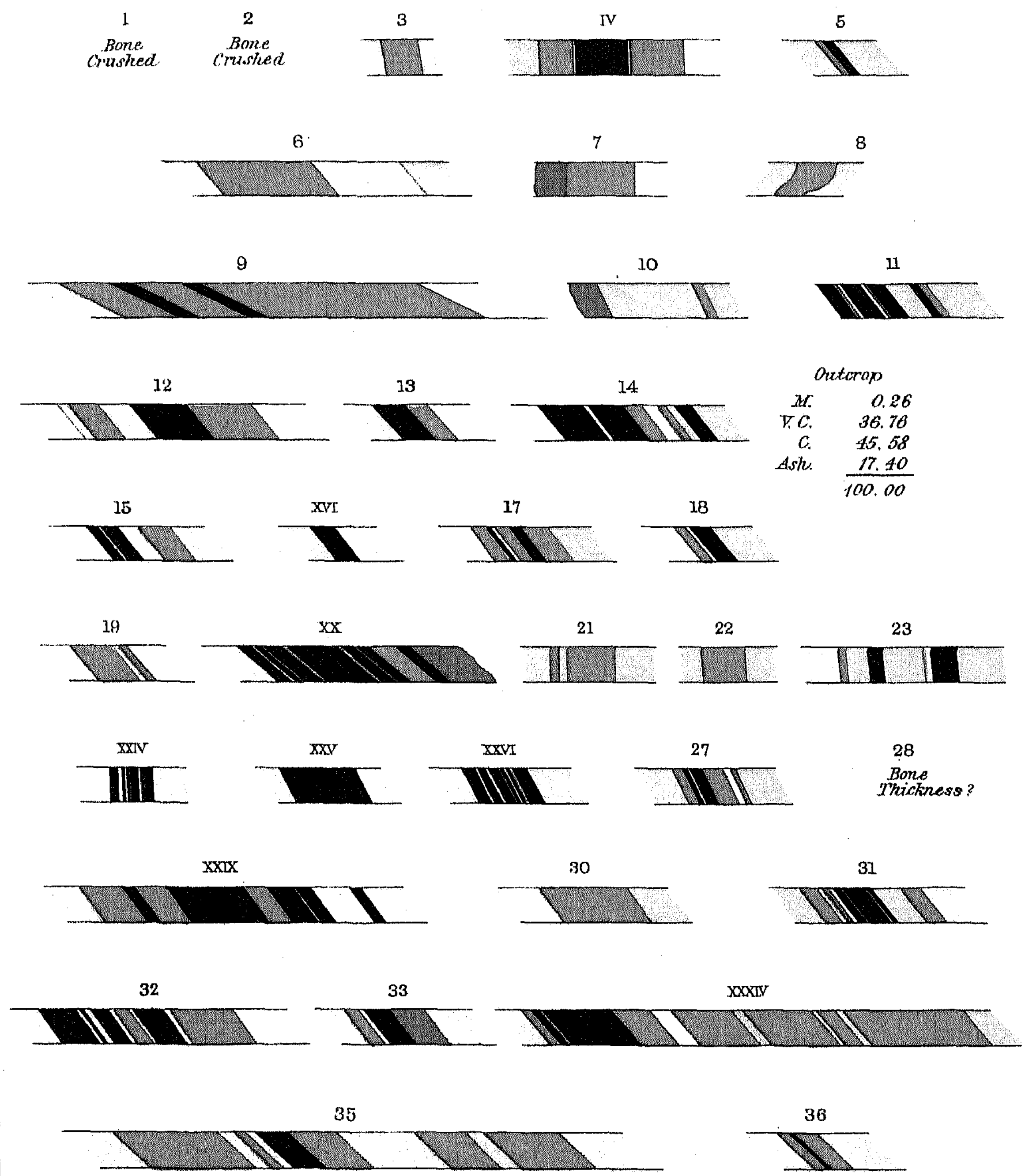
WILKESON COALFIELD

BEDS OF THE EVANS CREEK SERIES. W. C

W. C - Wilkeson Column

Coal — Bone — Slate — Sandstone — Volcanic rock

Observed and sampled by Bailey Willis, Geologist



Scale 10 feet to 1 inch.

From unpublished M.S. material of the Northern Transcontinental Survey.

Julius Bien & Co. Lith.

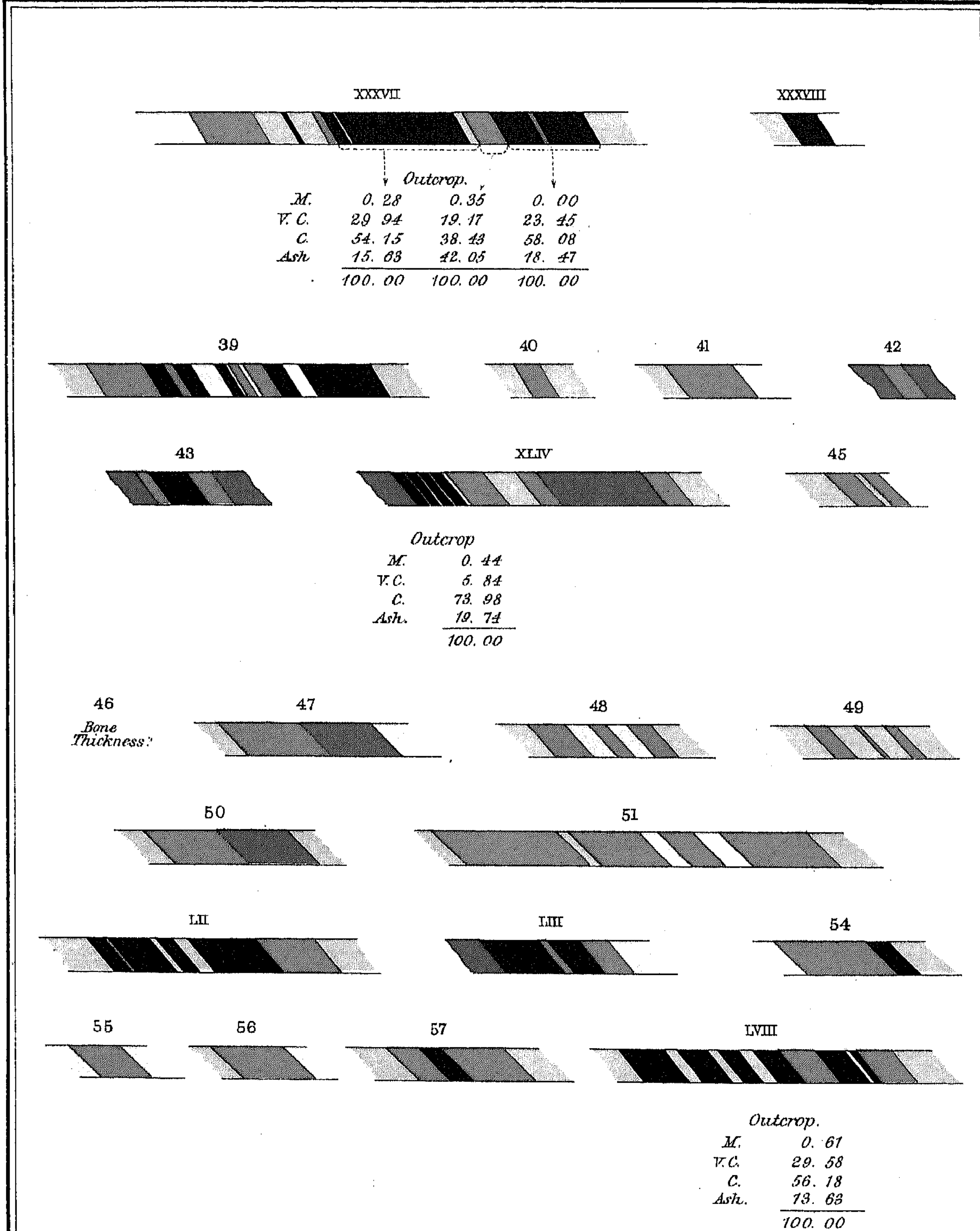
WILKESON COALFIELD

BEDS OF THE BUSY BROOK SECTION B.B.C.

B.B.C. Busy Brook Column.

Coal — Bone — Slate — Sandstone — Volcanic rock

Observed and sampled by Bailey Willis, Geologist.



Scale 10 feet to 1 inch.

From unpublished MS. material of the Northern Transcontinental Survey.

Julius Bien & Co. Lith.

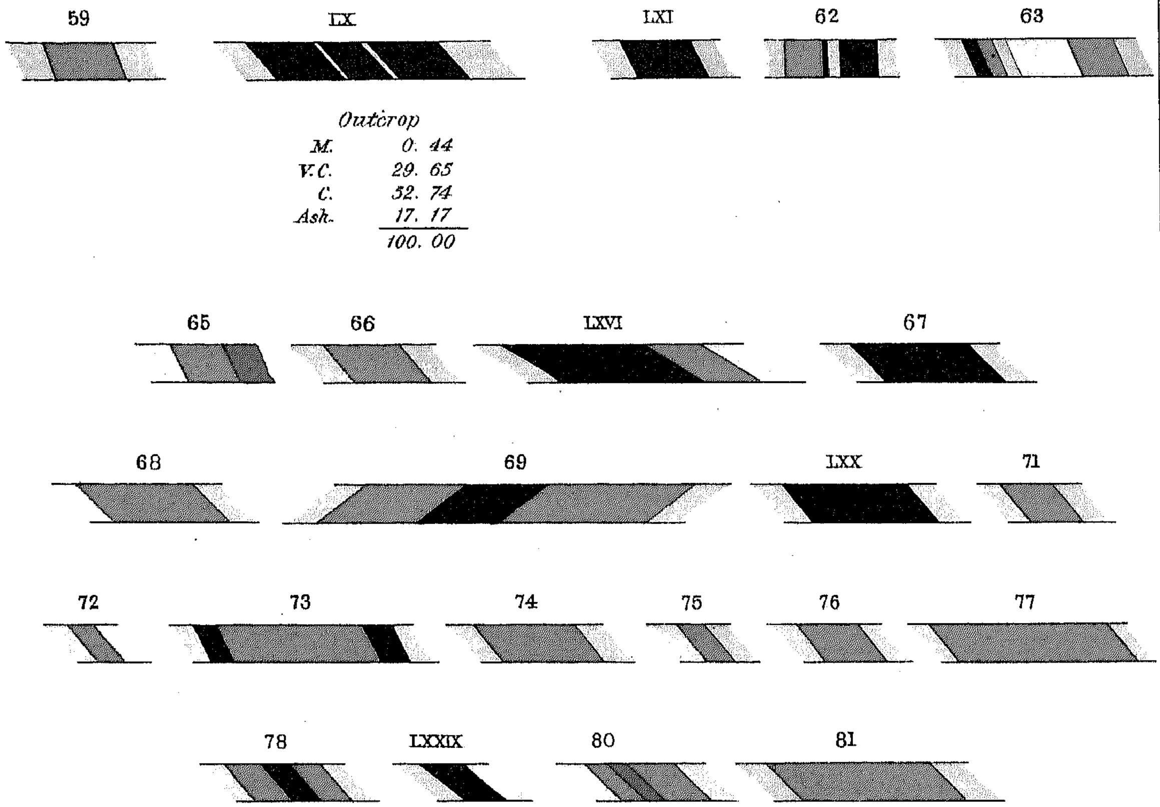
WILKESON COALFIELD

BEDS OF THE BUSY BROOK SECTION B.B.C.

B.B.C.= *Busy Brook Column*

Coal — Bone — Slate — Sandstone — Volcanic rock

Observed and sampled by Bailey Willis, Geologist.



Scale 10 feet to 1 inch.

From unpublished MS. material of the Northern Transcontinental Survey.

Julius Bien & Co. Lith.

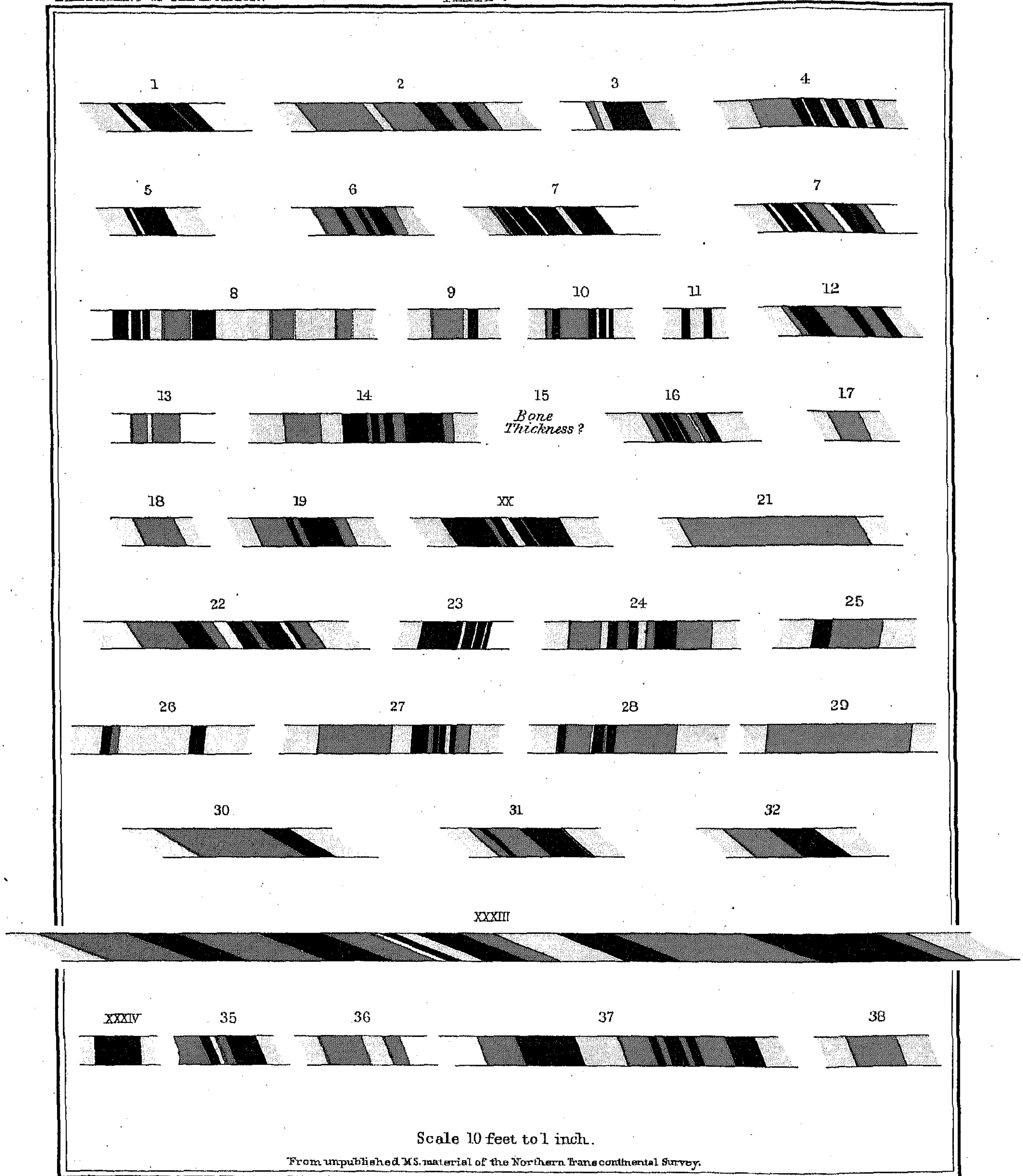
WILKESON COALFIELD

BEDS OF THE BUSY BROOK SECTION B.B.C.

B.B.C.= Busy Brook Column

Coal Bone Slate Sandstone Volcanic rock

Observed and sampled by Bailey Willis, Geologist.



Scale 10 feet to 1 inch.

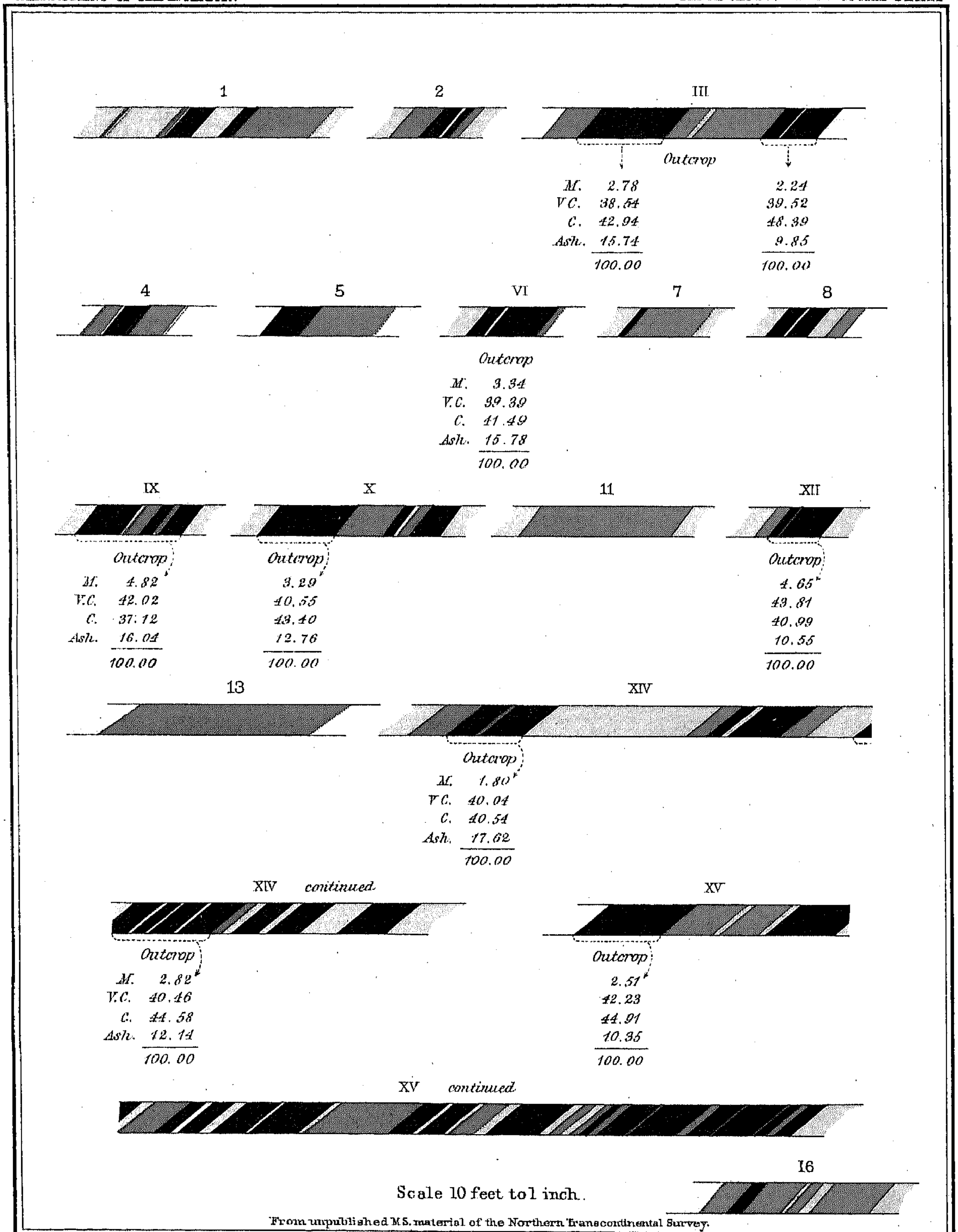
From unpublished MS. material of the Northern Transcontinental Survey.

Julius Bien & Co. Lith.

WILKESON COALFIELD

BEDS OF THE NARROWGAUGE SECTION

Observed and sampled by Bailey Willis, Geologist



Julius Bien & Co Lith.

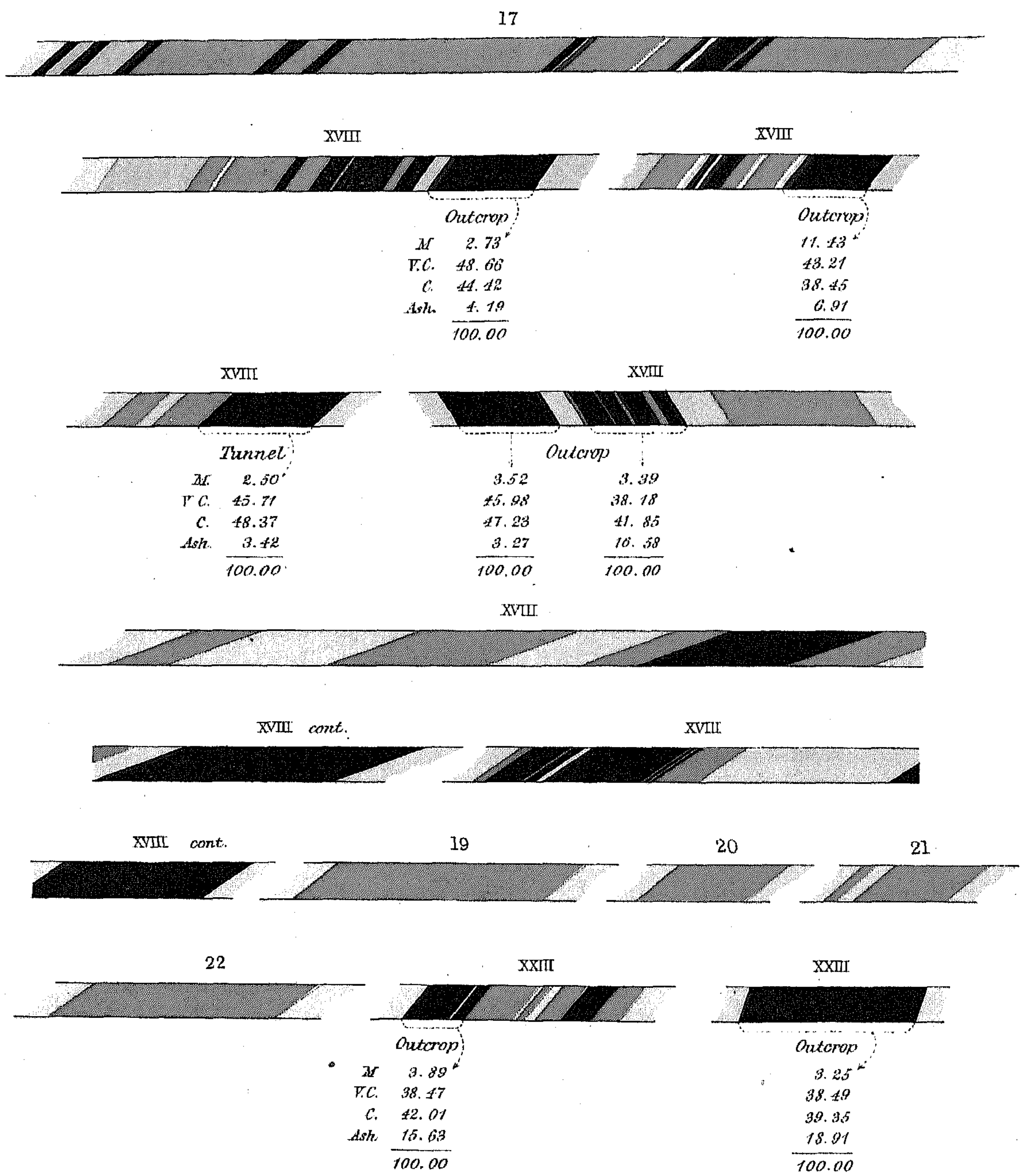
GREEN RIVER COALFIELD

BEDS OF THE McKAY BASIN G C

G.C = Green River Column

Coal Bone Slate Sandstone

Observed and sampled by Bailey Willis, Geologist



Scale 10 feet to 1 inch.

From unpublished MS. material of the Northern Transcontinental Survey.

Julius Bien & Co. Lith.

GREEN RIVER COALFIELD

BEDS OF THE McKAY BASIN G.C.

G.C = *Green River Column.*

Coal — Bone — Slate — Sandstone

Observed and sampled by Bailey Willis, Geologist.

TABLE 46.—*Analyses of commercial samples from the coal-fields of Washington territory. Samples taken by Bailey Willis.*

[Columnar numbers W., G., and B. B. refer respectively to the Wilkeson, Green River, and Busy Brook sections, accompanying the report.]

	Analysis.					Coal-bed.				
Number.	Moisture.	Volatile combustible matter.	Fixed carbon.	Ash.	Coke.	Thickness represented. Ft.	In.	Columnar number.	Name or field number.	Locality.
1	1.70	32.89	46.23	10.09	Good	2	6			Nos. 1 to 10 are from beds cut in the first 1,000 feet of the North Rock tunnel, Carbonado.
2	1.97	29.45	42.36	26.22	Fair	3	0			
3	1.78	27.63	51.66	18.93	Poor	7	0			
4	2.56	26.49	30.34	40.61	......do	5	0			
5	2.22	33.51	44.91	19.36	Fair	3	6			
6	1.55	32.37	45.43	20.75	Good	3	7			
7	2.10	29.42	36.21	32.27	......do	4	6			
8	2.28	32.39	42.89	22.44	......do	4	6			
9	2.41	32.06	46.64	18.89	......do	4	10			
10	2.85	28.50	36.26	32.39	Fair	5	2			
11	1.69	41.00	48.96	8.35	Good	4	6		Miller	Carbonado mines.
12	1.80	42.27	52.11	3.82	Very good	4	8		Wingate	Do.
13	1.41	33.05	46.63	18.91	Good	8	6			Do.
14	1.27	36.22	57.11	5.40	......do	3	0			Do.
15	4.27	36.24	52.40	7.09	Poor	13	0			Do.
16	6.80	35.10	52.14	5.96	......do	7	0			Do.
17	1.33	25.88	60.67	12.12	Excellent	6	8	XVIII W.	Smith vein	Fletts creek, near Wilkeson.
18	1.30	27.29	54.01	17.40	......do	8	0	XVII W.	Goodwin	Do.
19	1.10	24.77	58.86	15.27	......do	5	4	XVI W.	Gale	Do.
20	1.22	32.88	50.67	15.23	......do	7	2	XVII W.	Ainsworth	Old tunnel at Wilkeson.
21	0.78	32.55	46.76	19.91	Good	6	0	XVIII W.	Wright	Do.
22	2.03	22.49	57.77	17.71	Excellent	8	0	XVII W.	Goodwin	Outcrop 2½ miles from Wilkeson.
23	4.13	42.97	43.36	9.54	Non-coking	9	8		No. 2 vein	Newcastle lignite.
24	4.16	44.84	43.86	7.14	......do	9	10		......do	Do.
25	6.59	44.71	41.30	7.40	......do	10	5		......do	Do.
26	4.18	43.79	40.20	11.83	......do	7	6		Bagley	Do.
27	2.50	45.71	48.37	3.42	Poor	4	0	XVIII G.	Empire tunnel	McKay basin, Green river.
28	1.80	40.04	40.54	17.62	......do	2	10	XIV G.		Do.
20	2.82	40.46	44.58	12.14	Worthless	4	2	XIV G.		Do.
30	2.51	42.23	44.91	10.35	Poor	3	6	XV G.		Do.
31	3.89	38.47	42.01	15.63	Non-coking	2	8	XXIII G.		Do.
32	1.03	26.36	49.69	22.92	Worthless	5	3	II W.	G bed	Three miles south of Wilkeson.
33	3.56	29.01	52.26	15.17	......do	8	0	V W.	P bed	Do.
34	......	......	......	......						Part of sample 33.
35	2.86	30.86	58.25	8.03	Poor	4	9	V W.	P bed	Three miles south of Wilkeson.
36	1.17	27.32	56.36	15.15	Fair	3	5	II W.	G bed	Do.
37	1.54	28.17	59.70	10.59	Poor	6	4	I W.	H bed	Do.
38	2.43	36.33	45.14	16.10	Non-coking	6	4		Mammoth	Lizard mountain, Green river.
39	4.63	35.51	42.79	17.07	......do	9	7		......do	Do.
40	4.65	43.81	40.99	10.55	......do	2	5	XII G.		Northern field, Green river.
41	3.29	40.55	43.40	12.76	Sinter	4	0	X G.		Do.
42	4.82	42.02	37.12	16.04	None	4	11	IX G.		Do.
43	3.34	39.39	41.49	15.78	......do	5	3	VI G.		Do.
44	2.78	38.54	42.94	15.74	......do	4	3	III G.		Do.
45	2.24	39.52	48.39	9.85	......do	2	8	III G.		Do.
46	11.43	43.21	38.45	6.91	......do	3	8	XVIII G.	McKay bed	McKay basin, Green river.
47	2.73	45.66	44.42	4.10	Rather poor	5	0	XVIII G.	......do	Do.
48	3.25	38.49	39.35	18.01	Sinter	9	7	XXIII G.		Do.
40	1.84	42.45	45.90	9.81	Poor	4	4	XV G.		Do.
59	8.68	35.90	47.07	8.35	None	2	6			Lignite, Lower Green river.
51	7.46	37.14	32.20	23.20	......do	4	5	40 G.		Do.
a52	......	......	......	......				(?)		Do.
a53	......	......	......	......				(?)		Do.
a54	......	......	......	......				35 G.		Do.
55	9.35	40.77	47.25	2.63	None	7	0	34 G.		Do.
56	9.98	40.63	41.07	8.32	......do	5	0	33 G.		Do.
57	8.09	36.48	33.11	22.32	......do	8	0	38 G.		Do.
a58	......	......	......	......				(?)		Do.
50	7.27	36.02	28.48	28.23	None	15	3	(?)		Do.

a Not analyzed.

TABLE 46.—*Analyses of commercial samples from the coal-fields of Washington territory*—Continued.

ANALYSIS.						COAL-BED.			
Number.	Moisture.	Volatile combustible matter.	Fixed carbon.	Ash.	Coke.	Thickness represented.	Columnar number.	Name or field number.	Locality.
						Ft. In.			
60	1.35	31.84	48.60	18.21	Very good	9 0	XVIII W.	Kelly	One and a half miles south of Wilkeson.
61	1.19	32.06	48.14	18.61	do	9 0	XVIII W.	do	Do.
62	2.11	32.15	50.03	15.71	Poor	6 0		Henry, top	Near Carbonado.
63	2.24	32.77	52.56	12.43	do	7 0		Henry, bottom	Do.
64	1.16	29.09	60.38	9.37	Excellent	5 1	V W.	P. bottom bench	Three miles south of Wilkeson.
65	1.77	26.16	50.99	21.08	Dense	3 2	V W.	P. top bench	Do.
b66									
67	2.14	5.52	84.49	7.85		8 3	V W.	P. (coke)	Do.
68	2.56	8.43	83.27	5.74	Non-coking	2 0	d W.	d	Carbon river, Wilkeson.
69	0.99	25.36	64.41	9.24	Excellent	5 0	a W.	a	Do.
70	1.71	17.88	61.40	16.01	Non-coking	4 6	c W.	c. top bench	Do.
71	1.66	17.65	53.41	27.28	do	5 2	c W.	c. bottom bench	Do.
72	1.07	2.73	86.21	9.99		6 4	I W.	H. (coke)	Three miles south of Wilkeson.
73	1.23	3.10	86.14	9.53		5 3	II W.	G. (coke)	Do.
74	7.82	35.61	49.75	6.82	Non-coking	3 8	XX W.	Coggeshall	One and a half miles south of Wilkeson.
75	3.40	30.91	49.48	16.21	do	6 0	XVII W.	General	Do.
76	1.17	14.40	64.56	19.87	Poor	3 5		Connor	Skagit river, Washington territory.
c77									Do.
c78									Do.
79	14.10	36.95	35.76	13.19	Non-coking	4 9			Miles City, Montana.
80	3.00	26.99	46.85	23.16	Poor	7 5			Northwest part of Green River field.
81	12.12	33.25	46.28	8.35	None	3 10		Scenery vein, top	Do.
82	15.08	31.28	41.87	11.17	do	8 2		Scenery vein, bottom	Do.
83	2.78	22.39	33.93	40.90	do	3 9			Northern part of Green River field.
84	6.03	25.84	51.32	16.81	do	4 0	XVI W.	Gale	Near Wilkeson.
85	3.87	25.67	60.18	10.28	Poor	5 10	XVIII W.	Smith	Do.
86	1.08	24.40	34.71	39.81	do	1 6			Blue mountains, Oregon.
87						6 8			Carbon river, Wilkeson.
88	3.39	38.18	41.85	16.58	Poor	4 3	XVIII G.	Top bench	McKay basin, Green river.
89	3.52	45.98	47.23	3.27	do	5 0	XVIII G.	Bottom bench	Do.
90	1.40	21.17	43.32	34.11	Fair	1 2	XVIII W.	Smith	Samples 90 to 93 were taken by diamond-drill near Wilkeson, and contain much foreign sand.
91	1.46	18.73	35.70	44.11	do	5 0	XVIII W.	do	
92	1.36	20.80	41.06	36.78	Good	7 7	XVII W.	Goodwin	
93	1.13	14.28	21.66	62.93	Poor	7 0	XVI W.	Gale	
94	0.54	59.61	31.45	8.40	None				Float-coal from Kootenay river.
95	3.00	37.96	57.49	1.55					Picked coal from Admiralty island, Alaska.
96	0.80	18.14	40.49	40.57	None	2 6	XII W.	Black	Samples 96 to 99, inclusive, were taken by diamond-drill near Wilkeson, and contain much foreign sand.
97	0.63	22.31	56.16	20.90		7 7	XII W.	do	
98	0.90	19.72	45.80	33.58		3 1	XII W.	do	
99	1.35	18.07	37.78	42.80		4 1	XI W.	Stark	
100	0.86	9.80	50.93	38.41	None	5 3		120. Scotchman	Evans creek, Wilkeson field.
101	2.24	9.45	57.16	31.15	do	4 6		120. Scotchman	Do.
102	0.85	12.67	69.22	17.26	do				Several beds of Puyallup area, Wilkeson field.
103	0.37	17.25	45.01	37.37	do	4 2		488	Evans creek, Wilkeson field.
104	0.53	15.47	24.60	59.40	Poor	(?)			Do.
105	0.33	14.95	31.85	52.87		(?)			Do.
106									Limestone from Alaska.
107									Limestone from Skagit river.
108									Limestone from Baker river.
109	1.53	42.82	44.94	10.71	Poor	3 0			Camas mountain, southern Oregon.
110	1.06	24.41	47.19	27.34	Good	6 1		303. Nisqually Chief, top	Mishall basin, Wilkeson.
111	1.24	22.65	47.93	28.18	do	6 8		303. Nisqually Chief, middle	Do.
112	1.04	24.12	51.46	23.38	do	7 3		303. Nisqually Chief, bottom	Do.
113	0.88	26.09	64.54	8.49	do				Picked coal from Mishall basin, Wilkeson.
114	1.60	14.04	54.00	29.76	None	7 9		354	Mishall basin, Wilkeson.
115	0.91	26.78	47.67	24.64	Good	6 0		352	Do.
116	0.68	25.17	54.78	19.37	do	4 6		341	Do.
117	0.83	22.35	42.79	34.03	do	2 9		341	Do.
118	0.69	24.93	56.91	17.47	do	11 6		300	Do.
119	0.41	28.70	52.70	18.19	do	2 6	V W.	P. vein	Three miles south of Wilkeson.

a Lost.

b Iron ore.

TABLE 46.—*Analyses of commercial samples from the coal fields of Washington territory*—Continued.

Number.	Analysis.					Coal-bed.			Locality.
	Moisture.	Volatile combustible matter.	Fixed carbon.	Ash.	Coke.	Thickness represented.	Columnar number.	Name or field number.	
						Ft. In.			
120	0.45	27.62	52.04	19.89	......do	3 6	V W.	......do	Three miles south of Wilkeson.
121	0.00	28.91	56.16	14.93	Fair	8 0	V W.	......do	Do.
122	0.02	24.34	52.72	22.92	Good	5 4		108 top	Evans creek, Wilkeson field.
123	0.02	25.80	56.51	17.67	......do	3 2		108 bottom	Do.
124	7.04	31.25	27.75	33.96	None	6 0	CXXIII W.	405	Do.
125	3.98	28.64	51.10	13.28	.... do	4 10	CXXIII W.	405	Do.
126	0.93	17.14	62.78	19.15	......do	3 10		459	Do.
127	0.00	10.02	61.81	28.17	......do	5 8		461	Do.
128	2.42	28.75	53.89	14.94	......do	4 0		480	Do.
129	2.39	26.42	54.12	17.07	......do	7 0		483	Do.
130	0.80	29.28	61.03	8.89	......do	4 0		488	Do.
131	0.26	36.76	45.58	17.40	Fair	2 8	II B. B.	550	Busy brook, Wilkeson field.
132	0.00	23.45	58.08	18.47	None	4 9	XXXVII B. B.	578 top	Do.
133	0.35	19.17	38.43	42.05	......do	1 6	XXXVII B. B.	578 middle	Do.
134	0.28	29.91	54.15	15.63	Dense	7 0	XXXVII B. B.	578 bottom	Do.
135	0.44	5.84	73.98	19.74	None	2 0	XLIV B. B.	586	Do.
136	0.61	29.58	56.18	13.63	Poor	7 7	LVIII B. B.	601	Do.
137	0.54	5.86	56.98	36.62	None	6 4	LX B. B.	602	Do.
138	0.44	29.65	52.74	17.17	Fair	4 0	LX B. B.	619	Do.
139	0.60	28.48	45.25	25.67	......do	16 11		641 bottom	Do.
140	0.64	27.83	51.48	20.05	Dense	5 3		641 top	Do.
......	0.80	40.87	46.39	11.94	Fair	......			Picked coal from Upper Yakima, Washington territory.

ANALYSES

OF

COALS AND LIGNITES OF THE NORTHWEST,

AND

EXPERIMENTS ON THE CONVERSION OF THE LIGNITES INTO A FUEL OF HIGH HEATING POWER.

ANALYSES OF COALS AND LIGNITES OF THE NORTHWEST.

By F. A. Gooch.

In preparing these coals for analysis the usual method of exposing the powdered material during twenty-four hours previous to analysis at ordinary temperatures and under ordinary atmospheric conditions was followed at first, but later the exposure lasted forty-eight hours and was made in a perfectly dry atmosphere, over sulphuric acid, instead of in the ordinary air of the balance-room. The mode of preparation of each coal will be apparent in the tabular statement. It was found that in consequence of the variation in the contents of the coals in water according to the atmospheric conditions some examination of their hygroscopicity was a necessity; and, though the capacity of substances in general to take up water depends upon temperature and barometric pressure, as well as upon the hygrometric condition of the atmosphere, it appeared to be quite sufficient for the purpose in hand to adopt a uniform mode of treatment, and expose, in every case, a gram of the powdered material first over sulphuric acid during forty-eight hours, and then, after weighing, over water for the same length of time in a closed vessel provided with double walls to secure a uniform temperature and so prevent the deposition of dew, to weigh and, finally, to heat for an hour at 115° C. and weigh again. By these means, the amounts of water lost at 115° C. by the coal as taken for analysis, as dried over sulphuric acid, and as fully saturated hygroscopically, became known. In most cases the period of exposure is ample, and in the few in which it may, perhaps, be not quite enough, the condition of the coal under examination falls so little short of dryness or aqueous saturation, as the case may be, that the error is not considerable. Experiment indicates that the hygroscopic character of the powder is not materially different from that of the coal in the lump, but changes naturally proceed through the mass of the former with far greater rapidity. In the proximate analysis a gram of material was employed for each process. The water was determined in one portion, as indicated above, by the loss on drying during one hour at 115° C. The total volatile matter was found by igniting a second portion in a covered plantinum crucible by means of a blowpipe flame of sufficient size to envelop the crucible completely, gently at first if the flame showed signs of sparkling, at full heat as soon as the gas evolved began to burn quietly without sparks, and strongly for three minutes and a half after the gas from the coal had ceased to burn visibly. The loss of weight of crucible and coal under these conditions was taken as the measure of the total volatile material, and the difference between this value and that of the water found by drying at 115° C. is the "volatile combustible matter". The loss of weight of the residue of this treatment when ignited over a Bunsen burner in a free draught of air gave the "fixed carbon", and the difference between the final weight and the weight of the crucible itself was the weight of the ash. Muck's method of treating the ash—moistening with alcohol, evaporating with care, and again igniting before weighing—was found to be effective in compacting the residue and so bringing about complete combustion speedily. The sulphur was estimated by the ignition of a gram of coal with a gram and a half of Eschka's mixture—two parts of magnesic oxide with one part of sodic carbonate—the extraction of the residue with hot water and, after filtering from the insoluble matter, acidifying with hydrochloric acid and boiling to expel free bromine, precipitation as baric sulphate.

The elementary composition was determined by the combustion of a fourth portion—0.2 gram—in oxygen.

The analytical work was executed by F. A. Gooch, Edward Whitfield, and W. T. Richmond.

TABLE 47.—*Proximate analyses of the*

WASHINGTON TERRITORY.

	Field.	Locality.	Name or number of seam.	Thickness represented by sample. Ft.	In.
1	Wilkeson	Bed cut in the first 1,600 feet of the North Rock tunnel, Carbonado.		2	0
2	do	do		3	0
3	do	do		7	0
4	do	do		5	0
5	do	do		3	6
6	do	do		3	7
7	do	do		4	6
8	do	do		4	6
9	do	do		4	10
10	do	do		5	2
11	do	Carbonado mines	Miller	4	6
12	do	do	Wingate	4	8
13	do	do		8	6
14	do	do		3	0
15	do	do		13	0
16	do	do		7	0
17	do	Near Carbonado	Henry, top	6	0
18	do	do	Henry, bottom	7	0
19	do	3 miles south of Wilkeson	P. bottom bench	5	1
20	do	do	P. top bench	3	2
21	do	do	P. *coke*	8	3
22	do	Fletts creek, near Wilkeson	Smith	6	8
23	do	do	Goodwin	8	0
24	do	do	Gale	5	4
25	do	Old tunnel at Wilkeson	Ainsworth	7	2
26	do	do	Wright	6	0
27	do	Outcrop 2½ miles from Wilkeson	Goodwin	8	0
28	do	3 miles south of Wilkeson	G. bed	5	3
29	do	do	P. bed	8	0
30	do	3 miles south of Wilkeson (part of sample 33)	do		
31	do	do	do	4	9
32	do	do	G. bed	3	5
33	do	do	H. bed	6	4
34	do	1½ mile south of Wilkeson	Kelly	9	0
35	do	do	do	9	0
36	do	do	Coggeshall	3	8
37	do	do	General	6	0
38	do	3 miles south of Wilkeson	H. *coke*	6	4
39	do	do	G. *coke*	5	3
40	do	do	P. vein	2	6
41	do	do	do	3	6
42	do	do	do	8	0
43	do	Near Wilkeson	Gale	4	0
44	do	do	Smith	5	10
45	do	Carbon river	a	2	0
46	do	do	a	5	0
47	do	do	c, top bench	4	6
48	do	do	c, bottom bench	5	2
49	do	From diamond drill-holes near Wilkeson. The samples contain much foreign sand.	Smith	1	2
50	do	do	do	5	0
51	do	do	Goodwin	7	7
52	do	do	Gale	7	0
53	do	do	Black	2	6
54	do	do	do	7	7
55	do	do	do	3	1
56	do	do	Stark	4	1
57	do	Evans creek	120 Scotchman	5	3
58	do	do	do	4	6
59	do	do	488	4	2
60	do	do		?	
61	do	do		?	
62	do	do	108, top	5	4

coals and lignites of the Northwest.

WASHINGTON TERRITORY.

Sampler.	Number of sample.	Number on plate of graphic section.	Proximate analysis. Water.	Proximate analysis. Volatile combustible matter.	Proximate analysis. Fixed carbon.	Proximate analysis. Ash.	Sulphur.	Color of ash.	Character of coke.	Water in dry coal.	Water in saturated coal.	Fuel ratio, $\frac{c}{vc}$	Combustion analysis, see Table 48.	
Willis	1	....	1.79	32.89	46.23	19.09	0.78	Yellow brown	Good	0.66	2.10	1.40	......	1
.. do	2	....	1.97	29.45	42.36	26.22	3.60	Red brown.......	Fair	0.95	3.36	1.44	......	2
... do	3	....	1.78	27.63	51.66	18.93	0.64	....do	Poor...........	0.45	1.94	1.87	......	3
.. do	4	....	2.56	26.49	30.34	40.61	0.42	Dirty white.......	...do	0.71	2.49	1.14	......	4
....do	5	....	2.22	33.51	44.91	19.36	0.41	Yellow	Fair	0.67	2.45	1.34	......	5
....do	6	....	1.55	32.37	45.33	20.75	0.78	Reddish	Good	1.47	3.14	1.40	......	6
....do	7	....	2.10	29.42	36.21	32.27	2.36	Purple brown.....	....do	0.64	2.63	1.23	......	7
....do	8	....	2.28	32.39	42.89	22.44	2.58	Red brown	... do	0.70	2.53	1.32	......	8
....do	9	....	2.41	32.06	46.64	18.89	0.51	Light buff........	....do	1.31	2.88	1.45	......	9
....do	10	....	2.85	28.50	36.26	32.39	0.54	Reddish	Fair	0.81	3.33	1.27	......	10
....do	11	....	1.69	41.00	48.96	8.35	1.00	....do	Very good	1.60	2.91	1.22	1	11
....do	12	....	1.80	42.27	52.11	3.82	0.51	....do	....do	....	....	1.23	2	12
...do	13	....	1.41	33.05	46.63	18.91	0.51	.. do	Good	1.41	2.07	1.41	......	13
.. do	14	....	1.27	36.22	57.11	5.40	0.99	....do	....do	0.28	1.76	1.58	......	14
... do	15	....	4.27	36.24	52.40	7.09	0.36	....do	Very poor........	0.92	4.54	1.44	......	15
....do	16	....	6.80	35.10	52.14	5.96	0.33	... do	....do	1.58	6.80	1.48	......	16
....do	62	....	2.11	32.15	50.03	15.71	0.55	....do	Poor	0.94	3.04	1.56	......	17
....do	63	....	2.24	32.77	52.56	12.43	0.45	....do	... do	1.16	3.76	1.60	......	18
....do	64	V W.	1.16	29.09	60.38	9.37	0.41	....do	Excellent	0.39	2.05	2.07	10	19
....do	65	V W.	1.77	26.16	50.99	21.08	0.45	....do	Dense	0.62	2.47	1.95	11	20
....do	67	V W.	2.14	5.52	84.49	7.85	0.45	Light buff	....	1.19	3.20	....	......	21
.. do	17	XVIII W.	1.33	25.88	60.67	12.12	0.60	Brownish	Excellent	0.40	1.33	2.34	......	22
....do	18	XVII W.	1.30	27.29	54.01	17.40	0.41	.. do	... do	0.30	2.12	1.98	......	23
....do	19	XVI W.	1.10	24.77	58.86	15.27	1.04	... do	... do	0.15	1.07	2.38	3	24
....do	20	XVII W.	1.22	32.88	50.67	15.23	0.66	Reddish	... do	0.31	1.72	1.54	4	25
....do	21	XVIII W.	0.78	32.55	46.76	19.91	0.56	....do	Good	0.35	1.72	1.44	5	26
....do	22	XVII W.	2.03	22.49	57.77	17.71	0.60	Brownish	Excellent	0.40	2.54	2.57	......	27
....do	32	II W.	1.03	26.36	49.69	22.92	0.48	Reddish	Worthless	0.42	2.84	1.88	......	28
....do .... do	33 34	} V W.	3.56	29.01	52.26	15.17	0.30	....do	....do	0.65	5.08	1.80	6	{ 29 { 30
....do	35	V W.	2.86	30.86	58.25	8.03	0.56	....do	Poor	1.26	4.35	1.88	7	31
....do	36	II W.	1.17	27.32	56.36	15.15	0.43	....do	Fair	0.68	2.42	2.06	8	32
....do	37	I W.	1.54	28.17	59.70	10.59	0.47	Red...........	Rather poor.......	0.66	2.77	2.12	9	33
....do	60	XVIII W.	1.35	31.84	48.60	18.21	0.49	Reddish	Very poor	....	....	1.52	......	34
....do	61	XVIII W.	1.19	32.06	48.14	18.61	0.54	....do	Good	0.52	2.73	1.50	......	35
....do	74	XX W.	7.82	35.61	49.75	6.82	0.58	....do	None	2.42	8.70	1.54	......	36
....do	75	XVII W.	3.40	30.01	49.48	16.21	0.42	....do	....do	1.38	4.05	1.60	......	37
....do	72	I W.	1.07	2.73	86.21	9.99	0.52	Red...........	....	0.83	1.60	....	......	38
...do	73	II W.	1.23	3.10	86.14	9.53	0.57	....do	....	0.93	2.06	....	......	39
..do	119	V W.	0.41	28.70	52.70	18.19	......	White	Fair	0.41	1.58	1.83	......	40
....do	120	V W.	0.45	27.62	52.04	19.89	......	....do	....do	0.45	1.48	1.88	......	41
....do	121	V W.	0.00	28.91	56.16	14.93	.....	.. do	....do	0.00	0.75	1.94	......	42
....do	84	XVI W.	6.03	25.84	51.32	16.81	0.58	Buff	None	1.19	5.85	1.99	......	43
....do	85	XVIII W.	3.87	25.67	60.18	10.28	0.50	Reddish	Very poor........	0.53	4.06	2.02	......	44
....do	68	d W.	2.56	8.43	83.27	5.74	1.07	Dark red	None	1.59	3.52	9.88	12	45
....do	69	a W.	0.99	25.36	64.41	9.24	0.57	Reddish	Excellent........	0.84	1.54	2.54	13	46
....do	70	c W.	1.71	17.88	64.40	16.01	0.47	White	None	0.66	2.73	3.60	......	47
....do	71	c W.	1.66	17.65	53.41	27.28	0.44	Light brown	....do	0.88	2.45	3.03	14	48
....do	90	XVIII W.	1.40	21.17	43.32	34.11	0.42	....	Fair, but dense....	....	....	2.05	......	49
....do	91	XVIII W.	1.46	18.73	35.70	44.11	0.56	....	....do	0.41	2.46	1.90	......	50
....do	92	XVII W.	1.36	20.80	41.06	36.78	0.40	....	Good, but dense...	0.41	2.21	1.97	......	51
....do	93	XVI W.	1.13	14.28	21.66	62.93	0.37	....	Poor	0.53	2.08	1.51	......	52
....do	96	XII W.	0.80	18.14	40.49	40.57	0.47	Pinkish...........	....	....	....	2.23	......	53
....do	97	XII W.	0.63	22.31	56.16	20.90	0.54	....do	....	....	....	2.51	......	54
....do	98	XII W.	0.90	19.72	45.80	33.58	0.46	....	....	....	....	2.32	......	55
....do	99	XI W.	1.35	18.07	37.78	42.80	0.47	....	....	....	....	2.09	......	56
....do	100	....	0.86	9.80	50.93	38.41	0.49	Gray	None	0.20	2.86	5.19	......	57
...do	101	....	2.24	9.45	57.16	31.15	0.35	Reddish	....do	1.04	5.49	6.04	......	58
....do	103	....	0.37	17.25	45.01	37.37	0.85	Gray	....do	0.35	1.70	2.60	......	59
....do	104	....	0.53	15.47	24.60	59.40	0.48	....do	Poor	1.17	1.02	1.59	......	60
... do	105	....	0.33	14.95	31.85	52.87	0.78	....do	.. do	0.20	1.55	2.13	......	61
....do	122	....	0.02	24.34	52.72	22.92	......	Pink	Good	0.02	1.05	2.10	......	62

TABLE 47.—*Proximate analyses of the coals*

WASHINGTON TERRITORY—Continued.

	Field.	Locality.	Name or number of seam.	Thickness represented by sample.
				Ft. In.
63	Wilkeson	Evans creek	108, bottom	3 2
64	...do	...do	405	6 0
65	...do	...do	405	4 10
66	...do	...do	459	3 10
67	...do	...do	461	5 8
68	...do	...do	480	4 0
69	...do	...do	483	7 0
70	...do	...do	488	4 0
71	...do	Mishall basin	303 Nisqually Chief, top	6 1
72	...do	...do	303 Nisqually Chief, middle	6 8
73	...do	...do	303 Nisqually Chief, bottom	7 3
74	...do	...do	303 Nisqually Chief, picked coal	....
75	...do	...do	354	7 9
76	...do	...do	352	6 0
77	...do	...do	341	4 6
78	...do	...do	341	2 0
79	...do	...do	300	11 6
80	...do	Puyallup area	Several beds	....
81	Green river	McKay basin	Empire tunnel	4 0
82	...do	...do		2 10
83	...do	...do		4 2
84	...do	...do		3 6
85	...do	...do		2 8
86	...do	...do	McKay bed	3 8
87	...do	...do	...do	5 0
88	...do	...do		9 7
89	...do	...do		4 4
90	Green river	McKay basin	Top bench	4 3
91	...do	...do	Bottom bench	5 0
92	...do	Lizard mountain	Mammoth	6 4
93	...do	...do	...do	9 7
94	...do	Northern field		2 5
95	...do	...do		4 0
96	...do	...do		4 11
97	...do	...do		5 3
98	...do	...do		4 3
99	...do	...do		2 8
100	...do	Northwestern part of Green River field		7 5
101	...do	...do	Scenery vein, top	3 10
102	...do	...do	Scenery vein, bottom	8 2
103	...do	Northern part Green River field		3 9
104	...do	Lower Green River *lignite*		2 6
105	...do	...do		4 5
106	...do	...do		7 0
107	...do	...do		5 0
108	...do	...do		8 0
109	...do	...do		15 3
110	Busy brook	Busy brook	550	2 8
111	...do	...do	578, top	4 9
112	...do	...do	578, middle	1 6
113	...do	...do	578, bottom	7 0
114	...do	...do	586	2 0
115	...do	...do	601	7 7
116	...do	...do	602	6 4
117	...do	...do	619	4 0
118	...do	...do	641, bottom	16 11
119	...do	...do	641, top	3 3
120	Newcastle	Newcastle *lignite*	No. 2 vein	9 8
121	...do	...do	...do	9 10
122	...do	...do	...do	10 5
123	...do	...do	Bagley vein	7 6
124			Section 12; 8-foot vein; small pieces from top seam	....
125			Section 12; 8-foot vein; from foot-wall	....

and lignites of the Northwest—Continued.

WASHINGTON TERRITORY—Continued.

Sampler.	Number of sample.	Number on plates of graphic sections.	PROXIMATE ANALYSIS. Water.	Volatile combustible matter.	Fixed carbon.	Ash.	Sulphur.	Color of ash.	Character of coke.	Water in dry coal.	Water in saturated coal.	Fuel ratio, $\frac{\text{c}}{\text{vc}}$	Combustion analysis, see Table 48.	
Willis	123		0.02	25.80	56.51	17.07	......	White	Good	0.02	0.78	2.19	......	63
...do	124	CXXIII W.	7.04	31.25	27.75	33.96	......	...do	None	7.04	14.49	0.88	......	64
...do	125	CXXIII W.	3.08	28.64	54.10	13.28	......	...do	...do	3.98	11.27	1.88	......	65
...do	126		0.93	17.14	62.78	19.15	......	...do	...do	0.93	4.13	3.66	......	66
...do	127		0.00	10.02	61.81	28.17	......	...do	...do	0.00	3.05	6.10	......	67
...do	128		2.42	28.75	53.89	14.94	......	Yellowish	...do	2.42	8.88	1.87	......	68
...do	129		2.39	26.42	54.12	17.07	......	...do	...do	2.39	8.36	2.04	......	69
...do	130		0.80	29.28	61.03	8.89	......	Red	Worthless	0.80	3.95	2.08	......	70
...do	110		1.06	24.41	47.19	27.34	0.54	White	Good	0.81	2.61	1.93	......	71
...do	111		1.24	22.65	47.93	28.18	0.44	...do	...do	0.63	2.73	2.11	......	72
...do	112		1.04	24.12	51.46	23.38	0.54	...do	...do	0.57	2.28	2.13	......	73
...do	113		0.88	26.09	64.54	8.49	0.51	...do	...do	0.88	2.73	2.47	......	74
...do	114		1.60	14.04	54.60	29.76	1.55	Yellowish	None	0.61	3.69	3.88	......	75
...do	115		0.91	26.78	47.07	24.64	1.02	White	Good	0.32	2.25	1.78	......	76
...do	116		0.68	25.17	54.78	19.37	0.66	...do	...do	0.39	1.70	2.17	......	77
...do	117		0.83	22.35	42.70	34.03	1.13	...do	...do	0.35	2.06	1.91	......	78
...do	118		0.69	24.93	56.91	17.47	0.56	...do	Very good	0.25	1.95	2.28	......	79
...do	102		0.85	12.67	69.22	17.26	0.60	Pink	None	0.46	2.61	5.46	......	80
...do	27	XVIII G.	2.50	45.71	48.37	3.42	0.44	Red	Poor	1.28	6.26	1.06	......	81
...do	28	XIV G.	1.80	40.04	40.54	17.62	0.57	Reddish	Rather poor	0.74	5.08	1.00	......	82
...do	29	XIV G.	2.82	40.46	44.58	12.14	0.48	...do	Worthless	0.71	5.42	1.10	......	83
...do	30	XV G.	2.51	42.23	44.91	10.35	0.57	Pinkish	Poor	0.96	5.82	1.06	......	84
...do	31	XXIII G.	3.89	38.47	42.01	15.63	0.37	White	None	1.47	8.88	1.09	......	85
...do	46	XVIII G.	11.43	43.21	38.45	6.91	0.37	Pale red	...do	5.94	16.09	0.89	......	86
...do	47	XVIII G.	2.73	48.66	44.42	4.19	0.47	Red	Rather poor	1.54	5.64	0.91	15	87
...do	48	XXIII G.	3.25	38.40	39.35	18.91	0.53	Reddish	Worthless	1.81	6.77	1.02	......	88
...do	49	XV G.	1.84	42.45	45.90	9.81	0.55	Red	Poor	1.83	5.93	1.08	......	89
...do	88	XVIII G.	3.30	38.18	41.85	16.58	0.63	Pinkish	Sandy	1.46	6.15	1.10	......	90
...do	89	XVIII G.	3.52	45.98	47.23	3.27	0.73	...do	...do	1.61	5.84	1.03	......	91
...do	38		2.43	36.33	45.14	16.10	0.50	Reddish	None	2.08	6.67	1.24	......	92
...do	39		4.03	35.51	42.79	17.07	0.60	Brownish white	...do	2.31	7.09	1.20	......	93
...do	40	XII G.	4.65	43.81	40.99	10.55	0.56	Reddish	...do	2.46	8.36	0.93	......	94
...do	41	X G.	3.29	40.55	43.40	12.76	1.02	...do	Sinter	2.09	8.00	1.07	......	95
...do	42	IX G.	4.82	42.02	37.12	16.04	1.06	...do	None	1.54	9.34	0.88	......	96
...do	43	VI G.	3.34	39.39	41.49	15.78	0.71	...do	...do	1.68	7.47	1.05	......	97
...do	44	III G.	2.78	38.54	42.94	15.74	0.60	...do	Sinter	1.01	5.01	1.11	......	98
...do	45	III G.	2.24	39.52	48.39	9.85	1.20	...do	Worthless	1.27	6.37	1.22	......	99
...do	80		3.00	26.99	46.85	23.16	0.60	White	Very poor	1.23	4.48	1.73	16	100
...do	81		12.12	33.25	46.28	8.35	0.33	...do	None	3.09	11.63	1.39	......	101
...do	82		15.68	31.28	41.87	11.17	0.35	...do	...do	2.76	12.90	1.31	......	102
...do	83		2.78	22.39	33.03	40.90	0.65	...do	Sinter	0.91	3.80	1.47	......	103
...do	50		8.68	35.90	47.07	8.35	0.61	Bright red	None	4.98	14.41	1.03	......	104
...do	51	40 G.	7.46	37.14	32.20	23.20	0.60	White	...do	3.89	12.94	0.87	......	105
...do	55	34 G.	9.35	40.77	47.25	2.63	0.60	Red	...do	4.45	15.82	1.16	......	106
...do	56	33 G.	9.98	40.63	41.07	8.32	0.39	Reddish	...do	4.70	16.46	1.01	......	107
...do	57	38 G.	8.09	36.48	33.11	22.32	0.52	White	...do	3.53	13.89	0.91	......	108
...do	59	(?)	7.27	36.02	28.48	28.23	0.53	...do	...do	3.35	12.82	0.79	......	109
...do	131	11 B. B.	0.26	36.76	45.58	17.40	......	Purple	Fair	0.26	3.51	1.23	......	110
...do	132	XXXVII B. B.	0.00	23.45	58.08	18.47	......	White	Sandy	0.00	2.88	2.47	......	111
...do	133	XXXVII B. B.	0.35	19.17	38.43	42.05	......	...do	Worthless	0.35	2.95	2.00	......	112
...do	134	XXXVII B. B.	0.28	29.94	54.15	15.63	......	...do	Dense	0.28	1.63	1.80	......	113
...do	135	XLIV B. B.	0.44	5.84	73.98	19.74	......	Yellow	None	0.44	2.70	12.66	......	114
...do	136	LVIII B. B.	0.61	29.58	56.18	13.63	......	Pink	Friable	0.61	2.27	1.89	......	115
...do	137	LX B. B.	0.54	5.86	56.98	36.62	......	White	None	0.54	2.27	9.72	......	116
...do	138	LX B. B.	0.44	29.65	52.74	17.17	......	...do	Fair	0.44	3.38	1.77	......	117
...do	139		0.60	28.48	45.25	25.67	......	...do	...do	0.60	1.86	1.58	......	118
...do	140		0.64	27.83	51.48	20.05	......	...do	Dense	0.64	1.89	1.84	......	119
...do	23		4.13	42.97	43.36	9.54	0.48	...do	None	2.60	12.19	1.01	17	120
...do	24		4.16	44.84	43.86	7.14	0.42	...do	...do	3.03	11.98	0.98	......	121
...do	25		6.50	44.71	41.39	7.40	0.32	Dirty white	...do	3.31	12.21	0.92	18	122
...do	26		4.18	43.79	40.20	11.83	0.34	White	...do	2.81	11.26	0.92	19	123
Driver			1.81	8.13	62.90	27.16	0.37	Grayish white	...do	0.81	4.41	7.73	......	124
...do			2.00	8.01	53.02	36.97	0.26	White	...do	0.93	4.41	6.61	......	125

TABLE 47.—*Proximate analyses of the coals*

WASHINGTON TERRITORY—Continued.

	Field.	Locality.	Name or number of seam.	Thickness represented by sample.
				Ft. in.
126		North Fork Puyallup	Vein A	0 9
127		...do	Vein B	4 8
128		...do	Vein C	
129		Evans creek	Vein No. 1	9 3
130		...do	Vein No. 2	3 6
131		...do	Vein No. 3	4 3

MONTANA.

NOTE.—See plates to Mr. Eldridge's Report on *Montana Coal Fields*.

1	Bozeman	Chestnut mine (1881)		3 0
2	...do	...do		1 6
3	...do	Chestnut mine, new tunnel (1882)	5 benches, aggregating	7 1
4	...do	Chestnut mine, old tunnel (1882)	Upper middle bench	1 0
5	...do	...do	Lower middle bench	1 2
6	...do	Chestnut mine, opening southeast of house (1882)	Clear coal	2 9
7	...do	...do	Including clay parting	6 3
8	...do	Chestnut mine, Thompson's pit, No. 2 (1882)	Coal alone, aggregating	6 3
9	...do	...do	Coal and bone and clay, aggregating	9 9
10	...do	Maxey's seam	3 benches of coal, aggregating (total thickness 3 feet 7 inches)	1 11
11	...do	Tunnel on Sec. 24, T. 2, R. 7, 60 feet from entrance	Upper bench	1 6
12	...do	Tunnel on Sec. 24, T. 2, R. 7, 60 feet from entrance	Lower bench, excluding 2-inch parting	3 1
13	...do	Tunnel on Sec. 30, T. 2, R. 8, 60 feet from entrance	Upper bench, excluding waste streaks	1 6
14	...do	Tunnel on Sec. 30, T. 2, R. 8, 60 feet from entrance	Middle bench, excluding waste streaks	1 8
15	...do	Tunnel on Sec. 30, T. 2, R. 8, 60 feet from entrance	Lower bench, excluding waste streaks	3 2
16	...do	Incline on Sec. 24, T. 2, R. 8	Lower bench	7 0
17	...do	Tunnel on Sec. 26, T. 2, R. 8	*Coal*	
18	...do	Tunnel on Sec. 26, T. 2, R. 8	*Coke*	
19	...do	New incline on Sec. 32		
20	...do	Tunnel on Sec. 24, T. 2, R. 7	Sample from dump	
21	...do	Tunnel on Sec. 24, T. 2, R. 7	*Coke*	
22	...do	C seam below Sugarloaf		
23	...do	Deep pit, between Sugarloaf and Rock tunnel		
24	...do	Big tunnel on Sec. 30, T. 2, R. 7	9 benches, aggregating	6 7
25	...do	...do	*Coke*	
26	...do	...do		
27	...do	Tunnel on Sec. 24, T. 2, R. 7	4 benches, aggregating	3 7
28	...do	Sec. 24, T. 2, R. 8	*Best coal*	
29	...do	...do	*Average coal*	
30	...do	Incline on Sec. 24, T. 2, R. 8	Upper bench	0 8
31	...do	...do	Middle bench	1 0
32	...do	...do	Lower bench	3 7
33	...do	Sec. 22, T. 2, R. 8	Upper bench	0 4
34	...do	...do	Upper middle bench	1 7½
35	...do	...do	Middle bench	0 6
36	...do	...do	Lower middle bench	0 6
37	...do	...do	Lower bench	1 2
38	...do	Incline on Sec. 32, T. 2, R. 8	Top bench	0 5½
39	...do	...do	Upper middle bench	1 0
40	...do	...do	Lower middle bench	1 0
41	...do	...do	Bottom bench	0 8
42	...do	Single tunnel on Sec. 24, T. 2, R. 7	Top bench	0 11
43	...do	...do	Upper middle bench (clay)	0 8
44	...do	...do	Middle bench	0 10
45	...do	...do	Lower middle bench	0 8
46	...do	...do	Upper bottom bench	0 4½
47	...do	...do	Bottom bench	0 10
48	...do	Double tunnel on Sec. 30, T. 2, R. 8	Hanging-wall seam, top bench	1 1
49	...do	...do	Hanging-wall seam, lower top bench	1 0
50	...do	...do	Hanging-wall seam, upper middle bench	0 4
51	...do	...do	Hanging-wall seam, middle bench	0 5
52	...do	...do	Hanging-wall seam, lower middle bench	0 4

and lignites of the Northwest—Continued.

WASHINGTON TERRITORY—Continued.

Sampler.	Number of sample.	Number on plates of graphic sections.	PROXIMATE ANALYSIS. Water.	Volatile combustible matter.	Fixed carbon.	Ash.	Sulphur.	Color of ash.	Character of coke.	Water in dry coal.	Water in saturated coal.	Fuel ratio, $\frac{c}{vc}$	Combustion analysis, see Table 46.	
Driver	....	....	1.00	11.48	65.18	22.34	0.54	Pink	None	0.68	3.20	5.67	......	126
... do	....	....	0.97	11.03	61.97	26.03	0.47	Yellow white	...do	0.64	2.75	5.61	......	127
... do	....	....	0.48	13.88	68.11	17.53	0.53	Pink	...do	0.44	2.00	4.90	......	128
... do	....	....	0.47	24.71	50.50	24.32	0.51	... do	Good	0.44	1.01	2.04	......	129
... do	....	....	0.98	21.82	46.74	30.46	0.32	White	... do	0.57	2.08	2.14	......	130
... do	....	....	1.26	25.37	43.97	29.40	0.36	...do	...do	0.80	2.30	1.73	......	131

MONTANA.

[The Arabic numbers indicate the figures, the Roman numbers the plates.]

Sampler.	Number of sample.	Number on plates of graphic sections.	Water.	Volatile combustible matter.	Fixed carbon.	Ash.	Sulphur.	Color of ash.	Character of coke.	Water in dry coal.	Water in saturated coal.	Fuel ratio, $\frac{c}{vc}$	Combustion analysis, see Table 46.	
Eldridge	10	....	3.78	23.08	59.27	13.87	0.60	Red	None	0.77	4.26	2.56	......	1
... do	11	....	3.91	33.48	52.04	10.57	0.46	Pale red	Cokes	0.83	4.50	1.25	......	2
... do	1	4-IX.	1.03	30.48	41.37	18.12	0.64	Dirty white	Good	1.02	3.38	1.C4	......	3
... do	2	5-IX.	0.75	29.00	61.74	8.51	0.66	Reddish	None	0.75	3.04	2.12	......	4
... do	3	5-IX.	0.80	14.68	71.56	12.96	0.58	Dirty white	...do	0.10	2.27	4.87	......	5
... do	5	6-IX.	16.48	34.30	40.22	9.00	0.36	White	...do	3.61	15.98	1.14	......	6
... do	6	6-IX.	14.01	30.11	32.35	23.53	0.27	... do	... do	4.04	14.11	1.07	......	7
... do	7	1-IX.	10.64	34.64	42.86	11.86	0.32	...do	...do	3.94	12.40	1.23	......	8
... do	8	1-IX.	9.70	31.43	38.25	20.53	0.40	... do	... do	3.16	10.87	1.21	......	9
... do	4	10-IX.	1.58	42.11	48.66	7.65	0.61	Reddish	Good	0.82	4.53	1.15	......	10
... do	9	....	9.37	35.70	40.77	5.16	0.45	Pale red	None	3.17	10.47	1.30	......	11
... do	10	....	3.62	35.01	44.50	16.87	0.43	Reddish	... do	1.06	4.42	1.27	......	12
... do	11	....	9.37	33.78	47.19	9.66	0.42	... do	...do	2.75	10.18	1.30	......	13
... do	12	....	8.80	35.23	38.76	17.12	0.46	... do	... do	2.65	10.18	1.10	......	14
... do	13	....	5.59	34.46	49.41	10.54	0.49	... do	... do	1.71	6.82	1.43	......	15
... do	....	44-XI.	2.03	35.07	35.62	27.28	0.57	Pale red	Good	0.77	3.38	1.01	......	16
... do	....	....	2.47	27.88	25.89	43.76	1.24	Reddish	Poor	1.20	3.90	0.92	......	17
... do	....	....	5 70	6.00	78.09	10.21	0.67	Brownish red	....	1.88	7.17	....	......	18
... do	....	....	6.69	32.38	39.50	21.43	0.49	White	None	1.96	7.91	1.21	......	19
... do	....	....	3.02	36 14	43.45	17.39	0.45	Reddish	... do	1.04	4.11	1.20	......	20
... do	....	....	5.48	5.84	77.89	10.79	0.43	...do	....	1.35	6.[illegible]0	....	......	21
... do	....	....	12.51	37.63	32.83	17.03	0.47	White	None	4.34	13.80	0.87	......	22
... do	....	....	21.21	34.43	30.80	13.56	0.34	...do	...do	7.28	21.50	0.89	......	23
... do	....	....	2.74	39.63	48.88	8.75	0.65	Gray	Good	1.18	3.01	1.23	......	24
... do	....	....	4.48	9.82	76.25	9.45	0.71	Reddish	....	1.21	3.80	....	......	25
... do	....	....	1.99	37.76	47.43	12.82	0.77	...do	Good	0.88	3.41	1.25	......	26
... do	....	....	1.83	38.[illegible]5	50.20	9.62	0.52	... do	... do	1.10	3.07	1.30	......	27
... do	....	....	2.56	38.81	43.04	15.59	1.94	... do	... do	1.10	3.04	1.10	20	28
... do	....	....	2.73	34.34	38.85	24.08	0.86	...do	... do	0.64	3.20	1.13	......	29
... do	1	48-XI.	1.40	34.78	51.54	12.28	0.52	Pink	... do	0.96	3.23	1.48	......	30
... do	2	48-XI.	1.36	38.47	44.51	15.66	0.54	... do	... do	1.06	3.11	1.15	......	31
... do	3	48-XI.	1.52	35.93	39.81	22.74	0.69	Pale red	...do	0.71	3.29	1.10	......	32
... do	1	35-X.	11.76	35.69	36.32	16.23	0.47	... do	None	6.27	18.56	1.01	......	33
... do	2	35-X.	9.24	35.85	49.34	5.57	0.37	...do	...do	4.85	15.06	1.37	......	34
... do	3	35-X.	10.85	37.17	44.50	7.48	0.39	... do	... do	5.82	17.08	1.19	......	35
... do	4	35-X.	8.34	37.94	38.74	14.98	0.36	...do	... do	4.75	15.08	1.02	......	36
... do	6	35-X.	11.33	35.24	47.67	5.76	0.45	Brownish	...do	4.27	15.28	1.35	......	37
... do	1	30-X.	9.98	35.93	44.35	9.74	0.50	... do	... do	6.26	16.14	1.23	......	38
... do	2	30-X.	4.55	33.12	52.45	9.88	0.53	Red	... do	2.72	8.23	1.58	......	39
... do	3	30-X.	2.90	35.45	54.94	6.71	0.57	White	Poor (dense)	1.39	5.14	1.54	......	40
... do	4	30-X.	2.89	36.20	50.08	10.83	0.60	...do	...do	1.37	5.15	1.38	......	41
... do	1	16-X	1.97	41.65	51.13	5.35	0.54	Very red	Good	0.68	3.31	1.23	......	42
... do	2	16-X	1.76	29.[illegible]8	26.28	42.58	0.47	Pale red	Poor	0.52	3.41	0.89	......	43
... do	3	16-X	1.12	31.77	49.72	17.39	0.45	Dirty white	Good	0.47	2.82	1.56	......	44
... do	4	16-X	1.60	38.57	50.91	8.92	0.57	Brown	...do	1.08	3.59	1.31	......	45
... do	5	16-X	1.28	38.71	45.89	14.12	0.59	Gray	...do	1.13	3.38	1.18	......	46
... do	6	16-X	1.66	37.71	46.46	14.17	0.52	Light	Good, rather dense	1.43	3.51	1.23	......	47
... do	1	22-X	1.55	36.61	47.31	14.53	1.28	Brown	Good, but dense	0.80	3.52	1.29	......	48
... do	3	22-X	1.56	37.25	49.41	11.78	0.56	Pale red	Good	0.72	3.30	1.32	......	49
... do	4	22-X	1.35	30.45	43.22	24.98	0.45	...do	Rather poor	0.73	3.36	1.41	......	50
... do	5	22-X	1.46	39.15	47.26	12.13	0.57	White	Good, but dense	0.73	3.43	1.20	......	51
... do	6	22-X	1.09	29.11	43.79	16.01	0.55	Dirty white	Good	0.74	4.12	1.11	......	52

TABLE 47.—*Proximate analyses of the coals*

MONTANA—Continued.

	Field.	Locality.	Name or number of seam.	Thickness represented by sample.
				Ft. in.
53	Bozeman	Double tunnel on Sec. 30, T. 2, R. 8	Hanging-wall seam, bottom bench	0 4
54	...do	.....do	Foot-wall seam, top bench	0 4
55	...do	.....do	Foot-wall seam, upper middle bench	0 7½
56	...do	.....do	Foot-wall seam, lower middle bench	0 8
57	...do	.....do	Foot-wall seam, bottom bench	1 2
58	...do	Old incline on Sec. 24, T. 2, R. 8 (148 feet down incline)	Top bench	0 7
59	...do	.....do	Upper middle bench	0 11
60	...do	.....do	Lower middle bench	2 3
61	...do	.....do	Bottom bench	0 6
62	...do	Incline, Northern Pacific Coal Company, Sec. 24, T. 2, R. 8 (148 feet down incline).	Middle bench	3 6
63	...do	.....do	Lower bench	4 0
64	...do	Tunnel on Sec. 24, T. 2, R. 7 (220 feet from entrance)	Top bench	0 11
65	...do	.....do	Upper middle bench	0 7
66	...do	.....do	Lower middle bench	1 8½
67	...do	.....do	Bottom bench	1 6
68	...do	Incline on Sec. 32, T. 2, R. 8 (71 feet from entrance)	Top bench	1 4
69	...do	.....do	3 benches, aggregating	2 9½
70	...do	Hyer's claim on Sec. 30, T. 2, R. 8 (33 feet below top of shaft)	5 benches, aggregating	3 9½
71	...do	Tunnel on Sec. 24, T. 2, R. 7 (231 feet from entrance)	4 benches, aggregating	4 0½
72	...do	Incline Sugarloaf on Sec. 22, T. 2, R. 8 (B seam 38 feet down incline).	.....do	6 8½
73	...do	Incline, Northern Pacific Coal Company, Sec. 24, T. 2, R. 8 (280 feet down incline).	2 benches, aggregating	4 6
74	Bull mountain	Northern Pacific Coal Company's mine, head of Buffalo creek, southeast corner Bull mountains.	Middle bench	3 10
75	...do	.....do	Two lower benches aggregating	2 1
76	...do	.....do	Same as No. 1, 10 feet from it	3 10
77	...do	.....do	Same as No. 2, 10 feet from it	2 1
78	...do	W. A. Moody's claim, southwest corner mountains	Lower bench	2 10
79	...do	French's claim, head west branch of Buffalo creek, southwest end mountains.	.....do	2 10
80	...do	Head of Spring creek, north side mountains		4 2
81	...do	Head of Clearwater creek, northeast corner mountains	Top bench	2 0
82	...do	.....do	Upper middle bench	3 0
83	...do	.....do	Lower middle bench	2 10
84	...do	.....do	Bottom bench	2 3
85	...do	Samuel Salisbury's claim, southwest end mountains	Lower bench	2 5
86	...do	.....do	Middle bench	3 11
87	...do	.....do	Lower and middle benches (with 1 parting)	6 6½
88	...do	E. Thomas' claim, south end mountains	Lower middle bench	2 8
89	...do	.....do	Upper middle bench	4 0
90	...do	Second gulch west of Billings's Coal Company's claim, southeast end mountains.	Two middle benches (with 1 parting)	6 6¼
91	...do	.....do	Two upper benches (with 1 parting)	4 3
92	...do	Near head Middle forks, Wild Horse creek, west end mountains.	Middle and lower benches (with 1 parting)	6 4
93	...do	Near junction two forks Wild Horse creek, west end mountains.	Lower bench	2 3
94	...do	.....do	Middle bench	3 10
95	...do	New head of North fork Parrot creek, north end mountains	.....do	3 8
96	...do	.....do	Upper bench (with 2 partings)	4 10½
97	...do	First gulch west of Parrot creek, north end mountains	Middle bench (with 2 partings)	3 6¾
98	...do	First gulch east of Parrot creek, northeast end mountains	Two lower benches (with 1 parting)	4 10
99	...do	West fork Thaddy creek, northeast end mountains	Bottom bench (with 1 parting)	4 9½
100	...do	.....do	Middle bench (with 2 partings)	4 7
101	...do	.....do	Top bench	2 1
102	...do	First gulch east of main fork Thaddy creek, north side east spur.	Upper middle bench	5 6
103	...do	.....do	Middle bench	2 4
104	...do	.....do	Lower bench	2 7
105	...do	2 miles south of above, north side east spur	Lower bench (with 1 parting)	4 4½
106	...do	.....do	Middle bench (with 2 partings)	5 2
107	...do	.....do	Top bench	1 10
108	...do	Eastern extremity east spur	Middle bench (with 2 partings)	5 7½
109	...do	.....do	Upper lower bench	2 10
110	...do	.....do	Bottom bench	2 2

and lignites of the Northwest—Continued.

MONTANA—Continued.

Sampler.	Number of sample.	Number on plates of graphic sections.	PROXIMATE ANALYSIS. Water.	Volatile combustible matter.	Fixed carbon.	Ash.	Sulphur.	Color of ash.	Character of coke.	Water in dry coal.	Water in saturated coal.	Fuel ratio, $\frac{c}{vc}$	Combustion analysis, see Table 48.	
Eldridge	7	22-X	1.98	36.47	48.94	12.61	0.91	Gray	Good	0.96	4.01	1.34	......	53
...do	8	22-X	1.54	39.89	49.92	8.65	0.67	Reddish	...do	0.64	3.83	1.25	......	54
...do	9	22-X	1.68	39.98	48.78	9.56	0.84	...do	...do	0.87	3.56	1.22	......	55
...do	10	22-X	1.87	36.00	47.96	14.17	0.62	Gray	Good, but dense	0.93	4.01	1.33	......	56
...do	11	22-X	1.92	38.45	50.11	9.52	0.64	....	....	1.02	4.71	1.30	......	57
...do	I‴	49-XI	0.97	30.90	42.80	25.33	0.47	Pink	Poor	0.76	3.04	1.38	......	58
...do	II‴	49-XI	1.10	32.81	40.87	25.22	0.50	...do	...do	0.59	2.93	1.24	......	59
...do	III‴	49-XI	1.46	34.65	37.57	26.92	0.59	Pinkish	Good	0.52	3.03	1.10	......	60
...do	IV‴	49-XI	1.23	40.74	42.53	15.50	0.70	Pink	...do	0.67	3.05	1.04	......	61
...do	V‴	50-XI	1.22	36.86	41.54	20.38	0.68	White	...do	0.75	3.10	1.12	......	62
...do	VI‴	50-XI	0.93	39.05	45.94	14.08	0.68	Light red	...do	0.85	3.04	1.17	......	63
...do	VII‴	17-X	1.13	41.18	53.91	3.78	0.59	Very red	Good, but dense	0.97	4.04	1.30	26	64
...do	VIII″	....	1.69	25.30	21.81	51.20	0.64	Yellowish	Sandy	1.26	4.61	0.86	......	65
...do	IX‴	....	1.27	36.94	52.62	9.17	0.58	Red	Fair	1.08	3.64	1.42	27	66
...do	X‴	....	1.29	35.52	43.44	19.75	0.52	Pink	...do	1.11	3.38	1.22	28	67
...do	XII‴	31-X	4.81	33.90	36.49	24.80	0.50	...do	None	2.61	9.07	1.07	......	68
...do	XI‴	31-X	2.49	35.37	48.74	13.40	0.66	Pinkish	...do	1.93	5.19	1.37	......	69
...do	XIII‴	26-X	8.20	34.18	45.15	12.47	0.50	Pink	...do	2.95	12.18	1.32	......	70
...do	XIV‴	18-X	1.57	35.66	48.88	13.89	0.58	...do	Fair	0.59	3.10	1.37	......	71
...do	XV‴	....	3.50	34.66	53.17	8.67	0.52	...do	None	1.52	6.04	1.53	29	72
...do	XVI‴	51-XI	1.31	34.66	42.01	22.02	0.57	...do	Good	0.66	2.74	1.21	30	73
Eldridge	1	....	14.70	35.14	46.05	4.11	1.50	Red	None	2.47	16.17	1.33	......	74
...do	2	....	14.72	34.86	44.14	6.28	2.04	White	...do	2.28	15.82	1.26	.....	75
...do	3	....	16.59	35.33	44.29	3.79	0.50	....	...do	2.30	16.41	1.25	......	76
...do	4	....	14.10	36.66	41.91	7.33	0.80	White	...do	2.06	15.77	1.14	......	77
...do	5	....	16.06	38.76	42.05	3.13	0.74	Red	...do	4.63	18.04	1.08	......	78
...do	6	....	14.37	35.57	44.88	5.18	1.84	White	...do	3.50	17.30	1.26	......	79
...do	7	....	14.83	35.74	42.46	6.97	1.37	Pale red	...do	3.76	17.67	1.18	......	80
...do	8	....	13.18	37.51	45.16	4.15	1.12	Very red	...do	4.54	15.85	1.20	......	81
...do	9	....	12.84	37.47	43.19	6.50	1.87	Pale red	...do	3.40	15.89	1.15	......	82
...do	10	....	12.96	39.48	41.67	5.89	0.60	White	...do	2.72	14.96	1.05	......	83
...do	11	....	14.76	37.21	43.95	4.08	0.60	...do	...do	3.05	16.95	1.18	......	84
...do	I	43-XIX	5.74	36.97	52.61	4.68	......	...do	...do	5.74	16.10	1.42	......	85
...do	II	43-XIX	5.02	39.98	49.56	5.44	......	Red	...do	5.02	15.17	1.23	......	86
...do	III	43-XIX	6.20	38.13	50.89	4.78	......	Pink	...do	6.20	16.16	1.33	......	87
...do	IV	47-XX	4.15	38.16	52.08	5.61	......	White	...do	4.15	15.70	1.36	......	88
...do	V	47-XX	4.98	38.81	50.10	6.11	......	Pink	...do	4.98	15.37	1.29	......	89
...do	VI	50-XX	5.03	39.03	49.40	6.54	......	White	...do	5.03	15.31	1.26	......	90
...do	VII	50-XX	7.14	41.25	44.85	6.76	......	...do	...do	7.14	16.77	1.08	......	91
...do	VIII	42-XIX	4.71	39.39	50.65	5.25	......	Pink	...do	4.71	14.86	1.28	......	92
...do	IX	41-XIX	5.10	37.44	49.81	7.65	......	White	...do	5.10	15.12	1.33	......	93
...do	X	41-XIX	8.40	42.95	41.28	7.37	......	Pink	...do	8.40	19.08	0.96	......	94
...do	XI	36-XIX	2.40	41.24	50.41	5.95	......	White	...do	2.40	11.82	1.22	......	95
...do	XII	36-XIX	8.66	40.10	42.63	8.61	......	...do	...do	8.66	19.03	1.06	......	96
...do	XIII	33-XIX	5.55	36.93	51.15	6.37	......	Pink	...do	5.55	15.78	1.38	......	97
...do	XIV	32-XVIII	7.09	47.44	39.06	5.51	......	...do	...do	7.09	17.99	0.84	......	98
...do	XV	29-XVIII	5.42	39.19	48.06	7.33	......	...do	...do	5.42	15.29	1.22	......	99
...do	XVI	29-XVIII	4.87	38.90	51.02	5.21	......	White	...do	4.87	14.57	1.31	......	100
...do	XVII	29-XVIII	4.77	37.40	50.51	7.32	......	Pink	...do	4.77	13.78	1.35	......	101
...do	XVIII	25-XVIII	10.47	46.11	37.30	6.12	......	Red	...do	10.47	21.88	0.80	......	102
...do	XIX	25-XVIII	9.70	41.93	40.88	7.49	......	...do	...do	9.70	19.60	0.97	......	103
...do	XX	25-XVIII	9.30	43.29	42.20	5.21	......	...do	...do	9.30	20.08	0.97	......	104
...do	XXI	23-XVIII	9.48	45.08	38.93	6.51	......	White	...do	9.48	20.26	0.86	......	105
...do	XXII	23-XVIII	6.56	39.09	49.66	4.69	......	Very red	...do	6.56	16.55	1.27	......	106
...do	XXIII	23-XVIII	7.90	40.00	46.76	5.34	......	...do	...do	7.90	17.55	1.11	......	107
...do	XXIV	21-XVIII	10.39	46.43	35.11	8.07	......	Red	...do	10.39	21.32	0.75	......	108
...do	XXV	21-XVIII	7.64	41.67	38.98	11.71	......	Greenish	...do	7.64	19.42	0.93	......	109
...do	XXVI	21-XVIII	4.73	36.45	48.45	10.37	......	White	...do	4.73	16.04	1.32	......	110

TABLE 47.—*Proximate analyses of the coals*

MONTANA—Continued.

	Field.	Locality.	Name or number of seam.	Thickness represented by sample. Ft.	in.
111	Bull mountain	Eastern extremity, east spur	Upper lower and bottom benches, together with parting	4	4
112	...do	3 miles west of above, south side east spur	Lower bench (with 2 partings)	5	6
113	...do	1½ mile west of Sample XXVIII	...do	5	10
114	...do	Same as Sample XXVIII	Upper bench (with 3 partings)	7	10
115	...do	South side of mountain, 4 miles east of N. P. Coal Company's mine.	Lower bench (with 2 partings)	5	9¼
116	...do	...do	Upper bench (with 1 parting)	7	10
117	...do	South side of mountain, 3 miles east of N. P. Coal Company's mine.	Lower bench (with 1 parting)	6	10
118	...do	...do	Middle bench (with 1 parting)	5	3
119	...do	South side of mountain, ½ mile east of N. P. Coal Company's mine.	Lower middle bench	3	0
120	...do	...do	Upper bench	6	3
121	...do	...do	Lower bench (with 1 parting)	6	1½
122	...do	Jaycox claim, southeast end mountains	Upper bench (with 1 parting)	6	0½
123	...do	...do	Upper part of XXXVII	3	1
124	...do	...do	Lower part of XXXVII	2	11
125	...do	Billings coal claim, south side of mountain, 3 to 4 miles west of N. P. Coal Company's mine.	Lower bench (with 1 parting)	6	10
126	...do	...do	Upper bench (with 3 partings)	7	5
127	...do	...do	Lower part of XLI	3	0
128	...do	...do	Upper part of XLI	3	8
129	...do	Martin O'Brien's claim, southeast end mountain	Middle bench	3	6
130	...do	...do	Lower bench	3	2
131	Judith basin	Jeneaux, Big spring			10
132	...do	...do		1	7
133	...do	O. Richette, 3 to 4 miles northwest of Sample V′		1	5
134	...do	Big Spring		1	8
135	...do	Murphy's, near Utica		1	6
136	...do	Sage Creek outcrop (9 feet 3 inches of coal)	Lower bench	3	4
137	...do	...do	Middle bench	4	3
138	...do	...do	Upper bench	1	8
139	...do	...do	Lower half of VII′	...	...
140	...do	...do	Specimens of bone	...	...
141	...do	Wolf Creek outcrop (same seam as on Sage creek)	Lower bench (good coal)		6
142	...do	...do	Bright coal	2	0
143	...do	...do	Bluish coal		10
144	...do	...do	Upper bench	2	3
145	...do	...do	Upper part of XIV′		6
146	...do	Mann's ranch, Otter creek		1	5
147	...do	Millard's coal, Belt creek, near Kastner's	Lead-colored coal		6
148	...do	...do	Equivalent of XXI′	1	11¾
149	...do	...do	Equivalent of XXII′		3
150	...do	...do	Upper bench, equivalent of XXIII′	2	10
151	...do	Kastner's, on Belt creek	Lower bench	2	3½
152	...do	...do	Lead-colored coal		5
153	...do	...do	Upper coal, equivalent of XXIV′ and XXVI′	3	0
154	...do	...do	Equivalent of XXVI′	...	...
155	...do	...do	Equivalent of XXVII′	...	...
156	...do	...do	Upper bench	3	5
157	...do	...do	Lower bench	...	...
158	...do	McGiffen's, Sand coulée	Upper part lower bench	1	10
159	...do	...do	Lower part upper bench	1	5
160	...do	Bywater's, Sand coulée (near surface)	Lower bench	2	7
161	...do	...do	Upper bench	3	4
162	Rock creek	Yankee Jim claim, B seam	Bottom bench	2	0
163	...do	...do	Lower middle bench	2	4
164	...do	...do	Upper middle bench	1	8
165	...do	...do	Top bench with two partings (one ¾ inch thick in sample)	3	2
166	...do	Yankee Jim claim, C seam	Lower two benches with 4-inch partings (omitted from sample).	4	11
167	...do	Yankee Jim claim, G seam	Middle bench	3	6½
168	...do	Yankee Jim claim, F seam	Three benches aggregating	3	10½
169	...do	...do	...do	4	5¼
170	...do	Yankee Jim claim, E seam	With two streaks of bone (omitted from sample)	5	7

and lignites of the Northwest—Continued.

MONTANA—Continued.

Sampler.	Number of sample.	Number on plates of graphic sections.	PROXIMATE ANALYSIS.				Sulphur.	Color of ash.	Character of coke.	Water in dry coal.	Water in saturated coal.	Fuel ratio, $\frac{c}{vc}$	Combustion analysis, see Table 48.	
			Water.	Volatile combustible matter.	Fixed carbon.	Ash.								
Eldridge	XXVII	21-XVIII	6.80	38.77	44.11	10.32	......	White	None	6.80	18.05	1.13	......	111
...do	XXVIII	15-XVII	4.21	28.21	60.99	6.59	......	...do	...do	4.21	15.48	2.16	......	112
...do	XXIX	12-XVII	4.89	39.84	48.89	6.38	......	...do	...do	4.89	16.39	1.22	......	113
...do	XXX	15-XVII	5.29	48.95	40.66	5.10	......	Pink	...do	5.20	15.53	0.83	......	114
...do	XXXI	9-XVII	7.76	43.65	41.99	6.60	......	...do	...do	7.76	18.87	0.96	......	115
...do	XXXII	9-XVI	5.39	38.44	51.99	4.18	......	...do	...do	5.39	16.29	1.35	......	116
...do	XXXIII	6-XVI	4.08	39.03	50.50	6.39	......	White	...do	4.08	13.49	1.29	......	117
...do	XXXIV	6-XVI	6.53	42.38	46.48	4.61	......	Pink	...do	6.53	17.24	1.33	......	118
...do	XXXV	3-XVI	3.80	39.79	51.22	5.19	......	White	...do	3.80	14.40	1.28	......	119
...do	XXXVI	3-XVI	3.84	39.76	51.09	5.31	......	...do	...do	3.84	14.20	1.28	......	120
...do	XXXVII	1-XVI	5.22	38.69	50.32	5.77	......	...do	...do	5.22	13.96	1.30	......	121
...do	XXXVIII	1-XVI	6.74	37.88	49.91	5.47	0.89	Pink	...do	6.74	15.43	1.31	31	122
...do	XXXIX	1-XVI	5.19	37.35	50.97	6.49	0.48	White	...do	5.19	13.35	1.36	32	123
...do	XL	1-XVI	6.18	36.29	51.73	5.80	......	...do	...do	6.18	16.07	1.42	33	124
...do	XLI	51-LXXIV	6.08	36.16	51.80	5.96	0.73	...do	...do	6.08	15.18	1.43	......	125
...do	XLII	51-LXXIV	9.11	43.24	41.42	6.23	......	Red	...do	9.11	18.83	0.95	......	126
...do	XLIII	51-LXXIV	5.74	38.35	50.60	5.31	......	White	...do	5.74	15.03	1.31	......	127
...do	XLIV	51-LXXIV	6.13	37.94	50.65	5.28	......	...do	...do	6.13	14.98	1.33	......	128
...do	XLV	53-LXXIV	5.46	39.98	47.93	6.63	......	...do	...do	5.46	14.27	1.19	......	129
...do	XLVI	......	5.39	38.39	50.19	6.12	......	...do	...do	5.39	14.57	1.30	......	130
...do	II′	......	3.06	29.73	43.66	23.55	4.46	Pinkish	...do	2.02	9.26	1.44	......	131
...do	III′	......	4.26	33.50	41.12	21.12	6.01	...do	...do	1.59	9.87	1.22	......	132
...do	IV′	......	4.30	17.03	56.98	21.69	1.99	Yellowish	...do	2.90	8.03	3.34	......	133
...do	V′	......	7.38	35.67	40.85	16.10	1.22	...do	...do	5.26	14.21	1.14	......	134
...do	VI′	......	4.56	28.44	41.90	25.10	2.12	Pink	...do	2.70	8.70	1.47	......	135
...do	VI′	......	4.14	29.70	40.90	25.26	10.83	Pinkish	...do	2.34	10.41	1.37	......	136
...do	VII′	......	6.82	36.74	41.53	14.91	1.38	Pink	...do	3.07	10.54	1.13	21	137
...do	VIII′	......	6.54	36.09	45.10	12.27	1.50	White	...do	3.27	11.16	1.24	22	138
...do	IX′	......	7.91	36.62	46.00	9.47	1.48	Red	...do	3.23	11.36	1.25	......	139
...do	X′	......	3.35	20.87	38.53	37.25	1.11	White	...do	1.38	7.44	1.84	......	140
...do	XI′	......	6.28	35.78	45.76	12.18	1.83	Yellowish	...do	3.29	12.70	1.24	......	141
...do	XII′	......	6.25	37.47	44.19	12.09	1.49	Pink	...do	3.45	12.81	1.17	23	142
...do	XIII′	......	6.30	33.98	37.09	22.63	0.91	White	...do	3.43	11.26	1.12	......	143
...do	XIV′	......	8.52	38.76	44.11	8.61	1.48	...do	...do	6.05	16.88	1.13	......	144
...do	XV′	......	8.00	40.79	22.37	28.84	0.96	Yellowish	...do	5.13	16.01	0.54	......	145
...do	XVI′	......	7.81	33.49	42.45	16.25	0.50	White	...do	3.43	13.25	1.26	......	146
...do	XVII′	......	2.11	25.35	38.69	33.85	1.00	...do	...do	0.97	3.21	1.52	......	147
......	XVIII′	......	2.66	37.63	49.63	10.08	2.76	...do	Good but dense	1.28	4.20	1.31	......	148
......	XIX′	......	2.28	33.55	54.51	9.66	2.54	White	None	1.23	5.44	1.62	......	149
......	XX′	......	4.22	26.70	50.89	18.19	1.71	Pink	None	1.73	7.07	1.90	......	150
......	XXI′	......	3.53	38.46	47.65	10.36	3.79	White	Good but dense	1.04	5.14	1.23	24	151
......	XXII′	......	1.47	22.91	43.67	31.95	1.53	...do	Worthless	0.49	4.19	1.32	......	152
......	XXIII′	......	1.76	28.89	50.57	18.78	2.82	...do	None	0.48	5.47	1.75	25	153
......	XXIV′	......	1.58	27.18	48.85	22.39	0.38	...do	...do	0.49	4.66	1.79	......	154
......	XXV′	......	1.76	39.15	18.24	40.85	2.47	...do	Fair	0.71	5.57	0.46	......	155
......	XXVI′	......	2.13	25.92	50.87	21.08	2.06	...do	None	0.57	5.03	1.96	......	156
......	XXVII′	......	2.37	39.52	49.31	8.80	3.24	...do	Fair but dense	1.03	5.05	1.24	......	157
......	XXVIII′	......	2.92	28.86	47.27	20.95	5.23	None	Pink	0.56	7.83	1.63	......	158
......	XXIX′	......	2.20	26.48	45.07	26.25	3.67	...do	...do	0.47	7.77	1.70	......	159
......	XXX′	......	8.47	40.33	33.46	17.74	0.80	Red	...do	4.02	16.29	0.82	......	160
......	XXXI′	......	8.62	32.73	39.20	19.45	0.85	White	...do	4.84	15.95	1.19	......	161
Wolff	A	......	2.18	40.93	48.12	8.77	2.01	Pink	...do	2.18	9.40	1.17	35	162
...do	B	......	2.08	43.70	47.89	6.33	......	...do	...do	2.08	8.30	1.09	......	163
...do	C	......	4.52	38.06	41.76	15.66	......	...do	...do	4.52	12.37	1.09	......	164
...do	D	......	5.37	44.76	38.54	11.33	......	Yellowish white	...do	5.37	14.97	0.86	......	165
...do	E	......	6.91	48.41	37.37	7.31	......	Very red	...do	6.91	21.22	0.77	......	166
...do	F	......	5.65	39.79	49.57	5.09	......	Red	...do	5.55	16.76	1.24	......	167
...do	G	......	3.78	38.13	44.34	13.75	......	...do	...do	3.78	13.17	1.16	......	168
...do	H	......	5.09	38.67	49.97	6.27	......	...do	...do	5.09	......	1.29	......	169
...do	I	......	4.80	38.40	49.32	7.48	......	...do	...do	4.80	14.17	1.28	......	170

TABLE 47.—*Proximate analyses of the coals*

MONTANA—Continued.

	Field.	Locality.	Name or number of seam.	Thickness represented by sample.	
				Ft.	*in.*
171	Rock creek	Yankee Jim claim, seam below C		2	7½
172	...do	Six miles above Clark's fork		1	8½
173	Gallatin valley	Head of Sixteen-Mile creek, Gallatin county			
174	...do	...do			
175	...do	...do			
176	...do	...do			
177	...do	...do			
178	...do	...do			
179	...do	...do			
180	...do	...do			
181	...do	...do			
182	...do	...do			
183	...do	...do			
184	...do	...do			
185	...do	Star mine, Mullen pass		1	1
186	...do	Star mine (1881), Mullen pass		1	0
187	...do	Star mine, Mullen pass		1	6
188	...do	...do		1	6
189	...do	...do	A few tons at Helena		
190	Hell Gate, Missoula river.	Missoula			
191	...do	...do			
192	...do	...do			
193	...do	...do			
194	...do	...do	One ton coal on dump		
195	...do	...do	Specimens of black lignite		
196	...do	Near New Chicago		2	0
197	...do	...do			8
198	Judith basin	Deep creek	Upper bench	4	6½
199	...do	...do	Layer below sample XXII[1]	0	3
200	...do	Eagle rock			
201	...do	Deep creek		1	6
202	...do	...do		5	0
203	...do	Kastner's Belt creek	Blacksmith, lower	1	6
204	...do	...do	Available coal	5	0
205	...do	George Heiseman's, Utica		1	8
206	...do	Sand coulée			
207	Gardiner	Horr's tunnel	Top bench	0	8
208	...do	...do	Upper middle bench	0	3½
209	...do	...do	Lower middle bench	0	9
210	...do	...do	Bottom bench	0	11
211	...do	Horr's opening at wagon-road	Upper middle bench	1	2½
212	...do	Horr's opening at upper seam	Top and upper middle benches	2	6
213	...do	...do	Lower, middle, and bottom benches	2	4¾
214	...do	Coke from coal from Horr's tunnel (see samples 1 and 2, above)			
215	...do	Horr's mine			
216	...do	Cinnabar mountain			
217	...do	Gourley and Gillis's mine			
218	...do	Opposite Gardiner			
219	...do	Trout & Co.'s mine			
220	...do	Opposite mouth Gardiner river			
221	...do	Reese's claim, Cinnabar mountain			
222	...do	Outcrop at mouth of Wild Horse creek			
223	...do	Cinnabar mountain			
224	Flathead river	Upper Flathead river			
225	...do	...do			
226	Sun river, eastern Montana.	Goss Mine No. 2			
227	Eastern Montana	Near Miles City	100-pound sample		
228	...do	...do			
229	...do	Fort Keogh			
230	Dakota	Mouse river			
231	...do	...do			

and lignites of the Northwest—Continued.

MONTANA—Continued.

Sampler.	Number of sample.	Number on plates of graphic sections.	Proximate analysis.				Sulphur.	Color of ash.	Character of coke.	Water in dry coal.	Water in saturated coal.	Fuel ratio, $\frac{c}{vc}$.	Combustion analysis, see Table 48.	
			Water.	Volatile combustible matter.	Fixed carbons.	Ash.								
Wolff	J		4.79	20.33	62.82	3.06	0.00	Bright red	Pink	4.79	12.80	2.14	36	171
....do	K		2.06	35.09	43.79	19.06		Red	....do	2.06	7.60	1.24		172
....do	1 B		8.90	38.14	38.73	14.23		White	....do	5.88	14.87	1.01		173
....do	2 B		9.51	36.58	39.80	14.11		....do	....do	6.84	15.64	1.08		174
....do	5 B		8.20	33.05	35.67	23.08		....do	....do	5.75	13.25	1.07		175
....do	6 B		8.50	35.14	34.52	21.84		....do	....do	6.75	15.14	0.98		176
....do	7 B		7.12	35.21	39.64	18.03		....do	....do	6.59	13.54	1.12		177
....do	8 B		9.17	35.64	38.06	17.13		....do	....do	6.59	15.07	1.06		178
....do	9 B		11.22	29.03	26.92	32.83		Red	....do	4.05	12.41	0.92		179
....do	10 B		5.55	11.80	5.91	76.74		Brown	....do	0.51	7.59	0.50		180
....do	11 B		10.90	31.06	38.56	19.48		Red	....do			1.24		181
....do	12 B		7.43	28.74	43.64	20.19		Pinkish	....do	4.78	12.47	1.51		182
....do	X		2.20	36.30	50.71	10.79		Pink	Good	0.58	8.22	1.39		183
....do	Y		1.88	35.31	52.05	10.76		White	Poor	0.65	3.28	1.47		184
Eldridge	4		2.82	18.48	47.52	31.18	1.04	....do	Good	0.54	3.12	2.57		185
....do	5		2.97	23.20	63.30	10.53	0.84	....do	....do	0.42	3.00	2.72		186
....do	6		2.84	20.85	51.28	25.03	0.97	....do	....do	0.47	3.09	2.45		187
....do	7		4.13	19.19	42.23	34.45	1.28	Reddish	....do	1.10	5.37	2.20		188
Putnam	1		9.75	42.45	35.01	12.79	2.55	Pink	None	7.04	17.51	0.84		189
R. Pumpelly	1		21.32	33.66	28.10	16.92	1.67	Pale red	....do			0.83		190
....do	2		19.89	35.89	27.68	16.54	1.80	Brownish	....do			0.77		191
....do	5		23.39	35.74	31.97	8.90	1.03	Reddish	....do			0.89		192
....do	Y		23.44	38.08	27.02	11.46	0.98	....do	....do			0.70		193
Putnam			12.41	41.03	43.65	2.91		Light brown	Poor	6.06	16.23	1.06		194
....do			14.47	40.88	41.22	3.43		Yellow red	None	6.63	17.23	1.00		195
....do	4		7.89	29.36	7.87	54.88		Very red	....do	7.79	20.25	0.26		196
	4½		1.31	22.49	53.79	22.41	1.48	Pink	....do	0.80	4.09	2.39		197
Eldridge	XXXII[1]		2.58	31.46	48.22	17.74	2.89	White	None	0.60	5.56	1.53		198
....do	XXXIII[1]		1.80	28.63	38.70	30.87	0.98	....do	....do	0.32	3.55	1.35		199
R. Pumpelly			7.03	36.29	46.54	10.14	1.38	Gray	Worthless	2.48	8.85	1.28		200
....do			2.41	23.36	36.68	37.55	3.66	White	None			1.57		201
....do			4.30	32.64	48.79	14.27	1.79	....do	....do			1.49		202
....do			3.02	44.22	46.53	6.23	2.80	....do	Good			1.05		203
....do			2.84	29.30	47.37	20.49	5.38	Purplish	None			1.61		204
....do			7.43	30.52	43.69	18.36	2.77	White	....do			1.43		205
....do			3.35	28.04	46.13	22.48	2.49	....do	....do			1.64		206
Wolff	1		0.99	37.51	53.50	8.00		Pale red	Good	0.15	1.50	1.42		207
....do	2		0.99	39.47	54.39	5.15		....do	....do	0.40	1.74	1.37		208
....do	3		0.95	40.75	53.40	4.90		Pink	....do	0.46	1.57	1.31		209
....do	4		0.99	19.97	19.78	59.26		White	Worthless	0.27	1.42	0.99		210
....do	5		8.88	35.04	49.05	7.03		Pink	None	2.98	9.53	1.39		211
....do	6		7.92	36.29	47.49	8.30		....do	....do	2.65	8.53	1.30		212
....do	7		8.89	32.06	48.90	10.15		Red	....do	2.61	8.82	1.52		213
....do	1		2.12	12.50	77.40	7.98		....do						214
....do	1		2.81	36.89	53.63	6.67		....do	None	0.78	3.68	1.45		215
....do	2		3.43	29.28	39.82	27.47	0.87	....do	....do	0.97	4.20	1.35	34	216
....do	1		12.60	37.37	39.81	10.22		Pink	....do	5.19	14.35	0.97		217
....do	2		11.07	36.58	41.46	10.89		....do	....do	4.67	12.88	1.13		218
....do	1		7.70	35.71	47.76	8.83		Dark red	....do	2.91	7.12	1.33		219
....do	2		3.18	39.78	48.48	8.56		Pink	Worthless	1.26	4.04	1.21		220
....do	1		1.04	35.45	54.24	9.27		....do	Fair; dense	0.14	1.63	1.53		221
....do	1		22.04	33.11	36.98	7.87		....do	None	5.67	15.35	1.11		222
....do	2		15.57	33.95	44.23	6.25		....do	....do	4.34	12.59	1.30		223
R. Pumpelly	1		12.86	45.25	36.80	5.09	1.50	Yellowish red	....do	6.16	18.07	0.81		224
....do	1 A		3.49	50.03	36.51	9.97	3.71	Red	....do			0.72		225
....do			2.29	39.32	43.50	14.89	4.29	Very red	Good	1.33	6.34	1.10		226
Eldridge			13.12	33.23	42.06	10.99	0.56	Dirty white	None	5.53	17.67	1.28		227
Willis	79		14.10	36.95	35.76	13.19	0.73	....do	....do	8.17	18.79	0.97	37	228
Eldridge			13.55	38.39	37.83	10.23	0.55	Reddish	....do	6.90	17.82	0.98		229
....do	15		14.12	40.56	34.03	11.29	0.68	Buff	....do	7.95	21.89	0.83		230
....do	17		12.43	36.92	40.49	10.16	0.58	Reddish	....do	5.83	18.12	1.09		231

TABLE 47.—*Proximate analyses of the coals*

MONTANA—Continued.

	Field.	Locality.	Name or number of seam.	Thickness represented by sample.
				Ft. in.
232	Dakota	Mouse river		
233	...do	...do		
234	...do	Lake river		
235	...do	Bly mine		
236	...do	...do		
237	...do	...do		
238	...do	...do		
239	...do	...do		
240	...do	Little Missouri		

MISCELLANEOUS ANALYSES.

	Field.	Locality.	Name or number of seam.	Thickness represented by sample.
1	Wyoming	Evanston		
2	New Mexico	Raton		
3	Colorado	El Moro		
4	...do	El Moro coke		
5	...do	Trinidad, Starkville mines		
6	...do	Trinidad, Starkville coke		
7	Washington	Skagit river	Connor	8 5
8	...do	Upper Yakima	Picked coal	
9	Oregon	Blue mountains		1 6
10	Oregon, southern	Camas mountain		8 0
11	Idaho?	Float-coal from Kootanai river		
12	Alaska	Admiralty island	Picked coal	

and lignites of the Northwest—Continued.

MONTANA—Continued.

Sampler.	Number of sample.	Number on plate of graphic section.	PROXIMATE ANALYSIS. Water.	Volatile combustible matter.	Fixed carbons.	Ash.	Sulphur.	Color of ash.	Character of coke.	Water in dry coal.	Water in saturated coal.	Fuel ratio, $\frac{c}{vc}$	Combustion analysis, see Table 48.	
Eldridge	18		13.07	44.31	36.64	5.98	0.91	Yellowish red	None	5.84	17.21	0.82		232
....do	19		11.53	44.06	35.74	8.67	0.72	Reddish	....do	7.97	21.88	0.81		233
....do	20		13.70	41.94	31.12	13.24	1.05	Yellowish red	....do	8.72	23.49	0.74		234
....do	21		13.09	39.81	35.58	11.52	1.07	White	....do	5.66	17.14	0.89		235
....do	22		12.69	43.06	34.34	9.91	1.04	....do	....do	8.09	20.40	0.79		236
....do	23		14.26	37.72	33.20	14.82	0.05	....do	....do	8.14	19.57	0.88		237
....do	24		14.33	38.98	36.18	10.51	1.04	....do	....do	8.36	20.86	0.92		238
....do	25		14.30	43.26	32.57	9.87	1.10	....do	....do	8.04	19.94	0.72		239
....do			12.19	47.81	35.00	5.00	0.52	Reddish	....do			0.78		240

MISCELLANEOUS ANALYSES.

Sampler.	Number of sample.	Number on plate of graphic section.	Water.	Volatile combustible matter.	Fixed carbons.	Ash.	Sulphur.	Color of ash.	Character of coke.	Water in dry coal.	Water in saturated coal.	Fuel ratio, $\frac{c}{vc}$	Combustion analysis, see Table 48.	
R. Pumpelly			7.69	41.61	39.66	11.04	0.20	White	Worthless	3.80	10.28	0.95		1
....do			0.98	35.56	48.59	14.87	0.70	....do	Poor; dense	0.53	2.20	1.36		2
Eldridge			0.47	34.20	53.17	12.16	0.62	....do	Good	0.68	2.15	1.55		3
....do			0.31	2.09	82.66	14.94	0.41	Reddish		0.43	1.16			4
....do			0.78	32.47	56.81	9.94	0.74	White	Good	0.49	2.04	1.74		5
....do			0.30	2.18	78.88	18.64	0.38	Reddish white		0.35	0.90			6
....do	76		1.17	14.40	64.56	19.87	0.87	Reddish	Dense	0.62	2.51	4.48		7
....do			0.80	40.87	46.39	11.94		Red	Fair; dense	0.80	2.90	1.13		8
....do	86		1.08	24.40	34.71	30.81	0.91	....do	Worthless	0.02	1.70	1.42		9
....do	109		1.53	42.82	44.94	10.71	4.49	....do	None	1.53	6.28	1.04		10
	94		0.54	59.61	31.45	8.40	0.65	White	Fluffy	0.13	0.64	0.52		11
	95		3.00	37.96	57.49	1.55	0.73	Yellowish	None	1.43	5.37	1.51		12

TABLE 48.—*Elementary composition of some of the western coals and lignites, dried, ashless, and free from sulphur.*

Territory.	Field.	Samples.	Number of sample.	ANALYSIS. Carbon.	Hydrogen.	Oxygen and nitrogen.
Washington	Wilkeson	Willis	11	81.58	5.37	13.05
Do	do	do	12	82.42	5.60	11.98
Do	do	do	19	84.19	5.25	10.56
Do	do	do	20	85.07	5.40	9.53
Do	do	do	21	83.60	5.66	10.74
Do	do	do	33 and 34	80.35	5.11	14.54
Do	do	do	35	82.91	4.88	12.21
Do	do	do	36	85.23	4.73	10.04
Do	do	do	37	84.01	5.17	10.82
Do	do	do	64	85.71	5.21	9.08
Do	do	do	65	81.33	5.46	13.21
Do	do	do	68	93.43	2.41	4.16
Do	do	do	69	88.41	5.05	6.54
Do	do	do	71	88.23	4.66	7.11
Do	Green river	do	47	78.94	5.72	15.34
Do	do	do	80	83.35	5.16	11.49
Do	Newcastle	do	23	76.82	4.73	18.45
Do	do	do	25	76.43	5.36	18.21
Do	do	do	26	74.57	5.43	20.00
Montana	Bozeman, Sec. 24, T. 2, R. 8, best coal.	Eldridge	Sec. 24, T. 2, R. 8, best coal.	82.53	6.51	10.96
Do	Judith	do	VII′	73.67	3.55	22.78
Do	do	do	VIII′	73.78	3.70	22.52
Do	do	do	XII′	72.48	3.34	24.18
Do	do	do	XXI′	80.17	5.47	14.36
Do	do	do	XXIII′	81.57	4.52	13.91
Do	Bozeman	do	VII‴	81.14	5.39	13.47
Do	do	do	IX‴	82.22	5.24	12.54
Do	do	do	X‴	79.68	5.48	14.84
Do	do	do	XV‴	80.87	4.57	14.56
Do	do	do	XVI‴	81.36	5.77	12.87
Do	Bull mountains	do	XXXVIII	73.79	3.28	22.93
Do	do	do	XXXIX	76.15	2.94	20.91
Do	do	do	XL	....	....	....
Do	Gardiner	Wolff	Horr's mine, No. 2.	84.39	5.78	9.83
Do	Rock creek	do	A	73.08	4.02	22.90
Do	do	do	J	77.54	0.83	21.63
Do	Miles City	Willis	79	71.80	4.01	24.19

THE CONVERSION OF LIGNITE INTO FUEL OF HIGH HEATING POWER.

BY F. A. GOOCH.

The experiments, of which a brief account is here given, were, at the request of Mr. Pumpelly, the Director of the Northern Transcontinental Survey, undertaken in the attempt to make from non-coking lignites of low grade and feeble heating capacity a good locomotive fuel of comparatively high calorific power, and, though the investigation was hardly more than begun when interrupted by the discovery and opening by the survey of the Bozeman coal-field, it has been thought advisable to make record of such facts as were observed.

The problem of the utilization of combustible materials of fragile or pulverulent nature is by no means new, and the number of processes of treatment which have been proposed to this end is very large, but in most of these the product either possesses a calorific value scarcely greater than that of the original material—like the compressed brown coal of Europe—or is deprived of a portion of its possible serviceability by the admixture of incombustible cements.

Of all known modes of treatment, something like the process of manufacture of the so-called Parisian coal or like that of the Welsh anthracite coke seemed best suited to the case of the lignites, and attention was accordingly turned in these directions. The mode of preparation of the Parisian coal consists, in brief, in the grinding of charcoal refuse with from 8 to 12 per cent. of water, intermixing thoroughly 30 per cent. of coal-tar, molding the magma into cylinders, and coking the last in a muffle furnace. The product is said to be less fragile than ordinary charcoal and more inflammable than coke. The process of manufacture of the Welsh anthracite coke involves the intimate mixture of 60 parts of anthracite coal in fine powder with 35 parts of a good coking coal and 5 parts of coal-tar, and the coking of the mixture beneath a cover of 2 inches of bituminous coal. It is claimed for this coke that it is about 23 per cent. heavier than the best Welsh coke from bituminous coal, gains only from 1½ to 2 per cent. in weight when moistened with water, burns without decrepitating or crumbling, and is an excellent cupola or blast-furnace fuel. In certain experiments instituted to test this method of utilizing anthracite slack, in connection with the work of the geological survey of Pennsylvania, (*a*) mixtures made according to the Welsh formula failed to yield a product of the requisite coherence for use in the blast-furnace, but a mixture of 50 per cent. of anthracite with 50 per cent. of bituminous coal did yield a fuel said to be capable of bearing the burden of a 75-foot blast-furnace stack, and of good color and structure. Anthracite dust was the base of the coke, but that the dust was quite coarse is evident from specimens of the product kindly sent by Mr. John Fulton, of the Cambria Iron Company, in whose ovens the experiments of the Pennsylvania survey were made, and of that in the metahurgical collection of the National Museum at Washington. A large proportion of this dust must have failed to pass a screen of five meshes to the linear inch, and it may be that just here, in the degree of comminution of the material previous to coking, the occasion of the difference in quality between the products of these tests and that of the Welsh manufacture is to be sought. At all events, the experiments about to be described certainly point very strongly to the conclusion that the fine pulverization of the materials is of the greatest advantage in securing by coking the homogeneous fusion of bituminous and non-bituminous substances.

The materials employed in these experiments were lignites from several localities on the line of the Northern Pacific Railroad in western Dakota and Montana, bituminous coals from Connellsville, Pennsylvania, from Montana and from Washington territory, the composition of which is given in the following analyses:

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.
	Missoula.	Point 100 miles west of Miles City.	Montana (otherwise undescribed).	Little Missouri.	Bly mine.	Wilkeson mine, Washington territory.	Montana.	Connellsville, Pa.	III, partly roasted.	IV, partly roasted.	V, partly roasted.
Water	23.44	21.56	21.26	25.53	23.56	1.22	0.95	1.53	7.68	9.98	9.93
Vol. combustible matter	38.08	38.12	32.34	35.18	35.87	32.88	25.65	30.13	8.86	12.50	12.39
Fixed carbon	27.02	28.29	34.98	33.59	30.71	50.67	55.82	60.17	62.35	60.32	61.58
Ash	11.46	12.03	11.42	5.70	9.86	15.23	17.58	8.17	21.11	17.20	16.10
	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

a *Report of the Geological Survey of Pennsylvania*, vol. MM.

a The composition of the residue after drying or after complete roasting of the lignites out of contact with the air is, of course, readily seen in the figures of analyses I to V.

In experiments 1 to 12, finely-pulverized lignite from Missoula, the composition of which is given in analysis I, was employed with a coal-tar which yielded 33 per cent. of its weight of coke. Small amounts of material, from 5 to 10 grams, were used in each case, and the ignition was effected in closed platinum crucibles within the flame of a large gas blow-pipe, so that the coking might be accomplished at a high heat quickly applied, the most favorable condition for cementing the material and returning the largest yield of coke. In experiments 1 and 2 the lignite was taken in its natural condition; in experiments 3 and 4, after the expulsion of its water of composition, by drying at 115° C.; and in experiments 5 to 12, after thorough roasting out of contact with the air to remove the volatile matter. The proportions used are given in percentages, and the figures corresponding
b to different conditions of the lignite are given in each case to facilitate a comparison between the different experiments, but those figures which represent the composition of the lignite for the condition in which it was actually used are put in heavy type.

Materials.	1.	2.	3.	4.	5.	6.
	Missoula lignite; coal-tar.	Missoula lignite; coal-tar.	Missoula lignite; coal-tar.	Missoula lignite; coal-tar.	Missoula lignite; coal-tar.	Missoula lignite; coal-tar.
Natural lignite	**76.9**	**55.6**	65	56.6	95.3	91.6
Coal-tar	**23.1**	**44.4**	35	43.4	4.7	8.4
c Dried lignite			**58.7**	**50**		
Coal-tar			**41.3**	**50**		
Roasted lignite	56.1	32.5	40.2	31.3	**86.7**	**80.7**
Coal-tar	43.9	67.5	59.8	68.7	**13.3**	**19.3**
Treatment					Mixture tamped	Tar at bottom of crucible with lignite above it.
Residue	Not coherent	Coherent but granular and very fragile.	Coherent but granular and very fragile.	Coherent but granular and fragile.	Feebly coherent	Feebly coherent.

Materials.	7.	8.	9.	10.	11.	12.
d	Missoula lignite; coal-tar.	Missoula lignite; coal-tar.	Missoula lignite; coal-tar.	Missoula lignite; coal-tar.	Missoula lignite; coal-tar.	Missoula lignite; coal-tar.
Natural lignite	91.6	91.6	91.6	91.6	86.6	72.2
Coal-tar	8.4	8.4	8.4	8.4	13.4	27.8
Roasted lignite	**80.7**	**80.7**	**80.7**	**80.7**	**71.4**	**50**
Coal-tar	**19.3**	**19.3**	**19.3**	**19.3**	**28.6**	**50**
Treatment	Mixture not tamped.	Mixture tamped	Moistened with naphtha and tamped.	Moistened with water and tamped.	Moistened with water and tamped.	Not tamped.
Residue	Coherent but granular and fragile.	Coherent and hard, but not cellular.	Feebly coherent	Feebly coherent	Feebly coherent	A true coke of fair color and structure.

e It is evident that under the conditions of these experiments a mixture of roasted lignite and coal-tar is capable of producing a firm fuel, as in experiment 8, in which 19.3 per cent of tar was employed, or even a true coke of good structure, as in experiment 12, in which the roasted lignite was mixed with its own weight of tar. The bad effect of the presence of the volatile matter of the lignite is obvious in experiments 1 and 2, an amount of tar more than twice that of the fixed matter of the lignite proving insufficient to produce a firm cementing of the materials, and the removal of the water of composition alone seems to improve the matter little. Tamping, or the compression of the mixture before heating, is advantageous, but, as would be expected from the results of experiments 1 to 4, the addition of volatile matter to the mixture is deleterious; and this effect appears to be due to the mechanical disintegration of the mass by the evolution of gas at the time when the fusion of the particles should be in process, rather than to chemical action, though it would not be unnatural to expect some dissociation of aqueous vapor at
f the expense of the carbon, more especially as the application of heat is sudden.

In experiments 13 to 23 bituminous coals, either with or without the addition of coal-tar, were used for the cementing material. In experiments 13 to 17 the roasted lignite of analysis II, the Washington Territory coal of analysis VI, and coal-tar yielding 33 per cent. of coke were employed, and in experiment 18 the same lignite was used with the Montana coal of analysis VII. In experiments 15 to 18 portions of 400 grams were operated upon in fire-clay crucibles in a Fletcher gas-furnace, the crucible being at a red heat when the mixture was introduced. In other cases small portions of a few grams were treated in platinum crucibles as before. In experiments 19 to 23 the lignite from Montana, represented by analyses III and IX, in the natural, dried, partly roasted, and roasted conditions, was used in mixture with the Connellsville coal of analysis VIII.

Materials.	13. Lignite 100 miles west of Miles City; Wilkeson coal.	14. Lignite 100 miles west of Miles City; Wilkeson coal.	15. Lignite 100 miles west of Miles City; Wilkeson coal; coal-tar.	16. Lignite 100 miles west of Miles City; Wilkeson coal; coal-tar.	17. Lignite 100 miles west of Miles City; Wilkeson coal; coal-tar.	18. Lignite 100 miles west of Miles City; Montana coal; coal-tar. a
Natural lignite	90.8	78.8	86.4	88.7	88.1	78.8
Coking coal	9.2	21.2	8.7	9	9.5	18.5
Coal-tar	....	....	4.9	2.3	2.4	2.7
Roasted lignite	**80**	**60**	**72**	**76**	**75**	**60**
Coking coal	**20**	**40**	**18**	**19**	**20**	**35**
Coal-tar	....	....	**10**	**5**	**5**	**5** b
Residue	Firm and dense, but with no cellular structure.	Firm and dense, but with no cellular structure.	Firm and dense, but with no cellular structure.	Firm and dense, but with no cellular structure.	Firm and dense, but with no cellular structure.	Firm and dense, but with no cellular structure.

Materials.	19. Montana lignite; Connellsville coal.	20. Montana lignite; Connellsville coal.	21. Montana lignite; Connellsville coal.	22. Montana lignite; Connellsville coal.	23. Montana lignite; Connellsville coal.
Natural lignite	**50**	**68.3**	68.3	68.3	68.3
Coking coal	**50**	**31.7**	31.7	31.7	31.7
Dried lignite	....	....	**62.9**	....	....
Coking coal	....	....	**37.1**	....	 c
Partly-roasted lignite	....	....	....	**54.5**	....
Coking coal	....	....	....	**45.5**	....
Roasted lignite	31.9	50	50	50	**50**
Coking coal	68.1	50	50	50	**50**
Residue	Firm, color excellent, structure porous with marks of fusion.	Firm, color fair, structure porous with marks of fusion on surface of contact with crucible.	Firm, color good, structure porous with marks of fusion on exterior surfaces.	A true coke of good color and structure.	A true coke of excellent color and structure.

It appears from the first six experiments of the series just given that a firm fuel may be made under the conditions of the crucible experiments from mixtures containing proportions of coking material very much below d those of the Welsh formula, though the Welsh proportions did not yield a true coke. Seventy-five per cent. of roasted lignite, with 20 per cent. of a coking coal (which though good is not to be placed in the same rank with the Connellsville coal) and 5 per cent. of coal tar as serviceable proportions; so, also, is the mixture of 80 per cent. of the roasted lignite and 20 per cent. of the coking coal.

In the last five experiments the proportion of bituminous coal was equivalent to the fixed matter of the lignite and the fuel produced was in every case firm, and in experiments 22 and 23 a true coke; but, as in the experiments in which coal-tar was the sole cementing ingredient, the disadvantageous effect of the presence of volatile matter is clearly traceable, though in the case of the partly-roasted lignites—material taken from that used in experiments on a larger scale, which are about to be described, and which was partly roasted simply because the complete roasting of the large sample was an impossibility with the facilities at command—the influence e of the residual volatile matter was comparatively slight. Though, as was evident in the earlier experiments, the cementing quality of tar is adequate to the production of a true coke, these later experiments go to show very plainly that the value of good bituminous coal exceeds that of the same proportion of coal-tar. Thus, while in experiment 2 44.4 per cent. of coal tar to 55.6 per cent. of lignite in the natural condition is a proportion capable of yielding only a fragile product, in experiment 19 equal parts of natural lignite and Connellsville coal produce a firm fuel of good structure and color, though not a true coke; and in the comparison of experiments 7, 8, and 13, the bituminous coal seems to have the advantage. It is to be noted, however, that the superiority of the coking coal over the tar is particularly obvious when the lignite still retains its volatile matter, and it may be that the advantage of the coal lies in the longer retention, during exposure to high heat, of the capacity to coke, so that a larger proportion of the gaseous matter of the lignite may escape and be out of the way of doing harm before the f cementing of the material ceases.

Experiments 24 to 36 were made upon a considerably larger scale, for the purpose of testing the conditions of the coking oven. The materials were taken from the large lots which had been prepared for the final experiments 37 and 38. The roasting of the lignites was effected in retorts ordinarily used for making illuminating gas, and was but partial because it was found necessary to stop the process before completion to prevent the wasting of fixed carbon by the action of the air, which, under the circumstances, could not be entirely excluded. Each charge was drawn as soon as it appeared to be ashing slightly on the surface and drenched at once with water. A mill usually employed in grinding fire-clay offered the only means available for pulverizing the roasted lignite and the bituminous coal, but the conditions imposed in the use of the mill, that the material should be worked in moist condition to keep the dust down, effectually prevented the grinding of the materials to that degree of fineness which was greatly to be desired. Much of the ground lignite and coal would scarcely pass a sieve of ten meshes to the linear inch. The mixtures were made in the proportions indicated in the tabular statement, and small portions of each mixture were tested in the crucible after the manner of the experiments previously described. For convenience of comparison the figures corresponding to the proportions of lignite in the mixture for the natural condition and that after complete roasting are given as before in lighter type. The portions experimented upon, varying from 150 to 400 pounds in weight, according as sacks or barrels were used to contain them, were thrown directly upon the hot bottoms of bee-hive ovens from which the charges had just been drawn, immediately covered with the new charge of coking coal, and quenched and drawn with the charge of the oven after forty-eight hours. The analyses of the products are included in the table.

Materials.	24.	25.		26.	27.		28.	
	Montana lignite; Connellsville coal; coal-tar.	Montana lignite; Connellsville coal; coal-tar.		Little Missouri lignite; Connellsville coal; coal-tar.	Little Missouri lignite; Connellsville coal; coal-tar.		Bly Mine lignite; Connellsville coal; coal-tar.	
Natural lignite	84.4	84.4		85.5	85.5		85.3	
Coking coal	11.8	11.8		10.9	10.9		11.1	
Coal-tar	3.8	3.8		3.6	3.6		3.6	
Partly-roasted lignite	**75.1**	**75.1**		**75.1**	**75.1**		**75.1**	
Coking coal	**18.8**	**18.8**		**18.8**	**18.8**		**18.8**	
Coal-tar	**6.1**	**6.1**		**6.1**	**6.1**		**6.1**	
Roasted lignite	71.5	71.5		70.1	70.1		70.1	
Coking coal	21.5	21.5		22.6	22.6		22.6	
Coal-tar	7.0	7.0		7.3	7.3		7.3	
Weight of charge ... pounds	320	150		150	150		150	
Residue	Firm fuel	Fairly firm fuel		Rather fragile	Weak fuel		Weak fuel	
		Upper.	*Under.*		*Upper.*	*Under.*	*Upper.*	*Under.*
Water	5.98	5.71	4.70	7.21	6.54	6.02	4.84	5.23
V. C	4.33	5.39	3.87	8.51	5.79	7.06	8.07	7.30
C	70.24	69.08	69.50	68.25	70.05	72.11	66.24	65.72
Ash	19.45	19.82	21.93	16.03	17.62	14.81	20.85	21.75
	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Residue in parallel-crucible experiment	Color excellent, but grain coarse.	Color excellent, but grain coarse.		Color excellent, but grain coarse.	Color excellent, but grain coarse.		Color excellent, but grain coarse.	

Materials.	29.	30.	31.	32.
	Montana lignite; Connellsville coke.	Montana lignite; Connellsville coke.	Montana lignite; Connellsville coke.	Montana lignite; Connellsville coke.
Natural lignite	87.8	84.4	78.5	73
Coking coal	22.2	15.6	21.5	27
Partly roasted lignite	**80**	**75**	**67**	**60**
Coking coal	**20**	**25**	**33**	**40**
Roasted lignite	76.9	71.5	62.9	55.6
Coking coal	23.1	28.5	37.1	44.4
Weight of charge ... pounds	400	300	300	300
Residue	Too fragile to be drawn.	Feebly coherent	Firm, but not a true coke.	A fair coke, of good color and structure.
Water		6.53	6.59	2.79
V. C		5.10	6.73	3.09
C		68.89	67.71	75.07
Ash		19.48	18.97	19.05
		100.00	100.00	100.00
Residue in parallel crucible experiments	Color excellent, but grain coarse.	Color excellent, but grain coarse.	Color excellent, but grain coarse.	Color excellent, but grain coarse.

a

Materials.	33.		34.	35.		36.	
	Montana lignite; Connellsville coal.		Montana lignite; Connellsville coal.	Little Missouri lignite; Connellsville coal.		Bly Mine lignite; Connellsville coal.	
Natural lignite	73		64.3	74.8		74.2	
Coking coal	27		35.7	25.2		25.8	
Partly roasted lignite	**60**		**50**	**60**		**60**	
Coking coal	**40**		**50**	**40**		**40**	
Roasted lignite	55.6		45.5	53.8		53.8	
Coking coal	44.4		54.5	46.2		46.2	
Weight of charge ... pounds	150		220	150		150	
Residue	Good coke, of good color and structure.		Good coke, of good color and structure.	Weak fuel		Fairly firm, of good color, but not a true coke.	
	Upper.	*Under.*		*Upper.*	*Under.*	*Upper.*	*Under.*
Water	3.50	5.63	2.79	5.75	3.94	4.97	3.13
V. C	4.29	6.93	3.09	7.60	4.49	8.77	4.37
C	70.71	68.34	75.07	71.93	75.05	70.25	74.87
Ash	21.50	19.10	19.05	14.72	16.52	16.01	17.63
	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Residue in parallel crucible experiments	Color excellent, but grain coarse.		Color excellent, but grain coarse.	Color excellent, but grain coarse.		Color excellent, but grain coarse.	

c

Experiments 24 to 28 indicate pretty clearly the lowest proportions of cementing material by the admixture of which with the roasted lignites it may be hoped to secure a good fuel by coking. Why experiments 26, 27, and 28 should have yielded a feebly coherent product under apparantly the same conditions of mixture and experimentation which in experiments 24 and 25 gave a firm fuel is difficult to see, unless the cause is to be sought in the larger amount of volatile matter still remaining in the partly-roasted lignite of the first experiments. At any rate it is evident that these proportions lie near the limit of successful cementing. Experiments 29 to 36, with the companion tests, show unmistakably that the conditions of the crucible experiments are more favorable to the production of firm cokes of good color than the conditions which prevail beneath the surface of coal in process of coking in the beehive oven, and a comparison with experiments 13 to 18 and 23 emphasizes the value of a fine comminution of materials. d

In experiments 37 and 38 the materials were mixed for oven charges, as indicated in the table following, and thrown into hot beehive ovens. Heating began immediately, and a coherent crust formed upon each charge, and the surface cracked in an encouraging manner. In the case of experiment 37, however, it was possible to run a pole to the bottom of the oven after eight hours heating, and upon drawing the charge at the end of twenty-four hours the product was worthless excepting the thin surface crust. In experiment 38 the product, drawn twenty-two hours after charging, proved to be a good coherent fuel, but not a true coke. This fuel was used with success on a 27-ton locomotive, and gave every indication of being applicable to locomotive use, and the material was preserved for quantitative tests.

e

Materials.	37.			38.		
	Montana lignite; Connellsville coal; coal-tar.	Little Missouri lignite; Connellsville coal; coal-tar.	Bly mine lignite; Connellsville coal; coal-tar.	Montana lignite; Connellsville coal.	Little Missouri lignite; Connellsville coal.	Bly mine lignite; Connellsville coal.
Natural lignite	84.4	85.5	85.3	73	74.8	74.2
Coking coal	11.8	10.9	11.1	27	25.2	25.8
Coal-tar	3.8	3.6	3.6	...	...	...
Partly roasted lignite	**75.1**	**75.1**	**75.1**	**60**	**60**	**60**
Coking coal	**18.8**	**18.8**	**18.8**	**40**	**40**	**40**
Coal-tar	**6.1**	**6.1**	**6.1**	...	...	...
Roasted lignite	71.5	70.1	70.1	55.6	53.8	53.8
Coking coal	21.5	22.6	22.6	44.4	46.2	46.2
Coal-tar	7.0	7.3	7.3	...	...	...
Weight of charge ... pounds	2,000	2,000	2,000	1,330	2,730	1,330
Residue	Thin crust on surface			Fairly firm, but not a true coke.		
Water	...			...	6.92	
V. C	...			...	7.54	
C	...			...	69.24	
Ash	...			...	16.30	
					100.00	
Residue in parallel crucible experiments	Color excellent, but grain coarse			Color excellent, but grain coarse.		

a From the experiments which have been cited, it is plain that not only a good fuel but a fuel possessing the qualities of a true coke may be made under the conditions of the crucible experiments from mixtures of roasted lignite with either a coking coal or coal-tar, and the conclusion that the more thoroughly and quickly the heating of the mass takes place the better will be the product seems warranted. Fine pulverization of the materials before coking is shown distinctly to be advantageous in experiments on the small scale, which suggest at least the trial of the same mode of preparation on the large scale. The beehive oven is manifestly unsuited to the coking of material not abundantly charged with bituminous constituents, but some one of the many devices which have been lately put forward as improvements upon the plan of the Belgian ovens would doubtless prove valuable in such cases, some arrangement by which the material may be compressed and coked in thin layers being apparently most promising. Perhaps the most important point which has been brought out by these experiments in reference to
b the treatment of lignites by coking in mixture with bituminous materials is the great advantage to be gained in the removal of the volatile constituents before making the mixture to be coked. In the crucible experiments the yield is the sum of the fixed matter of the coal, the lignite and the tar as given by the ordinary proximate analysis; on the working scale it is probable that the waste of fixed carbon need not exceed that which is usual in the coking of bituminous coal. While the experiments have not been carried far enough to warrant a close estimate of the cost of producing the proposed fuel, the results justify the belief that this would not be prohibitory where the alternative was the bringing in of eastern coals.