BRITISH NORTH AMERICAN BOUNDARY COMMISSION.

GEOLOGICAL REPORT OF PROGRESS FOR THE YEAR 1873.

[IN PART.]

REPORT

ON THE

TERTIARY LIGNITE FORMATION,

IN THE VICINITY OF THE FORTY-NINTH PARALLEL.

BY

GEORGE M. DAWSON, Assoc. R. S. M.

ADDRESSED TO

CAPT. D. R. CAMERON, R.A., H. M. BOUNDARY COMMISSIONER.

Montreal:

DAWSON BROTHERS, ST. JAMES STREET.

1874.

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PRINTED BY JOHN LOVELL, 23 ST. NICHOLAS STREET.
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To CAPT. D. R. CAMERON, R.A.

H.M. N.A. Boundary Commissioner:—

SIR,—The geological work of the past summer embraced, *First*, an examination of the Lake of the Woods region, dealing chiefly with the Laurentian and Huronian formations: *Secondly*, an examination of the Cretaceous formations westward of Red River: *Thirdly*, a survey of the Lignite Tertiary formation overlapping the last and extending as far as the terminus of the season's work on the line. As the lignites, &c., obtained from the Tertiary rocks required a more careful examination than most of the other specimens, and appeared to be of economic importance, I have prepared in the first instance the Report on that formation, which will properly constitute the third part of the general Report of Progress, and have the honour to forward the same herewith.

Your obedient servant,

GEORGE M. DAWSON.

Montreal, Feb. 10th, 1874.

BRITISH NORTH AMERICAN BOUNDARY COMMISSION.

REPORT

ON THE

TERTIARY LIGNITE FORMATION,

IN THE VICINITY OF THE

FORTY-NINTH PARALLEL,

By G. M. DAWSON,

Associate R. S. M., Geologist to the Commission.

CONTENTS:—

The exposures of these rocks in the vicinity of the 49th parallel, first appear in the valley of the Souris River at a point 250 miles W. of Red River, about four miles E. of the tributary from the south known as Short Creek; near the debouchure of which the remarkable collection of grotesquely shaped rocks, known collectively as the "Roche Percé" is situated. These beds may underlie the prairie country still further eastward, as no sections are to be found for a long distance. The banks of the river valley, however, undergo about this place a remarkable change, becoming gently sloping and grassed from top to bottom, and it seems to me probable that this change coincides with the eastern edge of the Tertiary basin.

Sections are to be seen at frequent intervals on the banks of the river valley, from the point indicated, westward to the position occupied in the summer of 1873 by Wood End Depot Camp, a distance of about twelve miles by the line and considerably more by the river.

Details of Sections on the West Souris River.

Section 1.—(Six miles north from Wood End Depot on the bend of the river.)

1.	Fallen bank, no section, about	8′	
2.	Finely stratified greyish sandy clay	7′	
3.	Lignite		7″
4.	Sandy clay, greyish laminated, including two "leaf beds," each a few inches thick	7′	7″
5.	Yellowish fine sandy clay passing below to grey soft sandstone	11′	5″
6.	Ironstone, a nodular layer		3″
7.	Grey clay	1′	
8.	Whitish clay	1′	
9.	Carbonaceous shale	3′	3″
10.	Grey clay	3′	6″
11.	Ironstone		2″
		43′	7″

The beds appear to be perfectly horizontal. Those of sand and sandy clay, though having the appearance of well characterized layers at a little distance, and giving the banks an almost ribboned aspect, are found, on closer examination, to pass almost imperceptibly into each other. This peculiarity is often to be observed, in almost all localities where these rocks are found. The so-called "leaf beds" are of a greyish purple tint, and contain many impressions of flag-like parallel-veined leaves, which, though distinct enough when freshly taken from the bank, it is impossible to preserve on account of the crumbling nature of the matrix. The ironstone, though generally forming extensive sheets, is nodular in structure, and varies a good deal in thickness. It weathers a bright brownish-red, is hard, compact and very heavy, and on fresh fracture is bluish to yellowish-grey.

A short distance S. of this locality the bank shows the following section very perfectly:—[Plate I, Sec. 2.]

Section 2.—

	Prairie sod.		
1.	Mixed shale and drift	7′	
2.	Lignite	6′	6″
3.	Greyish sandy shale (about)	4′	
4.	Lignite	1′	6″
5.	Greyish and yellowish well-stratified fine sandy and shaly clays	14′	
6.	Ironstone (nodular)		4″
7.	Greyish and whitish clay	2′	
8.	Carbonaceous shale	1′	
9.	Grey soft sandstone	1′	8″
10.	Lignite	1′	
11.	Grey and yellowish laminated sandy clay	5′	
12.	Ironstone (nodular)		3″
13.	Lignite	1′	7″
14.	Carbonaceous shale	1′	6″
15.	Lignite	2′	2″

16. Grey sandy clay	2′	
17. Lignite	1′	5″
18. Sandy underclay with large and small roots badly preserved.	1′	6″
19. Lignite	3′	2″
20. Greyish sandy clay		
	57′	7″

The lower lignite beds are of excellent quality, firm and compact, and in some a c es shew spots of fossil resin. The structure of the component wood is also in many instances very plainly apparent. The upper lignite lying immediately below the surface, is soft and decomposed where exposed, being in many places penetrated by roots from above. It might, however, prove equally compact with the lower beds where undisturbed. Layer 18 is almost the only case observed in which lignite is seen to lie upon a pretty evident underclay with roots. The ironstones are specially good and compact in this section. Owing to the wearing away of the softer strata a large quantity of this material strews the surface of the hillside.

This section does not seem to correspond at all with the last, though situated only a few hundred yards from it: and if no fault or break in the strata intervenes (and there is no appearance of any such), the horizontal uncertainty of the deposit must be very great.

Fragments of a material resembling scoriaceous lava and vesicular in structure are very plentiful in this locality, as elsewhere in the region of country occupied by these lignite strata. On examination, however, it is seen that this is really a sort of clinker produced by the combustion of parts of the lignite beds *in situ*, and the consequent fusion of their proper ash and portions of the surrounding shales. Such fires may either be caused by the ignition of the beds by prairie fires, and fires of Indians' or traders' camps, or by the spontaneous combustion of the lignite where undergoing decomposition at the out-crop. The latter, however, seems improbable, as iron pyrites, the usual cause of such spontaneous combustion, is almost entirely absent from the lignites which I have examined chemically. [Plate II, Fig. 1.]

In one place the top of the bank shews an amphitheatrical depression a few feet below the general prairie level. In front of this the bank was strewn with many and large fragments of lignite clinker, and it was apparent that the upper lignite bed (already mentioned as being almost at the surface,) had been over this area entirely consumed. Fires similar to these have been mentioned as existing in coal and lignite beds in the western part of America, from near the Arctic Sea to the frontier of Mexico, by McKenzie, Richardson, Johnston, Lewis and Clark, Hayden and other travellers, and appear to have been common in the Tertiary and Cretaceou strata alo ı ; ı : eastern flank of the Rocky Mo un .

Nearly three miles south of the last mentioned locality, another very good section is exhibited on the right-hand side of the valley, and where the Souris, in one of its many devious windings, has undermined the foot of the bank. This section is specially interesting, as affording one of the best localities for the collection of the shells of Mollusca characteristic of the formation. The section is as below, measurements being estimated :

Section 3.—

Sand and sandy clay, stratified, and yellowish in general colour	40′	
Lenticular mass of poor clay ironstone, running out rapidly in both directions	2′	6″
Grey sand	2′	
Shell bed	1′	6″
Lignite	2′	6″
Sand and clay	10′	
	58′	6′

The shell bed is of hard grey sandy clay, and in some places is very full of shells, which are also less crushed and in a better state of preservation than is usual in this formation. A species of *Melania* is the predominent mollusc. A second species of the same genus also occurs, with fragments of a *Paludina* and *Unio*, and a *Corbula*, closely resembling if not identical with *Corbula* (*Potamomya*) *mactriformis*, M. and H., which must be considered a brackish-water type, and occurs in the lignite formation of the Missouri.

In the water of the stream at this place are several large spheroidal sandstone concretions which have a tendency to split into layers parallel to their flattened surfaces—one of them measuring four or five feet in diameter. These do not appear in the bank, but possibly may have been washed out of the lower part of the section which was not so clearly shown.

South of the last section, and about one mile nearly due north of the position occupied by Wood End Depot, an exposure, showing the most valuable lignite bed I have seen in the Souris Valley, is situated. The beds are arranged thus :—[Plate I, Sec. 4.]

Section 4.—

1. Drift material about	8′	
2. Yellowish and grey stratified sandy clays, obscured in most places by slips of the bank	52′	
3. Lignite	7′	3″
4. Grey soft unctuous sandy clay	1′	or more.

The bottom of the lignite is about twenty-five feet above the level of the river below, and this part of the section, though apparently consisting of yellowish sandy clays like those overlying it, is obscure. The lignite is continuously visible for at least two hundred feet along the face of the bank, and seems to preserve uniformity of character and thickness. Externally it is

often crumbling, and mixed with clay which has penetrated its joints from above; but where freshly exposed, it is hard and compact. It is quite black on freshly fractured surfaces, but has a brown streak, and in many places the structure of the original wood is still quite discernible. Some surfaces are strewn with fragments of mineral charcoal like that found in some true coals. Other specimens are apparently structureless, and resemble cannel coal in appearance though not in composition. The upper beds of sandy clay yield a few poorly preserved shells.

On the opposite side of the river valley, near this place, the upper part of the bank shows a good section of sandy clay, below which, and some fifteen or twenty feet below the prairie level, is a seam of lignite of good quality and four feet in thickness. This lignite bed would seem to occupy a position stratigraphically superior to the last.

Section 5.—Somewhat further up the stream, and on the same side of the valley about sixty feet below the prairie level, and sixteen feet above the river, a bed of lignite occurs of which the upper three feet only are visible. The bank above it is not well exposed, but appears to consist of sandy clays. The lignite is of good quality but much weathered at the out-crop. From this place lignite was obtained and taken to the smithy while the Depot was established at Wood End. It was, however, found difficult to obtain a welding heat with it, which may have been due, at least in part, to the damp condition in which the lignite was used. The same difficulty has, however, been found almost fatal to the use of similar fuel for smithy purposes, further south, and in the line of the Union Pacific Railway, (Hodge's Report). This seam may very probably represent the continuation of that included in Section 4.

The whole of these deposits, though in some places showing a dip amounting to a few degrees in one direction or other, appear to have no determinate direction of inclination, but to be over large areas as nearly as possible horizontal.

Section 6.---Sections more or less perfect are exhibited in many places in the Souris Valley, a mile or two west of the entrance into it, from the south, of Short Creek, and more especially on the north side of the valley. They show a great similarity, though not absolutely the same in any two places. One of the most perfect exposures seen was the face of a bank from sixty to seventy feet high, and consisted of sand, sandy clays, and hard fine clays, very regularly and perfectly stratified, and coloured in various shades of yellow-grey, grey and light drab. At two different levels harder sandstone layers of small thickness were seen, and also three distinct beds of lignite. The lowest is a hard compact lignite resembling cannel coal in aspect, and two feet three inches thick. A few feet above this a second seam,

eighteen inches thick, occurs, and still higher in the series, and about half-way up the bank, a third, of the same thickness. At the top of the bank some large nearly spherical sandstone nodules rest, and have evidently been derived from a superior bed which has been removed by denudation. The clays and sandy clays at several different levels include remains of molluscs, but these are very fragmentary, having been crushed by the compression of the containing material. A unio-like bivalve preponderates, and gasteropods are comparatively rare.

On the opposite side of the Souris Valley, which is here of considerable width, and not far from the last mentioned section, soft sandstone beds, capped by a harder layer also of sandstone, weather into table-like forms. These beds are doubtless the representatives of those which, a few miles eastward, produce the Roche Percé. Short Creek, already mentioned as an affluent from the south, shows many sections of the lignite strata. The banks of the stream have assumed the most picturesque forms from successive landslips, and are often quite red in colour from the alteration of the clays by the burning of lignites.

One of the most perfect sections is on the left bank, near the crossing place of the waggon trail, and extends from nearly the level of the prairie almost to the water of the stream. [Plate II, Sec. 7.]

Section 7.—

1. Soil	1′	6″
2. Yellowish coherent sand, grey externally, and holding some much broken *Unio*-like shells at its base	12′	6″
3. Grey clay	2′	10″
4. Yellowish and greyish thin bedded sands and sandy clays, with several very thin ironstone layers, weathering orange-red externally	6′	
5. Grey clay	2′	4″
6. Similar to No. 4., with decayed fragments of gasteropodous shells	12′	
7. Also similar to No. 4, but with a great number of thin ironstone sheets	3′	
8. Hard yellowish sandy clay, a few inches at the top carbonaceous	10′	
9. Good hard lignite	2′	2″
10. Hard yellowish sandy clay	2′	7″
11. Good lignite	4′	9″
12. Greyish sand and sandy clay, showing lines of stratification. In some places soft and incoherent, in others with large concretions, and sometimes forming a nearly solid sandstone	9′	
13. Hard grey clay	2′	
14. Greyish yellow clay with many thin layers of orange-weathering ironstone	3′	
15. Lignite	2′	6″
16. Greyish and yellowish hard sand and sandy clay	11′	
Section concealed by slope of detritus, about	12′	
	99′	2″

Small spherical ferruginous nodules, resembling bullets, occur in considerable numbers at the foot of the bank. They have a calcareous cement, and are derived from one or other of the sandy layers. This exposure is remarkable for the very gentle graduation of one bed into the next, making it almost impossible to draw lines between them in a measured section.

On the south side of the Souris Valley, and a short distance to the east of the valley of Short Creek, the Roche Percé group of rocks is situated. This locality has already been described by Hector and Palliser, who made a branch expedition to it from the North, in August, 1857, being induced to do so by the reports of Indians and Half-Breeds. (Palliser Expl. N. America, pp. 49 and 225.) Dr. Hector did not obtain any fossils from the rocks of this neighbourhood but sedge-like leaves, and doubtfully connects them with the Missouri Lignite basin or transition beds between this and the Cretaceous. The former supposition may now, I think, be considered as fully confirmed by their resemblance to and connection with undoubted Lignite Tertiary rocks of the regions further west, and also by the nature of the molluscous forms of associated beds. The rocks themselves, which have long been objects of superstition to the Indians inhabiting the surrounding country, owe their curious forms to the weathering away of a soft grey sandstone from below a bed of similar rock which weathers yellow, and is rendered durable by an abundant calcareous cement. Both the upper and lower sandstones show false bedded structure in great perfection, though that in the upper hard portion is on a smaller scale, owing to the thinner divisional planes of the rock.

The capping-sandstone is not hardened in a perfectly uniform manner, but in belts several yards in width, lying parallel in a N.W. and S.E. direction, and separated by spaces more easy of disintegration. There is also a system of cross-jointing nearly at right angles.

This combination of structures has given rise, under the long continued action of the weather, to the remarkably castellated, fantastic and picturesque rock scenery of this part of the Souris Valley. The hard belts form tongues projecting diagonally from the grass covered bank, and the erosion of the underlying soft sandstone, parallel to the cross-joints, has in several places produced window-like openings through them. The soft rock bears in many places rude Indian carvings representing various animals and birds, strings of beads, &c.

The north side of the river valley, for some way up and down, is fringed with weathered sandstone rocks, similar to, though not so striking as the Roche Percé. The whole formation would seem to have a slight dip

toward the south, and in this case the section in Short Creek, previously given, would overlie the Roche Percé sandstones.

The Souris Valley, for about four miles E. of this place, continues to show numerous sections of the usual clays and sands, and hardened sandstone beds,—the latter in one place nearly three miles east from Roche Percé forming a group almost equally picturesque with it. Rather hard sands and sandy clays are seen in several places to underlie the sandstone beds, and one of these was found to be filled with well-preserved specimens of a peculiar *Paludina*. About a mile farther east the valley changes its character considerably; the banks formerly scarped and clayey are replaced by regular grassy slopes, and, though followed for a distance of ten or fifteen miles beyond this point, yielded no further sections. This change I am at present disposed, in the absence of more certain data, to consider as indicating the passage from the Lower Tertiary beds to the Cretaceous. The eastern edge of the out-crop of the harder beds connected with the Roche Percé also appears to be indicated by a slight, though pretty well defined step in the level of the prairie, which may be considered as the first gentle rise of the Missouri Coteau, and runs about S.E. to the boundary line, which it crosses near the 240 mile point. The spring known among the Half-breeds as St. Peter's Spring lies at the foot of this step not far north of the line, and is probably connected with the junction of the more permeable sandstone beds with the underlying impervious clays. It is possible that lignite coals of importance may exist on a lower horizon than this, and in beds showing a more decided approximation to marine deposition and cretaceous forms of life, in which case their out-crop would occur still further to the east. It is not, however, very probable that this is the case, as the investigations of Hayden and others south of the line seem to show that in the eastern region the deposition of lignite did not commence till the conditions of the Cretaceous formation had distinctly passed away.

Sections on Missouri Coteau, west of 263 *Mile Point*

Westward from the 263 mile point, no sections of either Cretaceous or Tertiary rocks, so far as I have been able to examine, occur in the vicinity of the boundary line for nearly 80 miles. The valley of the Souris, when followed in this direction, rapidly becomes more open and shallower. Scarped banks are rare, and such as do occur seem only to exhibit a great thickness of drift material. It would seem that the absence of the harder beds associated with the strata already described had allowed the erosion of the beds to a great depth. The country also rises somewhat rapidly, and it is not till after having passed through the drift-hills

of the Coteau, and at a height of about 700 feet above that of the former sections, that the underlying rocks in the form of the Lignite Tertiary series are again exposed. Here, however, in a large valley crossing the line at the 345 mile point, which is the most eastern great channel of erosion that crosses the 49th parallel towards the Missouri river, the rocks of this formation are exposed on a grand scale. The lowest beds seen in this valley are curiously banded clays and shales, clay beds charged with plant remains and carbonaceous matter, and having quite a purple tint when viewed from a little distance, alternating with clays, nearly white, and yellowish sandstones. Above these comes in a sandstone layer which, though of no great thickness, has in several places produced curious conical mounds by forming a protecting capping for the softer strata below, these again forming slopes or nearly perpendicular steps according to their relative hardness, which, taken together with the remarkable and distinctive colouring of the beds, gives a very striking and peculiar aspect to the scenery. Above the sandstone capping of this lower part of the section, is a great deposit of sandy clays and concretionary sandstones among which three beds of lignite of various thicknesses are intercalated. The beds are almost horizontal, but undulate at low angles, and the valley of the stream appears to occupy, in the main, the centre of a shallow synclinal fold.

The upper part of the section in this valley consists of at least 100 and probably 150 feet of clays and argillaceous fine sands of greyish and yellowish-grey colours, and well stratified. They contain thin leaf-beds at several different levels, which are prominent from their grey-purple colour, but, though containing very many dicotyledonous and flag-like leaves, they do not yield recognisable specimens, from their soft and crumbling nature. This part of the section also includes at least three lignite beds. The highest of these is about 140 feet above the base of the section, and 3 feet or more in thickness. It would appear to be of fair quality, though much decomposed and quite crumbling at the out-crop, from the action of the weather.

The next is about 120 feet above the same datum, and can be traced a very considerable distance along the face of the bank; it is five feet in thickness, but includes, at the place examined, several thin layers of carbonaceous shale; and, though of good quality in places, not appearing to have the same uniformity in the various layers that is generally found in the coals of this region.

The lowest lignite is some seventy-five feet above the base of the section and is only a few inches in thickness.

By diligent search certain parts of this upper portion of the section may be found which contain quite numerous, though in general very badly preserved remains of molluscs, which appear to be such as would indicate the deposition of the beds in purely fresh water. A peculiar angular *Paludina* and a *Melania*, apparently specifically identical with that already noticed as occurring in the Souris Valley sections, are the most common.

Section 8.—The complete section may be thus represented.

1.	Upper part, yellowish sands and clays, lignites, &c.....	150′	
2.	Hard grey and yellowish, somewhat false-bedded sandstone, forming a "capping rock" to beds below (about).....	3′	
3.	Greenish yellow, finely bedded fine sand.....	15′	
4.	Soft yellowish sandy clay.....	2′	4″
5.	Greyish and yellowish hard-bedded clay.....	2′	6′
6.	Blackish thin-bedded clay or shale with plant remains.....	5	
7.	Greyish thin-bedded clay, becoming darker toward the top (plant remains) graduating into next bed.....	10′	
8.	Hard, pale brown, compact clay, with very few plant remains.	1′	4″
9.	Hard whitish clay with some plant remains, and a scattered layer of heavy ironstone balls about a foot from the top	9′	
10.	Thin-bedded greyish and blackish hard clays, with leaves, and some small bunches of selenite crystals.....	7′	
11.	Fine bedded clay filled with leaves and plant remains, hard and rusty in the upper portion.....	1′	8″
12.	Grey hard sand with charcoal-like fragments in some places.	3′	
13.	Ironstone with many plant remains, mostly sedge-like blades.		3″
14.	Soft grey clay.....		
		200′	1″

The lower part of the section forms a group well distinguished by its colour and the perfection of its stratification from the upper, and often endures, protected by its hard sandstone (No. 2) when the more crumbling upper division has been removed. The plant remains, though occurring more or less throughout the whole section, are best preserved in the lower purplish layers. They consist chiefly of leaves of dicotyledonous trees which appear to have fallen when mature, in the course of nature, and with the change of the seasons, and floated without violence to the great lake in the fine shelly deposits of which they have been preserved. Leaves and small branches of coniferous trees are also common. They belong chiefly to the genus *Taxites*, and one variety seems to be specifically identical with that subsequently to be mentioned as occurring in the Porcupine Creek section. Sedge and flag-like leaves and stems are also abundant. The leaves of deciduous trees appear to resemble more closely those figured by Lesquereux for the Fort Union region than they do those obtained from Porcupine Creek, and are probably older than he latter, having in some cases almost a Cretaceous facies.

Many of the crumbling hill-tops in this valley have a brick-red colour resembling that seen in parts of the Souris Valley, and due, as there, to the combustion *in situ* of the deposits of lignite. The slag or clinker produced in the same way is also to be found here, though it was not observed actually in place.

Section. 9.—A section on the west side of the valley, and almost exactly where the 49th parallel crosses it, shows in a bank about thirty feet high, toward the base, several layers of concretionary ironstone, each of a few inches in thickness. The top of the bank, (which is merely an outlying projection from the base of the high and steep slope bounding the valley) holds a seam of lignite four feet thick, with, however, a few shaly partings. This bed would have passed unnoticed, but for the fact that the little marmots had been burrowing into the crumbling bank, throwing out heaps of black material at the mouth of their holes.

The next stream crosses the line at the 351 mile point; it also flows through a deep valley of erosion, and may be called Pyramid Creek, from a remarkable pyramidal hill formed of the usual clays and sands, capped by a portion of a layer of hard grey sandstone, the cement of which is calcareous. It has a tendency to break into large quadrangular masses along intersecting jointage planes, and shows conspicuous false-bedded structure. Below this is a thickness of about fifty feet of rather incoherent fine yellowish sand sometimes rather argillaceous. This, producing a sloping bank, is not very well exposed, but constitutes about one-third of the thickness of the beds exposed in this valley. The middle third consists of soft crumbling sandstone or compact sand without any apparent cementing matter, and of which the constituent particles are rather coarse, contrasting strikingly in this respect with the overlying material. It shows evidence of having been deposited by water in rather rapid motion, through its entire thickness; but the false bedding is very definitely cut off at many different horizons by perfectly horizontal planes, above which it again commences. The weather acting on these beds causes the hill sides composed of them to assume a well-marked terraced appearance on a small scale, each horizontal break producing a terrace level. The sandstone contains here and there a few badly-preserved shells, among which can be recognized two species of *M ania*, fragments of *Paludina* and of *Unio*. In one place a layer of ironstone, about three inches thick, is seen to run for some distance. The most noticeable feature, however, of this part of the section is the remarkable concretionary character of some layers of the sandstone The concretions are hard, and of all shapes and sizes. Some are spherical, many are flattened spheres, and two or more of them are often confluent

forming dumb-bell like masses or more or less continuous sheets of a lumpy character. Many are long and root-like, and project curiously from the bank. The sandstone is so soft in some places that the sand-martens have been able to make their nests in it; and where these have been abandoned, the wind forming an eddy, and carrying with it loose sandy particles, has enlarged them into cavities resembling in shape the pot-holes found in rocks below rapids and waterfalls.

The lower third of the section in this valley is, as seems often to be the case with the lower layers of these rocks, much more clearly defined, and divided into thinner beds in which dark colours predominate. Altogether the section here much resembles that seen in the last great valley; the lower beds of this probably correspond with the purplish leaf-beds there, and the great thickness of sands and sandstones above correspond in a general way; though in this place they differ in the absence, so far as could be ascertained, of beds of lignite. The layers of hardened sandstone must also in this case occupy different horizons in the two sections, but this is not to be wondered at, when the extremely local, and indeed often nodular character of the induration is considered, and the fact that it merely depends upon the introduction of a small proportion of calcareous cement among the particles already compacted by pressure.

Section 10.—The whole section in Pyramid Valley may be represented thus:

1.	Hard capping sandstone, (several feet,)	
2.	Soft yellowish sandy beds forming a sloping bank, about...	50′
3.	Soft sandstone, grey, false-bedded, about	50′
4.	Stratified sandy clay	3′
5.	Purplish plant-beds with thin layers of lignite and much selenite in thin sheets, isolated crystals and stellar groups	3′
6.	Lignite, with many spots of amber	1′ 6″
7.	Purplish bed with a few plants	2′
8.	Grey slightly coherent sand, with nodules of arenaceous selenite crystals	4′
9.	Purplish bed with obscure remains of leaves	1′
10.	Incoherent arenaceous clay and sand	7′
11.	Purplish-grey arenaceous clay, with obscure plant remains and some fossil wood	3′
12.	Brownish clay with ferruginous layers	6′
13.	Lignite	1′
14.	Brown earthy bed	6″
15.	Grey somewhat coherent coarse sand, with argillaceous matter	12′
	About	144′

The rocks show no well marked dip, but appear to undulate slightly at very low angles.

The occurrence of gypsum as selenite is nearly always in association with plant-beds, and generally with those holding many half-obliterated vege table remains and of a purplish shade.

A few miles west of Pyramid Creek several hills are capped with heavy and hard sandstone beds, a feature quite exceptional in a country so gently undulating. These do not appear to be quite horizontal, but have a gentle dip to the west. They may be equivalent to the capping sandstone of the Pyramid Hill, but more probably are yet higher in the series.

Ten miles west of Pyramid Valley, in the upper part of the valley of another stream, yellowish and grey stratified sandy clays are again seen, but are not perfectly exposed. At one place a layer of hard ripple-marked sandstone is exposed, the ripple-marks being about an inch and a half wide and very perfect, and indicating a current North-west Magnetic.

With the exception of this exposure, the underlying rocks are nowhere clearly visible in the vicinity of the line from Pyramid Valley to Porcupine Creek, a distance of about 35 miles; one very considerable stream is crossed about midway, but its valley is very wide and with gently sloping banks. Highlands appear to the north, and may possibly show sections of strata overlying those seen in the banks of the streams, but I was unable to reach them, as both in going and returning, the ground, especially in the vicinity of these highlands, was covered with snow, which rendered travel. ling very slow and toilsome.

Beds exposed in Porcupine Creek and tributary valleys, from the 385 *Mile Point to about the* 391 *Mile Point*

Many partial sections occur in this vicinity. Lignite is seen in three places near the line, and just above the level of the brook in each instance. The exposures seem to belong to the same bed, and if so, nearly a mile of its horizontal extent can be traced.

The lignite and associated beds undulate slightly in all the sections; the lignite decreasing from four feet in thickness in the most northern bank to one foot in that furthest south. The overlying rocks consist of yellowish and grey sands and clays, well stratified and much resembling those forming the upper part of the section in the 345 mile valley. (Pl. II.)

The best exhibition of these strata was obtained in a bank about forty feet in height on removing the decomposed material from the surface.

Section 11.—

1.	Soil.	
2.	Siliceous pebble drift	Several feet.
3.	Soft greenish sandy clay	2′ or more
4.	Soft blackish clay	1′ 6″

5.	Rusty crumbling sandy clay		6″
6.	Grey clay with some plant remains	9′	
7.	Grey clay with well preserved dicotyledonous leaves	1′	8″
8.	Impure ironstone in concretions		3″
9.	Yellowish sand and sandy clay with obscure plant remains	9′	
10.	Greyish and yellowish fine sandy clay	1′	3′
11.	Scattered layer of small ironstone balls		
12.	Grey fine sandy clay	1′	
13.	Rusty layer with crumbling plants		3″
14.	Grey sand		4″
15.	Detached masses of lignite shewing the form of flattened tree trunks, about		4″
16.	Yellowish grey fine sand		6″
17.	Grey clay with plant remains		4″
18.	Lignite, not of best quality. The grain and form of component wood generally clearly perceptible. Bed undulating slightly	3′ to 4′	
19.	Soft grey arenaceous clay	1′ to 2′	
	About	31′	

The vegetable remains imbedded in the rocks overlying the lignite are mostly those of deciduous trees, and in certain beds are very perfectly preserved. Lignite from this section was used for camp fires, in the absence of wood, but did not burn very freely, as it was taken damp from the bed and piled on the ground without any provision for draught from below. The most interesting and important section, however, in this region, is that which occurs in a valley joining that of Porcupine Creek from the west, which exhibits a bed of lignite eighteen feet in thickness, and has also yielded some of the most perfect and curious remains of plants. The bank in which this out-crop is situated is over half-a-mile south of the line. The beds are arranged thus: (Plate I, Sect. 12.)

Section 12.—

1.	Surface soil	1′	
2.	Siliceous pebble drift	1′	6″
3.	Yellowish and grey sandy clays well stratified, but somewhat soft, about	9′	
4.	Lignite		9″
5.	Banded clays, yellowish, grey and purple, with well preserved remains of plants and in some layers much crystalline gypsum	5′	
6.	Lignite, weathering soft, some layers laminated, others rotten and brownish. Forms a steep slope	10′	
7.	Lignite, hard compact, horizontally laminated, but also breaking into large cubical blocks along vertical planes	8′	
8.	Soft grey sandstone much jointed, and breaking out in pieces bounded by plane faces, some vertical and some oblique. Holds root-like remains and gives issue to springs of water	5′	
		40′	3″

Though undulating a little, the strata have no true dips, and are as nearly as possible horizontal on the large side.

The lower part of the lignite bed is very compact and tough under the pick; it holds in some layers many drops of amber. The jointage planes form a conspicuous feature, and were not noticed in anything like the same perfection in any other lignite beds examined. The divisional planes cause the coal to break off in large cubical pieces which encumber the stream at its base. Some of them shew thin seams of white gypsum, and in one case a thin film of iron pyrites was detected, being the first appearance of this mineral in connection with these lignite deposits.

The plants in layer (5) are in a beautiful state of preservation, and, when the clay is first split open, show every vein-mark in perfection, not only in the larger and coarser leaves but in delicate ferns which are here unusually common. The matrix is, however, unfortunately very soft; it crumbles easily, and tends to crack on drying.

This section also exhibits the first and only distinct instance of dislocation which has been observed to affect these beds. The eighteen foot lignite and associated strata are seen to have been brought to their present position by a downthrow fault, and on the other side of the Creek their place is taken by underlying sandy clays. (Plate I.)

The southern side of the valley, opposite this great lignite bed, is broken down and forms a gentle though irregular slope, which is encumbered by many large, strangely shaped and coloured blocks of stone, much harder than any rocks occurring in the neighbourhood, and in pieces larger than the drift-blocks found in the region. They proved on inspection to consist of masses of beds such as those associated with the lignite, but indurated by its combustion, which has also caused the interruption in the edge of the valley. About a fourth of mile east on the same valley the great lignite is again exposed, and apparently in much the same development and association.

A considerable number of specimens of fossil plants from the vicinity of Porcupine Creek have been preserved, though all in a more or less shattered condition. I am indebted to Principal Dawson for a preliminary examination of these. The following genera are represented by clearly recognisable specimens: Onoclea, Sphenopteris, Phragmites, Trapa ? Thuja, Sequoia, Glyptostrobus, Populus, Salix, Fagus, Alnus, Platanus, Rubus ? Hedera ? As far as can be ascertained these generic forms and some of the species are identical with those characteristic of the Tertiary beds of the Western States, which have been catalogued and described by Lesquereux and Newberry. The fern *Onoclea sensibilis* is especially

abundant. It is a species still living, and recognized by Newberry in the Tertiary of Nebraska, and by the Duke of Argyll in that of the Island of Mull. The Thuja, also common, is identified by Newberry with his *Th. articulata*. It will be well to leave the specific determination of these leaves until the appearance of the volume now in the press on the plants of the U.S. Tertiary by Dr. Newberry. In the meantime they may be stated to correspond very closely with the plants described as occurring in connection with the Lignite Tertiary, called by Hayden, in its southern extension, the Fort Union group.

General Remarks on the Lignite Formation.

It would seem premature at the present time to enter very fully into the discussion of the general relations and limits of the lignite-bearing series of rocks, as another season will probably afford much additional information of value in this direction.

The formation is, however, undoubtedly an extension of the Great Lignite or Fort Union group of strata of Hayden, which, as developed in the Western States and Territories, has been fully described by him in his various reports (Annual Reports Geol., Surv. Territ., 1868 to '72). These strata, immediately succeeding the Cretaceous rocks, are the lowest American representatives of the Tertiary series, and have been called for this reason Eocene, though it is impossible to affirm that their deposit was more than approximately synchronous with that of the Eocene as constituted in Europe. The flora of the Fort Union group indeed, according to Newberry and Lesquereux, who have examined the collections of the various western expeditions, has, when compared with European forms, a Miocene aspect, and the animal remains, which are chiefly those of fresh-water molluscs, do not form a very trustworthy criterion in regard to age. The advent of the Tertiary period in the western basin of America appears to have been contemporaneous with the change of the inland sea from salt-water to fresh-water conditions.

The change in character of the Fauna is thus, taken broadly, a good mark by which to distinguish rocks of Cretaceous and Tertiary age, though it would appear exceedingly probable that the Cretaceous forms were brought to a rather abrupt end by the change in physical conditions, so far as regards the area in question. It will suffice then at present to correlate these beds with those of Hayden's Lowest Tertiary or Fort Union group, which is largely developed southward in Dakota and Montana, and to which also the smaller isolated lignite basins, now beginning to be

largely worked in the neighbourhood of the Union Pacific R.R. in Wyoming, &c., are believed to appertain, though it is probable that a part of these may ultimately be attached to the Upper Cretaceous with which the lower beds show a marked stratigraphical and zoological connection. The sections in the vicinity of the Roche Percé seem to belong to the lowest part of this formation which is exposed in the vicinity of the line, and contain the only mollusc found which is known to live in salt or brackish waters, the *Corbula* already mentioned. Hayden's sections, however, show that southward, over large areas, the Lowest Tertiary beds are characterized by abundant remains of Ostrea associated with lignites—a circumstance which would indicate still more markedly marine conditions, and which would appear to lead to the conclusion that there may be a small portion of the formation still lower than the Roche Percé series which has been so soft as to yield to eroding forces and become concealed beneath the drift formations. The beds in the Souris Valley and near the Roche Percé are in great measure arenaceous, and many of them appear to indicate rather disturbed water, both from this fact and the frequency with which some of the molluscs have sustained fractures of their shells during life. Nothing, however, in the nature of a conglomerate is found, and even the sandstones can rarely be considered coarse. The beds here are also not of great thickness individually, and succeed each other rapidly, as will be seen by the sections. In this they resemble the lowest part of the sections seen further west in the 345 Mile Valley and Pyramid Creek, though, from the great distance entirely concealed by drift deposits between Roche Percé rocks and these exposures, it is impossible to identify any particular bed or series of beds. Indeed from the estuarine character of the formation, as a whole, and the rapidity with which individual strata are seen to change when followed for short distances, no such close parallelism is to be expected. The sections exhibited in 345 Mile Valley and in Pyramid Creek, 6 miles apart, show, however, a very close general resemblance, each being composed at the base of purplish and whitish sands and sandy clays, passing upward into beds of almost pure and but slightly coherent sand, and the highest beds seen being formed of yellowish soft arenaceous clays without much evident stratification. The furthest west exposures seen, those in Porcupine Creek and neighbourhood, may belong to a still higher part of the series, though it is probable that no very great thickness of beds is represented by the sections over the entire area examined. The rocks in many places seem to be absolutely horizontal, but very generally show slight dips in one direction or other, which, when followed a short distance, prove to become reversed and to arise merely from a gentle undulation of the beds.

A scarped bank rarely presents itself in the area covered by this formation without exhibiting one or more beds of lignite, and these vary in thickness from a few inches to eighteen feet. The entire number of beds thus seen was very great, but, in the absence of trustworthy data with regard to their equivalency, it would be misleading to enumerate them. The lignites seldom show intercalation of shale or sand, and, though some of them may have been formed from accumulations of drift-wood in shallow water it is difficult to understand how such collection could go on for long periods without the contemporaneous deposit of sandy or muddy matters which would have been suspended in waters moving with sufficient force to convey the wood. It would also appear difficult under this theory to explain the regular and even superposition of the sandy and clayey beds which overlie the lignites, and the fact that these do not send extensions downward into them, as they must have done if formed above a tangled mass of trunks and branches of trees. It seems likely, therefore, (though layers like true root-beds were only observed in one or two instances to underlie the lignit beds) that at least the majority of the lignite beds were produceel by the growth and partial decay of trees, and also perhaps of peaty matter from swamp mosses, in the positions which they now occupy. Their method of formation would, therefore, agree with that already proved for coals of the true Carboniferous formation. This is rendered more probable by the circumstance that lignite beds are sometimes immediately covered by beds holding leaves of trees, ferns, and grasses, a fact which has been noted by Hayden and others with regard to the lignite beds further south, and which is also found to obtain with coal beds of the Carboniferous period.

Composition and Practical Value of the Lignites and Ironstones.

The coaly material of the beds above described is, for the most part, true lignite, as distinguished from brown coal, being composed of flattened and carbonized tree-trunks. The fossil woods associated with the plants, and which can be recognized in the mass of the lignites themselves, are all Coniferous, and may, from their structure, have belonged to the species of Thuja and Sequoia represented by the leaves found in the accompanying clays. I have made some assays of the lignites, for the purpose of ascertaining as far as possible their economic value, and in doing so have not thought it necessary to confine my examination to those beds only which are of workable thickness, as a general comparison of the various seams, thick or thin, is of more value in giving an idea of the average quality of the lignites of the formation now known and those which further

exploration may bring to light over the same region. The analyses, therefore, include a selection from the various sections, and several beds of good quality and thickness are unrepresented.

The lignites all contain, when in the bed, a very considerable percentage of hygroscopic water, and even those which are very hard and tough under the pick at first, when exposed to the air tend from the loss of water to crack into angular fragments or split up along the layers of deposition. The same phenomenon has been observed with similar lignites mined on the Union Pacific R.R., and it is found necessary to prevent loss from this slacking to convey them to their destination as soon as practicable after their extraction from the mine. The lignites generally present a rather unpromising appearance in the banks where they crop out, from the fact of their having undergone superficially a certain amount of fissuring and the interstices being filled with clay from above. When followed inward a few feet however, they usually become quite solid and compact. They vary a good deal in appearance, some beds having a dull lustre almost like that of cannel coal ; others, and this is perhaps the most common form, have the same black colour on faces of fracture, but tend rather to split parallel to planes of deposit andshow on careful examination distinct traces of the medullary rays and rings of growth of the component wood. Other samples have almost a shaly appearance, caused by numerous layers of mineral charcoal, which is present in small quantities in nearly all the beds. Amber spots are common but generally quite small. The lignites do not soil the fingers like ordinary bituminous coal. Their powder is generally a dark shade of brown but sometimes quite black.

They all yield easily a dark brown solution when treated with caustic potash. The lignites from various beds might be designated by such names as *pitch coal*, *brown coal*, *lamellar brown coal*, &c., but it seems better, as they pass by easy gradations from one variety to another, to class them under the generic term lignite.

In this connection it should be mentioned that though some authors have persistently used the term *coal* for the fuels of the Tertiary formations further south, the name is mineralogically inapplicable, from their composition, to all but one or two which appear to have been altered by local outbursts of igneous rock.

Though giving below the actual amount of hygroscopic and combined water as found by analysis, it must be premised that it depends entirely on the conditions to which the lignites have previously been subjected, and that, by prolonged exposure to dry air, it might have been in many cases very considerably reduced. I have, therefore, thought it advisable in

another place to reduce the results of all analyses to correspond to a certain percentage of moisture, that they may be better compared with each other and with foreign lignites. The high percentage of volatile combustible matters renders the difference due to slow and rapid coking in some cases very marked.

Souris Valley. Section 6. Lowest lignite, two feet three inches thick. Conchoidal fracture with rather dull surfaces and resembling cannel coal, ash reddish-white.

		By rapid coking.
Water	12.07	
Fixed carbon	45.44	38.90
Volatile matter	39.74	
Ash	2.75	
	100.00	

Souris Valley. Section 2. *Layer* 19. A weathered specimen separating into laminæ horizontally. Clay from overlying bed filling fissures. Ash yellow-brown.

		By rapid coking.
Water	13.94	
Fixed carbon	45.27	38.35
Volatile matter	35.00	
Ash	5.79	
	100.00	

Souris Valley. Section 2. *Layer* 17. Weathered specimen. Black, compact, with shining faces. Ash yellowish.

		By rapid coking.
Water	12.67	
Fixed carbon	31.39	28.01
Volatile matter	49.52	
Ash	6.42	
	100.00	

Souris Valley. Section 2. *Layer* 10. Lustre dull, separating along horizontal planes. Ash light yellowish.

		By rapid coking.
Water	14.90	
Fixed carbon	36.94	36.68
Volatile matter	42.98	
Ash	5.18	
	100.00	

Souris Valley. Section 2. *Layer* 2. A weathered specimen soft and crumbling. Ash greyish-white.

		By rapid coking.
Water	17.97	
Fixed carbon	32.86	30.10
Volatile matter	44.56	
Ash	4.61	
	100.00	

Souris Valley. Section 5. Black compact lignite with much woody structure apparent. Ash yellow.

		By rapid coking.
Water	14.73	
Fixed carbon	42.48	34.07
Volatile matter	39.99	
Ash	2.80	
	100.00	

Souris Valley. Section 4. 7 *foot seam.* Hard compact black lignite, breaking with pseudo-conchoidal fracture, and showing traces of structure of wood. Ash yellowish-white, light.

		By rapid coking.
Water	15.11	
Fixed carbon	47.57	41.67
Volatile matter	32.76	
Ash	4.56	
	100.00	

Section 8 *Lowest Lignite.* Weathered specimen, crumbling. Ash grey.

		By rapid coking.
Water	18.74	
Fixed carbon	35.69	30.04
Volatile matter	40.54	
Ash	5.03	
	100.00	

Section 8. *Middle Lignite.* Weathered specimen. Soft, breaking into layers along deposition surfaces. Largely composed of comminuted charcoal-like fragments.

		By rapid coking.
Water	16.28	
Fixed carbon	46.25	29.18
Volatile matter	33.19	
Ash	4.28	

Section 8. *Upper Lignite.* Out-crop specimen. Crumbling. Tends to break into layers parallel to deposition planes.

		By rapid coking.
Water	15.20	
Fixed carbon	34.45	27.61
Volatile matter	44.43	
Ash	5.92	
	100.00	

Section 9. Out-crop specimen. Brownish. Fracture almost conchoidal. Ash yellowish-white.

		By rapid coking.
Water	15.51	
Fixed carbon	37.12	28.44
Volatile matter	42.65	
Ash	4.72	
	100.00	

Section 12. *Lower part of* 18 *foot seam.* Tough, compact lignite, separating into horizontal layers. Much amber in small spots, a good deal of woody structure apparent and some mineral charcoal. Ash light-grey.

		By rapid coking.
Water	12.05	
Fixed carbon	46.18	41.03
Volatile matter	35.12	
Ash	6.65	
	100.00	

Section 12. *Upper part of* 18 *foot seam.* Out-crop specimen, crumbling. Ash white.

		By rapid coking.
Water	16.87	
Fixed carbon	34.32	24.30
Volatile matter	37.51	
Ash	11.30	
	100.00	

The lignites, it will be observed, are on the whole uniform in composition and contain an average amount of over 40 per cent. fixed carbon, when the water content is estimated at 12 per cent. They thus fall somewhat behind the lignites given in Table II, from Wyoming, Utah, &c., and which are found in proximity to the Rocky Mountains and parallel ranges, and have probably been somewhat improved by metamorphism simultaneous with their elevation. The lignites here described, however, gain some advantage in a practical point of view from occurring in a horizontal position and out-cropping in the sides of valleys in such a way that they might be worked by simple adits, avoiding the expense and trouble necessary when vertical sinking has to be resorted to in the first instance, as in the case of some of the other localities named, where the beds are often highly inclined or nearly vertical.

It is a disadvantage, however, that none of those yet found yield a coherent coke, as is the case with one or two of those of nearly the same age in the United States.

The lignites examined merely shrink somewhat in size during the expulsion of the volatile combustible matter, and turn out of the crucible in a dry incoherent powder. The volatile matter is, as might be expected, comparatively poor in luminous gases, and the lignites would, consequently, be of little use in the manufacture of illuminating gas.

The ash is generally of pale colours; grey and white, passing into yellowish-white, being the prevailing shades. One or two only yield a deeply-coloured ash, wihch is then of a brick-red colour. It is small in amount in most of the specimens, and does not usually appear of a nature to form

troublesome clinker. The lignites when burning yield a peculiar empyreumatic odour but no smell of sulphur, and indeed, as might be foreseen from the nature of the ash, the quantity of sulphur present is very small.

In the table below the analyses of all the lignites are calculated to correspond with a quantity of water, combined or hygroscopic, equal to twelve per cent., which, may I think, be accepted for the samples examined as the practical limit of desiccation in dry air at ordinary temperatures. This will allow of a more accurate comparison of the value of those from different parts of the series.

TABLE I. RESULTS OF ASSAYS OF LIGNITES, WATER BEING ESTIMATED AT AN AVERAGE OF 12 PER CENT.

	Locality.	Miles West of Red River.	Thickness of bed.	Water estimated at 12 per cent.	Fixed Carbon.	Volatile combustible matter.	Ash.	Remarks on ash.
1	Souris Valley. Sect. 6...	255	2′ 3″		45.48	39.77	2.76	Reddish-white.
2	" " " 2...	263	3′ 2″		46.18	35.90	5.92	Yellow brown.
3	" " " 2...	263	1′ 5″		31.51	50.02	6.47	Yellowish.
4	" " " 2...	263	1′ 0″		38.08	44.57	5.35	Light Yellowish.
5	" " " 2...	263	6′ 6″		34.82	48.30	4.88	Greyish-white.
6	" " " 5...	262			43.72	42.40	2.88	Yellow.
7	" " " 4...	263	7′ 3		49.31	33.98	4.71	Yellowish-white.
8	Big Valley. " 8...	344	a few inches		38.65	43.92	5.43	Grey.
9	" " " 8...	344	5′		48.61	34.90	4.49	Grey.
10	" " " 8...	344	3′		36.92	44.95	6.13	White.
11	" " " 9...	346	4′		38.63	44.48	4.89	Yellowish-white.
12	Porcupine Valley Lower part..... " 12....	390	18′		46.20	35.14	6.66	Light grey.
13	Upper part..... " 12...	390	"		36.33	39.97	11.70	White.
	Average.....				41.1	41.41	5.55	

It should be stated that, with the exception of two or three specimens, all those analysed were mere out-crop samples, and, from the facility with which these lignite coals deteriorate under atmospheric influences, show a

result much inferior to that which would be obtained from the same beds at some depth. Nos. 1 and 12 with one or two others were obtained from portions of the beds recently exposed by slips of the bank, and probably represent more fairly the quality of the better class of lignites. The total percentage of carbon, inclusive of that which passes off with the volatile matters, varies probably between 60 and 70 per cent. The lignites do not appear to be suited for smithy purposes, and the smiths who tried them reported it difficult to obtain a welding heat. The same fault has been found, I believe, with even the best classes of similar fuels found in the vicinity of the Union Pacific Railway, and arises, no doubt, from the great proportion of volatile combustible matter to fixed carbon, and the quantity of hygroscopic and combined water. As the lignites do not coke, they would appear to be unsuited for the smelting of iron in the blast furnace, though it is possible they might be economically employed for this purpose in the raw state, especially if mixed with a proportion of wood charcoal and burned in furnaces of not too great height.* They are perfectly suited for puddling iron, and the metallurgical treatment of various ores, if burned in gas furnaces. Similar fuels have already been extensively employed in this way at Golden City and other localities in Colorado, and in the mining districts of the Southern Rocky Mountain region, and appear several years ago to have commanded prices ranging from $2.00 to $4.00 per ton at the pit's mouth. Similar and even inferior lignites are extensively used for steam purposes in various parts of the world, and in Wyoming, Utah, &c., are employed on the railways, though locomotives to perfectly burn these fuels, in order to give satisfactory results, must have, compared to those worked on bituminous coal, larger grates and fire-boxes, and larger boiler-tubes, giving a greater heating surface compared with the horse-power.

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* Excellent charcoal is, I believe, made from similar Lignites in Germany, by treating them in coking ovens in the state in which they are extracted from the mine.

TABLE II. SHOWING COMPOSITION OF LIGNITES AND OTHER FUELS FOR COMPARISON WITH LIGNITES IN TABLE I.

Locality.	Water.	Fixed carbon.	Volatile matter.	Ash.	Colour of ash.	Analyst.
1. Wood, average of air-dried..	18.55	25.69	53.99	1.77		
Lignites, United States,						
2. Golden City, C.T.....	13.43	45.57	37.15	3.85	Grey.	J. T. Hodge.
3. Carbon Stn., W.T.....	6.80	49.72	35.48	8.00	Light grey.	"
4. Evanston, Utah.....	8.10	47.67	34.60	9.67	Grey.	O. D. Allen.
5. Murphy's, Ralston Cr. C.T.	13.83	44.44	35.88	5.83	Orange.	J. T. Hodge.
6. Chesnut R., Near Boyeman, Montana...	3.00	43.50	41.50	12.00		A. C. Peale.
7. Marshall Mine, Boulder City C.T., average of 5.	16.00	41.50	38.00	4.50		A. L. Ford.
8. Van Dyke, W. T.....	8.12	53.23	36.65	2.00	Light grey.	J. T. Hodge.
European Lignites.						
9. Zsemle, Hungary	12.60	55.20	27.85	4.35		Schrotter.
10. Wildsthut, Upper Austria	26.15	39.12	19.15	15.58		Regnault.
11. Dax, France.....		44.11	50.80 with water	4.99		Schrotter.
12. Utweiller, Rhine.....	———	67.3	31.80	0.90		"
13. Minerve, L'Aude.....	———	32.6	57.40	10.00		"
Bituminous Coals.						
14. Nottinghamshire (coking).	3.50	59.18	33.32	3.90		
15. St. Helen's Lancashire. (non-coking).	3.23	60.33	31.27	5.17		
16. Sidney, C. B.....	———	67.57	23.81	5.49		W.R.Johnson.
17. Pictou, N.S.....	1.75	61.95	25.87	10.42		J. W. Dawson.

No. 1, from Tables in Percy's Metallurgy. Nos. 2, 3, 5, 7, 9, from Geological Survey of Territories for 1870. No. 4, from Hague and King's Mining Industry of 40th parallel. No. 6, from Geological Survey of Territories for 1872. Nos. 9, 10, 11, from Percy's Metallurgy. Nos. 12 and 13 quoted by Hodge in Geological Survey of Territories for 1870. Nos. 14 and 15, Percy's Metallurgy. No. 16, from Coal Trade of British America, W. R. Johnson. No. 17, Acadian Geology.

o. 8 from VanDyke, together with another lignite of similar composition

from the neighbouring locality of Rock Springs, are considered by Mr. Hodge the best lignites in the Rocky Mountain region.

The ironstones of this formation, though occurring very frequently in the same sections, and in close proximity to the coals, have not been observed in any place to attain a considerable thickness. They generally run in nodular sheets of only a few inches thick, through the clays and argillaceous sands. Externally they weather to various shades of chocolate-brown and reddish-brown, but are hard and compact in structure and within preserve their original bluish or yellowish-grey colour. They ring beneath the hammer, and break off in conchoidal chips. Considerable quantities of this material might be gathered from the surface in some localities, and it is probable that further search might bring to light localities in which so many layers of ironstone occur in the same section as to render it profitable to work over the entire bank. Should these ores ever come to be worked, limestone for use as a flux could be obtained in considerable quantities from the boulders of Silurian age which strew the plains in many places.

Clay Ironstone from Souris Valley. Section 2.

Protoxide of iron	49.00
Water lost at 115° C.	1.21
Carbonic Acid lost on ignition	28.57
Siliceous matter insol. in HCl	17.04
Sulphuric Acid	0.26
Phosphorus	*Trace*
Metallic iron per cent, in raw ore	38.11
Metallic iron in calcined ore	54.27

Clay Ironstone from 345 Mile Valley. Section 9.

Protoxide of iron	46.72
Water lost at 115° C.	3.57
Carbonic Acid lost on ignition	21.23
Siliceous matter insol. in H Cl	8.72
Sulphuric acid	0.30
Phosphorus	0.03
Metallic iron in raw ore	37.53
Metallic iron in calcined ore	49.90

A small quantity of iron is present as peroxide in each ore, but I have not thought it necessary to make a separate estimation of this.

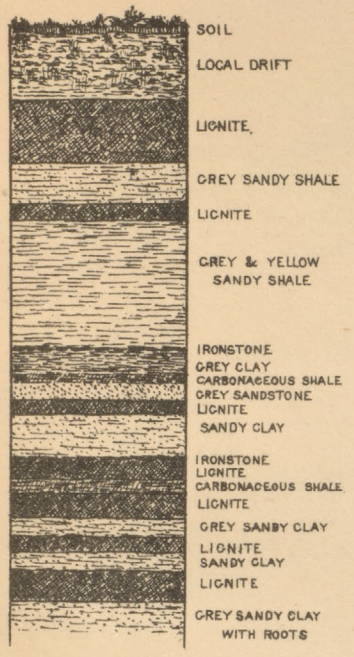
A third specimen from the 345 Mile Valley, section 8, examined for iron, gave a percentage in the raw ore of only 37.95.

The percentage of iron in the specimens examined is very good for the class of ores to which they belong. The average percentage of iron of several good English clay-ironstones amounts to 33.84; of several samples

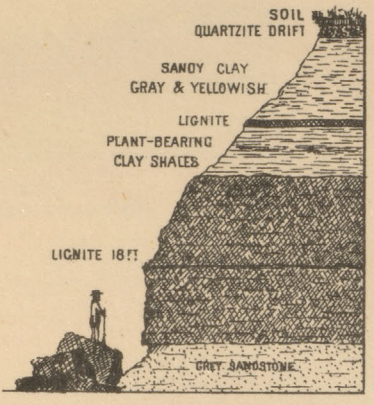
of black-band ironstones to 35.39. Where these ironstones are unweathered, the whole of the iron appears to be in combination with carbonic acid. The quantity of sulphur present is small, and it is entirely as sulphuric acid and in combination with lime. Phosphorus is also present in very small quantities.

The clays and argillaceous sands accompanying the lignites are in many places of the nature of fire clays, and contain but very small quantities of iron or lime. It is probable that many of them would make very refractory fire bricks. Clay of sufficiently good quality for the manufacture of ordinary bricks and pottery is present everywhere in close connection with the lignites.

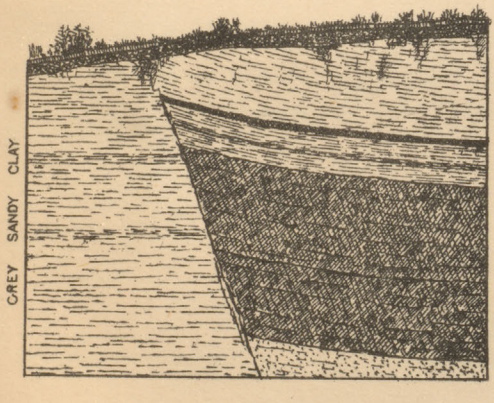
REFERENCE TO SECTIONS.



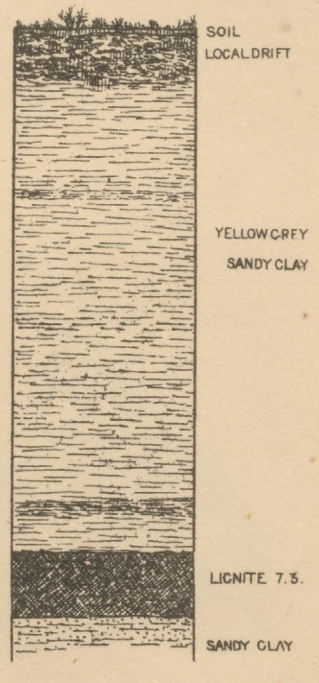
SECTION 2. SOURISVALLEY



SECTION 12. 18FT LIGNITE. PORCUPINE CREEK.



FAULT AFFECTING 18FT LIGNITE.



SECTION 4. SOURIS VALLEY.

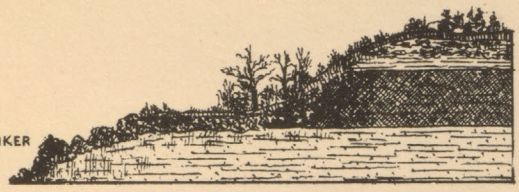
20 FEET

G.M.Dawson Delt.

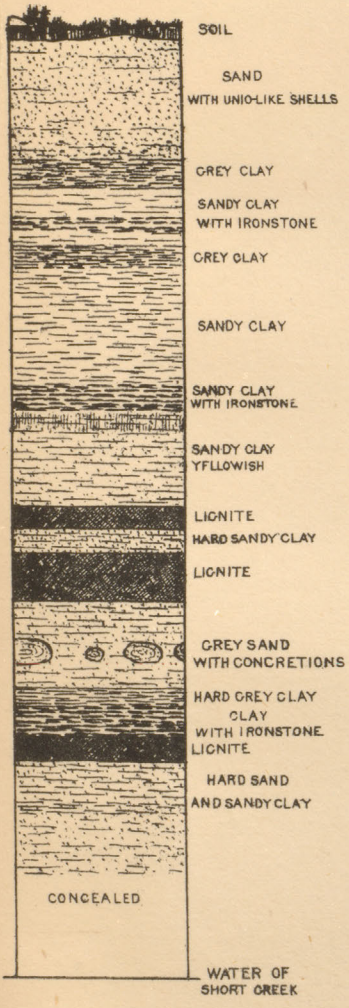
The Desbarats Litho. & Publg. Compy Montreal. Lith.

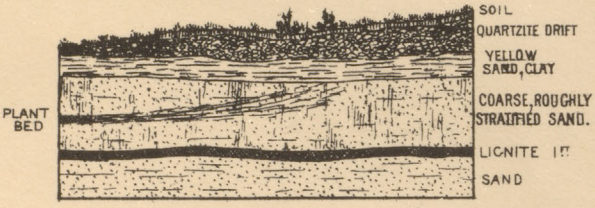
SECTIONS TERTIARY LIGNITE FORMATION.

FORTY-NINTH PARALLEL.

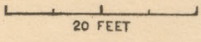


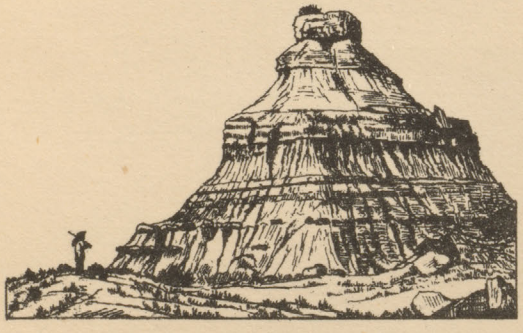
SOURIS VALLEY
LIGNITE BED BURNED AT OUTCROP





SECTION IN PORCUPINE CREEK





SECTION 7. SHORT CREEK

SECTION 8. [LOWER PORTION]

G.M.Dawson Delt.

The Desbarats Litho. & Publg. Compy Montreal. Lith.

SECTIONS TERTIARY LIGNITE FORMATION.

FORTY-NINTH PARALLEL.

BRITISH NORTH AMERICAN BOUNDARY COMMISSION

GEOLOGICAL REPORT OF PROGRESS FOR THE YEAR 1873.

[IN PART.]

REPORT

ON THE

TERTIARY LIGNITE FORMATION,

IN THE VICINITY OF THE FORTY-NINTH PARALLEL,

BY

GEORGE M. DAWSON, Assoc. R. S. M.

ADDRESSED TO

CAPT. D. R. CAMERON, R.A., H. M. Boundary Commissioner.

Montreal:

DAWSON BROTHERS, ST. JAMES STREET.

1874.

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PRINTED BY JOHN LOVELL, 23 ST. NICHOLAS STREET.
1874.

To CAPT. D. R. CAMERON, R.A.

H.M. N.A. Boundary Commissioner:—

SIR,—The geological work of the past summer embraced, *First*, an examination of the Lake of the Woods region, dealing chiefly with the Laurentian and Huronian formations: *Secondly*, an examination of the Cretaceous formations westward of Red River: *Thirdly*, a survey of the e Tertiary formation overlapping the last and extending as far as the terminus of the season's work on the line. As the lignites, &c., obtained from the Tertiary rocks required a more careful examination than most of the other specimens, and appeared to be of economic importance, I have prepared in the first instance the Report on that formation, which will properly constitute the third part of the general Report of Progress, and have the honour to forward the same herewith.

Your obedient servant,

GEORGE M. DAWSON.

Montreal, Feb. 10th, 1874.

BRITISH NORTH AMERICAN BOUNDARY COMMISSION.

REPORT

ON THE

TERTIARY LIGNITE FORMATION,

IN THE VICINITY OF THE

FORTY-NINTH PARALLEL,

By G. M. DAWSON,
Associate R. S. M., Geologist to the Commission.

CONTENTS:—

The exposures of these rocks in the vicinity of the 49th parallel, first appear in the valley of the Souris River at a point 250 miles W. of Red River, about four miles E. of the tributary from the south known as Short Creek; near the debouchure of which the remarkable collection of grotesquely shaped rocks, known collectively as the "Roche Percé" is situated. These beds may underlie the prairie country still further eastward, as no sections are to be found for a long distance. The banks of the river valley, however, undergo about this place a remarkable change, becoming gently sloping and grassed from top to bottom, and it seems to me probable that this change coincides with the eastern edge of the Tertiary basin.

Sections are to be seen at frequent intervals on the banks of the river valley, from the point indicated, westward to the position occupied in the summer of 1873 by Wood End Depot Camp, a distance of about twelve miles by the line and considerably more by the river.

Details of Sections on the West Souris River.

Section 1.—(Six miles north from Wood End Depot on the bend of the river.)

1.	Fallen bank, no section, about	8′	
2.	Finely stratified greyish sandy clay	7′	
3.	Lignite		7″
4.	Sandy clay, greyish laminated, including two "leaf beds," each a few inches thick	7′	7″
5.	Yellowish fine sandy clay passing below to grey soft sandstone	11′	5″
6.	Ironstone, a nodular layer		3″
7.	Grey clay	1′	
8.	Whitish clay	1′	
9.	Carbonaceous shale	3′	3″
10.	Grey clay	3′	6″
11.	Ironstone		2″
		43′	7″

The beds appear to be perfectly horizontal. Those of sand and sandy clay, though having the appearance of well characterized layers at a little distance, and giving the banks an almost ribboned aspect, are found, on closer examination, to pass almost imperceptibly into each other. This peculiarity is often to be observed, in almost all localities where these rocks are found. The so-called "leaf beds" are of a greyish purple tint, and contain many impressions of flag-like parallel-veined leaves, which, though distinct enough when freshly taken from the bank, it is impossible to preserve on account of the crumbling nature of the matrix. The ironstone, though generally forming extensive sheets, is nodular in structure, and varies a good deal in thickness. It weathers a bright brownish-red, is hard, compact and very heavy, and on fresh fracture is bluish to yellowish-grey.

A short distance S. of this locality the bank shows the following section very perfectly:—[Plate I, Sec. 2.]

Section 2.—

	Prairie sod.		
1.	Mixed shale and drift	7′	
2.	Lignite	6′	6″
3.	Greyish sandy shale (about)	4′	
4.	Lignite	1′	6″
5.	Greyish and yellowish well-stratified fine sandy and shaly clays	14′	
6.	Ironstone (nodular)		4″
7.	Greyish and whitish clay	2′	
8.	Carbonaceous shale	1′	
9.	Grey soft sandstone	1′	8″
10.	Lignite	1′	
11.	Grey and yellowish laminated sandy clay	5′	
12.	Ironstone (nodular)		3″
13.	Lignite	1′	7″
14.	Carbonaceous shale	1′	6″
15.	Lignite	2′	2″

16. Grey sandy clay	2′	
17. Lignite	1′	5″
18. Sandy underclay with large and small roots badly preserved.	1′	6″
19. Lignite	3′	2″
20. Greyish sandy clay		
	57′	7″

The lower lignite beds are of excellent quality, firm and compact, and in some a c es shew spots of fossil resin. The structure of the component wood is also in many instances very plainly apparent. The upper lignite lying immediately below the surface, is soft and decomposed where exposed, being in many places penetrated by roots from above. It might, however, prove equally compact with the lower beds where undisturbed. Layer 18 is almost the only case observed in which lignite is seen to lie upon a pretty evident underclay with roots. The ironstones are specially good and compact in this section. Owing to the wearing away of the softer strata a large quantity of this material strews the surface of the hillside.

This section does not seem to correspond at all with the last, though situated only a few hundred yards from it: and if no fault or break in the strata intervenes (and there is no appearance of any such), the horizontal uncertainty of the deposit must be very great.

Fragments of a material resembling scoriaceous lava and vesicular in structure are very plentiful in this locality, as elsewhere in the region of country occupied by these lignite strata. On examination, however, it is seen that this is really a sort of clinker produced by the combustion of parts of the lignite beds *in situ*, and the consequent fusion of their proper ash and portions of the surrounding shales. Such fires may either be caused by the ignition of the beds by prairie fires, and fires of Indians' or traders' camps, or by the spontaneous combustion of the lignite where undergoing decomposition at the out-crop. The latter, however, seems improbable, as iron pyrites, the usual cause of such spontaneous combustion, is almost entirely absent from the lignites which I have examined chemically. [Plate II, Fig. 1.]

In one place the top of the bank shews an amphitheatrical depression a few feet below the general prairie level. In front of this the bank was strewn with many and large fragments of lignite clinker, and it was apparent that the upper lignite bed (already mentioned as being almost at the surface,) had been over this area entirely consumed. Fires similar to these have been mentioned as existing in coal and lignite beds in the western part of America, from near the Arctic Sea to the frontier of Mexico, by McKenzie, Richardson, Johnston, Lewis and Clark, Hayden and other travellers, and appear to have been common in the Tertiary and Cretaceou strata alo ı ; n › eastern flank of the Rocky Moun .

Nearly three miles south of the last mentioned locality, another very good section is exhibited on the right-hand side of the valley, and where the Souris, in one of its many devious windings, has undermined the foot of the bank. This section is specially interesting, as affording one of the best localities for the collection of the shells of Mollusca characteristic of the formation. The section is as below, measurements being estimated :

Section 3.—

Sand and sandy clay, stratified, and yellowish in general colour	40′
Lenticular mass of poor clay ironstone, running out rapidly in both directions	2′ 6″
Grey sand	2′
Shell bed	1′ 6″
Lignite	2′ 6″
Sand and clay	10′
	58′ 6″

The shell bed is of hard grey sandy clay, and in some places is very full of shells, which are also less crushed and in a better state of preservation than is usual in this formation. A species of *Melania* is the predominent mollusc. A second species of the same genus also occurs, with fragments of a *Paludina* and *Unio*, and a *Corbula*, closely resembling if not identical with *Corbula* (*Potamomya*) *mactriformis*, M. and H., which must be considered a brackish-water type, and occurs in the lignite formation of the Missouri.

In the water of the stream at this place are several large spheroidal sandstone concretions which have a tendency to split into layers parallel to their flattened surfaces—one of them measuring four or five feet in diameter. These do not appear in the bank, but possibly may have been washed out of the lower part of the section which was not so clearly shown.

South of the last section, and about one mile nearly due north of the position occupied by Wood End Depot, an exposure, showing the most valuable lignite bed I have seen in the Souris Valley, is situated. The beds are arranged thus :—[Plate I, Sec. 4.]

Section 4.—

1.	Drift material about	8′
2.	Yellowish and grey stratified sandy clays, obscured in most places by slips of the bank	52′
3.	Lignite	7′ 3″
4.	Grey soft unctuous sandy clay	1′ or more.

The bottom of the lignite is about twenty-five feet above the level of the river below, and this part of the section, though apparently consisting of yellowish sandy clays like those overlying it, is obscure. The lignite is continuously visible for at least two hundred feet along the face of the bank, and seems to preserve uniformity of character and thickness. Externally it is

often crumbling, and mixed with clay which has penetrated its joints from above; but where freshly exposed, it is hard and compact. It is quite black on freshly fractured surfaces, but has a brown streak, and in many places the structure of the original wood is still quite discernible. Some surfaces are strewn with fragments of mineral charcoal like that found in some true coals. Other specimens are apparently structureless, and resemble cannel coal in appearance though not in composition. The upper beds of sandy clay yield a few poorly preserved shells.

On the opposite side of the river valley, near this place, the upper part of the bank shows a good section of sandy clay, below which, and some fifteen or twenty feet below the prairie level, is a seam of lignite of good quality and four feet in thickness. This lignite bed would seem to occupy a position stratigraphically superior to the last.

Section 5.—Somewhat further up the stream, and on the same side of the valley about sixty feet below the prairie level, and sixteen feet above the river, a bed of lignite occurs of which the upper three feet only are visible. The bank above it is not well exposed, but appears to consist of sandy clays. The lignite is of good quality but much weathered at the out-crop. From this place lignite was obtained and taken to the smithy while the Depot was established at Wood End. It was, however, found difficult to obtain a welding heat with it, which may have been due, at least in part, to the damp condition in which the lignite was used. The same difficulty has, however, been found almost fatal to the use of similar fuel for smithy purposes, further south, and in the line of the Union Pacific Railway, (Hodge's Report). This seam may very probably represent the continuation of that included in Section 4.

The whole of these deposits, though in some places showing a dip amounting to a few degrees in one direction or other, appear to have no determinate direction of inclination, but to be over large areas as nearly as possible horizontal.

Section 6.---Sections more or less perfect are exhibited in many places in the Souris Valley, a mile or two west of the entrance into it, from the south, of Short Creek, and more especially on the north side of the valley. They show a great similarity, though not absolutely the same in any two places. One of the most perfect exposures seen was the face of a bank from sixty to seventy feet high, and consisted of sand, sandy clays, and hard fine clays, very regularly and perfectly stratified, and coloured in various shades of yellow-grey, grey and light drab. At two different levels harder sandstone layers of small thickness were seen, and also three distinct beds of lignite. The lowest is a hard compact lignite resembling cannel coal in aspect, and two feet three inches thick. A few feet above this a second seam,

eighteen inches thick, occurs, and still higher in the series, and about half-way up the bank, a third, of the same thickness. At the top of the bank some large nearly spherical sandstone nodules rest, and have evidently been derived from a superior bed which has been removed by denudation. The clays and sandy clays at several different levels include remains of molluscs, but these are very fragmentary, having been crushed by the compression of the containing material. A unio-like bivalve preponderates, and gasteropods are comparatively rare.

On the opposite side of the Souris Valley, which is here of considerable width, and not far from the last mentioned section, soft sandstone beds, capped by a harder layer also of sandstone, weather into table-like forms. These beds are doubtless the representatives of those which, a few miles eastward, produce the Roche Percé. Short Creek, already mentioned as an affluent from the south, shows many sections of the lignite strata. The banks of the stream have assumed the most picturesque forms from successive landslips, and are often quite red in colour from the alteration of the clays by the burning of lignites.

One of the most perfect sections is on the left bank, near the crossing place of the waggon trail, and extends from nearly the level of the prairie almost to the water of the stream. [Plate II, Sec. 7.]

Section 7.—

1. Soil	1′	6″
2. Yellowish coherent sand, grey externally, and holding some much broken *Unio*-like shells at its base	12′	6″
3. Grey clay	2′	10″
4. Yellowish and greyish thin bedded sands and sandy clays, with several very thin ironstone layers, weathering orange-red externally	6′	
5. Grey clay	2′	4″
6. Similar to No. 4., with decayed fragments of gasteropodous shells	12′	
7. Also similar to No. 4, but with a great number of thin ironstone sheets	3′	
8. Hard yellowish sandy clay, a few inches at the top carbonaceous	10′	
9. Good hard lignite	2′	2″
10. Hard yellowish sandy clay	2′	7″
11. Good lignite	4′	9″
12. Greyish sand and sandy clay, showing lines of stratification. In some places soft and incoherent, in others with large concretions, and sometimes forming a nearly solid sandstone	9′	
13. Hard grey clay	2′	
14. Greyish yellow clay with many thin layers of orange-weathering ironstone	3′	
15. Lignite	2′	6″
16. Greyish and yellowish hard sand and sandy clay	11′	
Section concealed by slope of detritus, about	12′	
	99′	2″

Small spherical ferruginous nodules, resembling bullets, occur in considerable numbers at the foot of the bank. They have a calcareous cement, and are derived from one or other of the sandy layers. This exposure is remarkable for the very gentle graduation of one bed into the next, making it almost impossible to draw lines between them in a measured section.

On the south side of the Souris Valley, and a short distance to the east of the valley of Short Creek, the Roche Percé group of rocks is situated. This locality has already been described by Hector and Palliser, who made a branch expedition to it from the North, in August, 1857, being induced to do so by the reports of Indians and Half-Breeds. (Palliser Expl. N. America, pp. 49 and 225.) Dr. Hector did not obtain any fossils from the rocks of this neighbourhood but sedge-like leaves, and doubtfully connects them with the Missouri Lignite basin or transition beds between this and the Cretaceous. The former supposition may now, I think, be considered as fully confirmed by their resemblance to and connection with undoubted Lignite Tertiary rocks of the regions further west, and also by the nature of the molluscous forms of associated beds. The rocks themselves, which have long been objects of superstition to the Indians inhabiting the surrounding country, owe their curious forms to the weathering away of a soft grey sandstone from below a bed of similar rock which weathers yellow, and is rendered durable by an abundant calcareous cement. Both the upper and lower sandstones show false bedded structure in great perfection, though that in the upper hard portion is on a smaller scale, owing to the thinner divisional planes of the rock.

The capping-sandstone is not hardened in a perfectly uniform manner, but in belts several yards in width, lying parallel in a N.W. and S.E. direction, and separated by spaces more easy of disintegration. There is also a system of cross-jointing nearly at right angles.

This combination of structures has given rise, under the long continued action of the weather, to the remarkably castellated, fantastic and picturesque rock scenery of this part of the Souris Valley. The hard belts form tongues projecting diagonally from the grass covered bank, and the erosion of the underlying soft sandstone, parallel to the cross-joints, has in several places produced window-like openings through them. The soft rock bears in many places rude Indian carvings representing various animals and birds, strings of beads, &c.

The north side of the river valley, for some way up and down, is fringed with weathered sandstone rocks, similar to, though not so striking as the Roche Percé. The whole formation would seem to have a slight dip

toward the south, and in this case the section in Short Creek, previously given, would overlie the Roche Percé sandstones.

The Souris Valley, for about four miles E. of this place, continues to show numerous sections of the usual clays and sands, and hardened sandstone beds,—the latter in one place nearly three miles east from Roche Percé forming a group almost equally picturesque with it. Rather hard sands and sandy clays are seen in several places to underlie the sandstone beds, and one of these was found to be filled with well-preserved specimens of a peculiar *Paludina*. About a mile farther east the valley changes its character considerably; the banks formerly scarped and clayey are replaced by regular grassy slopes, and, though followed for a distance of ten or fifteen miles beyond this point, yielded no further sections. This change I am at present disposed, in the absence of more certain data, to consider as indicating the passage from the Lower Tertiary beds to the Cretaceous. The eastern edge of the out-crop of the harder beds connected with the Roche Percé also appears to be indicated by a slight, though pretty well defined step in the level of the prairie, which may be considered as the first gentle rise of the Missouri Coteau, and runs about S.E. to the boundary line, which it crosses near the 240 mile point. The spring known among the Half-breeds as St. Peter's Spring lies at the foot of this step not far north of the line, and is probably connected with the junction of the more permeable sandstone beds with the underlying impervious clays. It is possible that lignite coals of importance may exist on a lower horizon than this, and in beds showing a more decided approximation to marine deposition and cretaceous forms of life, in which case their out-crop would occur still further to the east. It is not, however, very probable that this is the case, as the investigations of Hayden and others south of the line seem to show that in the eastern region the deposition of lignite did not commence till the conditions of the Cretaceous formation had distinctly passed away.

Sections on Missouri Coteau, west of 263 Mile Point

Westward from the 263 mile point, no sections of either Cretaceous or Tertiary rocks, so far as I have been able to examine, occur in the vicinity of the boundary line for nearly 80 miles. The valley of the Souris, when followed in this direction, rapidly becomes more open and shallower. Scarped banks are rare, and such as do occur seem only to exhibit a great thickness of drift material. It would seem that the absence of the harder beds associated with the strata already described had allowed the erosion of the beds to a great depth. The country also rises somewhat rapidly, and it is not till after having passed through the drift-hills

of the Coteau, and at a height of about 700 feet above that of the former sections, that the underlying rocks in the form of the Lignite Tertiary series are again exposed. Here, however, in a large valley crossing the line at the 345 mile point, which is the most eastern great channel of erosion that crosses the 49th parallel towards the Missouri river, the rocks of this formation are exposed on a grand scale. The lowest beds seen in this valley are curiously banded clays and shales, clay beds charged with plant remains and carbonaceous matter, and having quite a purple tint when viewed from a little distance, alternating with clays, nearly white, and yellowish sandstones. Above these comes in a sandstone layer which, though of no great thickness, has in several places produced curious conical mounds by forming a protecting capping for the softer strata below, these again forming slopes or nearly perpendicular steps according to their relative hardness, which, taken together with the remarkable and distinctive colouring of the beds, gives a very striking and peculiar aspect to the scenery. Above the sandstone capping of this lower part of the section, is a great deposit of sandy clays and concretionary sandstones among which three beds of lignite of various thicknesses are intercalated. The beds are almost horizontal, but undulate at low angles, and the valley of the stream appears to occupy, in the main, the centre of a shallow synclinal fold.

The upper part of the section in this valley consists of at least 100 and probably 150 feet of clays and argillaceous fine sands of greyish and yellowish-grey colours, and well stratified. They contain thin leaf-beds at several different levels, which are prominent from their grey-purple colour, but, though containing very many dicotyledonous and flag-like leaves, they do not yield recognisable specimens, from their soft and crumbling nature. This part of the section also includes at least three lignite beds. The highest of these is about 140 feet above the base of the section, and 3 feet or more in thickness. It would appear to be of fair quality, though much decomposed and quite crumbling at the out-crop, from the action of the weather.

The next is about 120 feet above the same datum, and can be traced a very considerable distance along the face of the bank; it is five feet in thickness, but includes, at the place examined, several thin layers of carbonaceous shale; and, though of good quality in places, not appearing to have the same uniformity in the various layers that is generally found in the coals of this region.

The lowest lignite is some seventy-five feet above the base of the section and is only a few inches in thickness.

By diligent search certain parts of this upper portion of the section may be found which contain quite numerous, though in general very badly preserved remains of molluscs, which appear to be such as would indicate the deposition of the beds in purely fresh water. A peculiar angular *Paludina* and a *Melania*, apparently specifically identical with that already noticed as occurring in the Souris Valley sections, are the most common.

Section 8.—The complete section may be thus represented.

1.	Upper part, yellowish sands and clays, lignites, &c	150′	
2.	Hard grey and yellowish, somewhat false-bedded sandstone, forming a "capping rock" to beds below (about)	3′	
3.	Greenish yellow, finely bedded fine sand	15′	
4.	Soft yellowish sandy clay	2′	4″
5.	Greyish and yellowish hard-bedded clay	2′	6″
6.	Blackish thin-bedded clay or shale with plant remains	5′	
7.	Greyish thin-bedded clay, becoming darker toward the top (plant remains) graduating into next bed	10′	
8.	Hard, pale brown, compact clay, with very few plant remains.	1′	4″
9.	Hard whitish clay with some plant remains, and a scattered layer of heavy ironstone balls about a foot from the top	9′	
10.	Thin-bedded greyish and blackish hard clays, with leaves, and some small bunches of selenite crystals	7′	
11.	Fine bedded clay filled with leaves and plant remains, hard and rusty in the upper portion	1′	8″
12.	Grey hard sand with charcoal-like fragments in some places.	3′	
13.	Ironstone with many plant remains, mostly sedge-like blades.		3″
14.	Soft grey clay		
		200′	1″

The lower part of the section forms a group well distinguished by its colour and the perfection of its stratification from the upper, and often endures, protected by its hard sandstone (No. 2) when the more crumbling upper division has been removed. The plant remains, though occurring more or less throughout the whole section, are best preserved in the lower purplish layers. They consist chiefly of leaves of dicotyledonous trees which appear to have fallen when mature, in the course of nature, and with the change of the seasons, and floated without violence to the great lake in the fine shelly deposits of which they have been preserved. Leaves and small branches of coniferous trees are also common. They belong chiefly to the genus *Taxites*, and one variety seems to be specifically identical with that subsequently to be mentioned as occurring in the Porcupine Creek section. Sedge and flag-like leaves and stems are also abundant. The leaves of deciduous trees appear to resemble more closely those figured by Lesquereux for the Fort Union region than they do those obtained from Porcupine Creek, and are probably older than the latter, having in some cases almost a Cretaceous facies.

Many of the crumbling hill-tops in this valley have a brick-red colour resembling that seen in parts of the Souris Valley, and due, as there, to the combustion *in situ* of the deposits of lignite. The slag or clinker produced in the same way is also to be found here, though it was not observed actually in place.

Section. 9.—A section on the west side of the valley, and almost exactly where the 49th parallel crosses it, shows in a bank about thirty feet high, toward the base, several layers of concretionary ironstone, each of a few inches in thickness. The top of the bank, (which is merely an outlying projection from the base of the high and steep slope bounding the valley) holds a seam of lignite four feet thick, with, however, a few shaly partings. This bed would have passed unnoticed, but for the fact that the little marmots had been burrowing into the crumbling bank, throwing out heaps of black material at the mouth of their holes.

The next stream crosses the line at the 351 mile point; it also flows through a deep valley of erosion, and may be called Pyramid Creek, from a remarkable pyramidal hill formed of the usual clays and sands, capped by a portion of a layer of hard grey sandstone, the cement of which is calcareous. It has a tendency to break into large quadrangular masses along intersecting jointage planes, and shows conspicuous false-bedded structure. Below this is a thickness of about fifty feet of rather incoherent fine yellowish sand sometimes rather argillaceous. This, producing a sloping bank, is not very well exposed, but constitutes about one-third of the thickness of the beds exposed in this valley. The middle third consists of soft crumbling sandstone or compact sand without any apparent cementing matter, and of which the constituent particles are rather coarse, contrasting strikingly in this respect with the overlying material. It shows evidence of having been deposited by water in rather rapid motion, through its entire thickness; but the false bedding is very definitely cut off at many different horizons by perfectly horizontal planes, above which it again commences. The weather acting on these beds causes the hill sides composed of them to assume a well-marked terraced appearance on a small scale, each horizontal break producing a terrace level. The sandstone contains here and there a few badly-preserved shells, among which can be recognized two species of *Mania*, fragments of *Paludina* and of *Unio*. In one place a layer of ironstone, about three inches thick, is seen to run for some distance. The most noticeable feature, however, of this part of the section is the remarkable concretionary character of some layers of the sandstone The concretions are hard, and of all shapes and sizes. Some are spherical, many are flattened spheres, and two or more of them are often confluent

forming dumb-bell like masses or more or less continuous sheets of a lumpy character. Many are long and root-like, and project curiously from the bank. The sandstone is so soft in some places that the sand-martens have been able to make their nests in it; and where these have been abandoned, the wind forming an eddy, and carrying with it loose sandy particles, has enlarged them into cavities resembling in shape the pot-holes found in rocks below rapids and waterfalls.

The lower third of the section in this valley is, as seems often to be the case with the lower layers of these rocks, much more clearly defined, and divided into thinner beds in which dark colours predominate. Altogether the section here much resembles that seen in the last great valley; the lower beds of this probably correspond with the purplish leaf-beds there, and the great thickness of sands and sandstones above correspond in a general way; though in this place they differ in the absence, so far as could be ascertained, of beds of lignite. The layers of hardened sandstone must also in this case occupy different horizons in the two sections, but this is not to be wondered at, when the extremely local, and indeed often nodular character of the induration is considered, and the fact that it merely depends upon the introduction of a small proportion of calcareous cement among the particles already compacted by pressure.

Section 10.—The whole section in Pyramid Valley may be represented thus:

1.	Hard capping sandstone, (several feet,).....	
2.	Soft yellowish sandy beds forming a sloping bank, about...	50′
3.	Soft sandstone, grey, false-bedded, about.....	50′
4.	Stratified sandy clay.....	3′
5.	Purplish plant-beds with thin layers of lignite and much selenite in thin sheets, isolated crystals and stellar groups.....	3′
6.	Lignite, with many spots of amber.....	1′ 6″
7.	Purplish bed with a few plants.....	2′
8.	Grey slightly coherent sand, with nodules of arenaceous selenite crystals.....	4′
9.	Purplish bed with obscure remains of leaves.....	1′
10.	Incoherent arenaceous clay and sand.....	7′
11.	Purplish-grey arenaceous clay, with obscure plant remains and some fossil wood.....	3′
12.	Brownish clay with ferruginous layers.....	6′
13.	Lignite.....	1′
14.	Brown earthy bed.....	6″
15.	Grey somewhat coherent coarse sand, with argillaceous matter.....	12′
	About.....	144′

The rocks show no well marked dip, but appear to undulate slightly at very low angles.

The occurrence of gypsum as selenite is nearly always in association with plant-beds, and generally with those holding many half-obliterated vege table remains and of a purplish shade.

A few miles west of Pyramid Creek several hills are capped with heavy and hard sandstone beds, a feature quite exceptional in a country so gently undulating. These do not appear to be quite horizontal, but have a gentle dip to the west. They may be equivalent to the capping sandstone of the Pyramid Hill, but more probably are yet higher in the series.

Ten miles west of Pyramid Valley, in the upper part of the valley of another stream, yellowish and grey stratified sandy clays are again seen, but are not perfectly exposed. At one place a layer of hard ripple-marked sandstone is exposed, the ripple-marks being about an inch and a half wide and very perfect, and indicating a current North-west Magnetic.

With the exception of this exposure, the underlying rocks are nowhere clearly visible in the vicinity of the line from Pyramid Valley to Porcupine Creek, a distance of about 35 miles; one very considerable stream is crossed about midway, but its valley is very wide and with gently sloping banks. Highlands appear to the north, and may possibly show sections of strata overlying those seen in the banks of the streams, but I was unable to reach them, as both in going and returning, the ground, especially in the vicinity of these highlands, was covered with snow, which rendered travel. ling very slow and toilsome.

Beds exposed in Porcupine Creek and tributary valleys, from the 385 *Mile Point to about the* 391 *Mile Point*

Many partial sections occur in this vicinity. Lignite is seen in three places near the line, and just above the level of the brook in each instance. The exposures seem to belong to the same bed, and if so, nearly a mile of its horizontal extent can be traced.

The lignite and associated beds undulate slightly in all the sections; the lignite decreasing from four feet in thickness in the most northern bank to one foot in that furthest south. The overlying rocks consist of yellowish and grey sands and clays, well stratified and much resembling those forming the upper part of the section in the 345 mile valley. (Pl. II.)

The best exhibition of these strata was obtained in a bank about forty feet in height on removing the decomposed material from the surface.

Section 11.—

1.	Soil.	
2.	Siliceous pebble drift	Several feet.
3.	Soft greenish sandy clay	2′ or more
4.	Soft blackish clay	1′ 6″

5.	Rusty crumbling sandy clay		6″
6.	Grey clay with some plant remains	9′	
7.	Grey clay with well preserved dicotyledonous leaves	1′	8″
8.	Impure ironstone in concretions		3″
9.	Yellowish sand and sandy clay with obscure plant remains	9′	
10.	Greyish and yellowish fine sandy clay	1′	3′
11.	Scattered layer of small ironstone balls		
12.	Grey fine sandy clay	1′	
13.	Rusty layer with crumbling plants		3″
14.	Grey sand		4″
15.	Detached masses of lignite shewing the form of flattened tree trunks, about		4″
16.	Yellowish grey fine sand		6″
17.	Grey clay with plant remains		4″
18.	Lignite, not of best quality. The grain and form of component wood generally clearly perceptible. Bed undulating slightly	3′ to 4′	
19.	Soft grey arenaceous clay	1′ to 2′	
	About	31′	

The vegetable remains imbedded in the rocks overlying the lignite are mostly those of deciduous trees, and in certain beds are very perfectly preserved. Lignite from this section was used for camp fires, in the absence of wood, but did not burn very freely, as it was taken damp from the bed and piled on the ground without any provision for draught from below. The most interesting and important section, however, in this region, is that which occurs in a valley joining that of Porcupine Creek from the west, which exhibits a bed of lignite eighteen feet in thickness, and has also yielded some of the most perfect and curious remains of plants. The bank in which this out-crop is situated is over half-a-mile south of the line. The beds are arranged thus: (Plate I, Sect. 12.)

Section 12.—

1.	Surface soil	1′	
2.	Siliceous pebble drift	1′	6″
3.	Yellowish and grey sandy clays well stratified, but somewhat soft, about	9′	
4.	Lignite		9″
5.	Banded clays, yellowish, grey and purple, with well preserved remains of plants and in some layers much crystalline gypsum	5′	
6.	Lignite, weathering soft, some layers laminated, others rotten and brownish. Forms a steep slope	10′	
7.	Lignite, hard compact, horizontally laminated, but also breaking into large cubical blocks along vertical planes	8′	
8.	Soft grey sandstone much jointed, and breaking out in pieces bounded by plane faces, some vertical and some oblique. Holds root-like remains and gives issue to springs of water	5′	
		40′	3″

Though undulating a little, the strata have no true dips, and are as nearly as possible horizontal on the large side.

The lower part of the lignite bed is very compact and tough under the pick; it holds in some layers many drops of amber. The jointage planes form a conspicuous feature, and were not noticed in anything like the same perfection in any other lignite beds examined. The divisional planes cause the coal to break off in large cubical pieces which encumber the stream at its base. Some of them shew thin seams of white gypsum, and in one case a thin film of iron pyrites was detected, being the first appearance of this mineral in connection with these lignite deposits.

The plants in layer (5) are in a beautiful state of preservation, and, when the clay is first split open, show every vein-mark in perfection, not only in the larger and coarser leaves but in delicate ferns which are here unusually common. The matrix is, however, unfortunately very soft; it crumbles easily, and tends to crack on drying.

This section also exhibits the first and only distinct instance of dislocation which has been observed to affect these beds. The eighteen foot lignite and associated strata are seen to have been brought to their present position by a downthrow fault, and on the other side of the Creek their place is taken by underlying sandy clays. (Plate I.)

The southern side of the valley, opposite this great lignite bed, is broken down and forms a gentle though irregular slope, which is encumbered by many large, strangely shaped and coloured blocks of stone, much harder than any rocks occurring in the neighbourhood, and in pieces larger than the drift-blocks found in the region. They proved on inspection to consist of masses of beds such as those associated with the lignite, but indurated by its combustion, which has also caused the interruption in the edge of the valley. About a fourth of mile east on the same valley the great lignite is again exposed, and apparently in much the same development and association.

A considerable number of specimens of fossil plants from the vicinity of Porcupine Creek have been preserved, though all in a more or less shattered condition. I am indebted to Principal Dawson for a preliminary examination of these. The following genera are represented by clearly recognisable specimens: Onoclea, Sphenopteris, Phragmites, Trapa ? Thuja, Sequoia, Glyptostrobus, Populus, Salix, Fagus, Alnus, Platanus, Rubus ? Hedera ? As far as can be ascertained these generic forms and some of the species are identical with those characteristic of the Tertiary beds of the Western States, which have been catalogued and described by Lesquereux and Newberry. The fern *Onoclea sensibilis* is especially

abundant. It is a species still living, and recognized by Newberry in the Tertiary of Nebraska, and by the Duke of Argyll in that of the Island of Mull. The Thuja, also common, is identified by Newberry with his *Th. articulata*. It will be well to leave the specific determination of these leaves until the appearance of the volume now in the press on the plants of the U.S. Tertiary by Dr. Newberry. In the meantime they may be stated to correspond very closely with the plants described as occurring in connection with the Lignite Tertiary, called by Hayden, in its southern extension, the Fort Union group.

General Remarks on the Lignite Formation.

It would seem premature at the present time to enter very fully into the discussion of the general relations and limits of the lignite-bearing series of rocks, as another season will probably afford much additional information of value in this direction.

The formation is, however, undoubtedly an extension of the Great Lignite or Fort Union group of strata of Hayden, which, as developed in the Western States and Territories, has been fully described by him in his various reports (Annual Reports Geol., Surv. Territ., 1868 to '72). These strata, immediately succeeding the Cretaceous rocks, are the lowest American representatives of the Tertiary series, and have been called for this reason Eocene, though it is impossible to affirm that their deposit was more than approximately synchronous with that of the Eocene as constituted in Europe. The flora of the Fort Union group indeed, according to Newberry and Lesquereux, who have examined the collections of the various western expeditions, has, when compared with European forms, a Miocene aspect, and the animal remains, which are chiefly those of fresh-water molluscs, do not form a very trustworthy criterion in regard to age. The advent of the Tertiary period in the western basin of America appears to have been contemporaneous with the change of the inland sea from salt-water to fresh-water conditions.

The change in character of the Fauna is thus, taken broadly, a good mark by which to distinguish rocks of Cretaceous and Tertiary age, though it would appear exceedingly probable that the Cretaceous forms were brought to a rather abrupt end by the change in physical conditions, so far as regards the area in question. It will suffice then at present to correlate these beds with those of Hayden's Lowest Tertiary or Fort Union group, which is largely developed southward in Dakota and Montana, and to which also the smaller isolated lignite basins, now beginning to be

largely worked in the neighbourhood of the Union Pacific R.R. in Wyoming, &c., are believed to appertain, though it is probable that a part of these may ultimately be attached to the Upper Cretaceous with which the lower beds show a marked stratigraphical and zoological connection. The sections in the vicinity of the Roche Percé seem to belong to the lowest part of this formation which is exposed in the vicinity of the line, and contain the only mollusc found which is known to live in salt or brackish waters, the *Corbula* already mentioned. Hayden's sections, however, show that southward, over large areas, the Lowest Tertiary beds are characterized by abundant remains of Ostrea associated with lignites—a circumstance which would indicate still more markedly marine conditions, and which would appear to lead to the conclusion that there may be a small portion of the formation still lower than the Roche Percé series which has been so soft as to yield to eroding forces and become concealed beneath the drift formations. The beds in the Souris Valley and near the Roche Percé are in great measure arenaceous, and many of them appear to indicate rather disturbed water, both from this fact and the frequency with which some of the molluscs have sustained fractures of their shells during life. Nothing, however, in the nature of a conglomerate is found, and even the sandstones can rarely be considered coarse. The beds here are also not of great thickness individually, and succeed each other rapidly, as will be seen by the sections. In this they resemble the lowest part of the sections seen further west in the 345 Mile Valley and Pyramid Creek, though, from the great distance entirely concealed by drift deposits between Roche Percé rocks and these exposures, it is impossible to identify any particular bed or series of beds. Indeed from the estuarine character of the formation, as a whole, and the rapidity with which individual strata are seen to change when followed for short distances, no such close parallelism is to be expected. The sections exhibited in 345 Mile Valley and in Pyramid Creek, 6 miles apart, show, however, a very close general resemblance, each being composed at the base of purplish and whitish sands and sandy clays, passing upward into beds of almost pure and but slightly coherent sand, and the highest beds seen being formed of yellowish soft arenaceous clays without much evident stratification. The furthest west exposures seen, those in Porcupine Creek and neighbourhood, may belong to a still higher part of the series, though it is probable that no very great thickness of beds is represented by the sections over the entire area examined. The rocks in many places seem to be absolutely horizontal, but very generally show slight dips in one direction or other, which, when followed a short distance, prove to become reversed and to arise merely from a gentle undulation of the beds.

A scarped bank rarely presents itself in the area covered by this formation without exhibiting one or more beds of lignite, and these vary in thickness from a few inches to eighteen feet. The entire number of beds thus seen was very great, but, in the absence of trustworthy data with regard to their equivalency, it would be misleading to enumerate them. The lignites seldom show intercalation of shale or sand, and, though some of them may have been formed from accumulations of drift-wood in shallow water it is difficult to understand how such collection could go on for long periods without the contemporaneous deposit of sandy or muddy matters which would have been suspended in waters moving with sufficient force to convey the wood. It would also appear difficult under this theory to explain the regular and even superposition of the sandy and clayey beds which overlie the lignites, and the fact that these do not send extensions downward into them, as they must have done if formed above a tangled mass of trunks and branches of trees. It seems likely, therefore, (though layers like true root-beds were only observed in one or two instances to underlie the lignit beds) that at least the majority of the lignite beds were produceed by the growth and partial decay of trees, and also perhaps of peaty matter from swamp mosses, in the positions which they now occupy. Their method of formation would, therefore, agree with that already proved for coals of the true Carboniferous formation. This is rendered more probable by the circumstance that lignite beds are sometimes immediately covered by beds holding leaves of trees, ferns, and grasses, a fact which has been noted by Hayden and others with regard to the lignite beds further south, and which is also found to obtain with coal beds of the Carboniferous period.

Composition and Practical Value of the Lignites and Ironstones.

The coaly material of the beds above described is, for the most part, true lignite,as distinguished from brown coal, being composed of flattened and carbonized tree-trunks. The fossil woods associated with the plants, and which can be recognized in the mass of the lignites themselves, are all Coniferous, and may, from their structure, have belonged to the species of Thuja and Sequoia represented by the leaves found in the accompanying clays. I have made some assays of the lignites, for the purpose of ascertaining as far as possible their economic value, and in doing so have not thought it necessary to confine my examination to those beds only which are of workable thickness, as a general comparison of the various seams, thick or thin, is of more value in giving an idea of the average quality of the lignites of the formation now known and those which further

exploration may bring to light over the same region. The analyses, therefore, include a selection from the various sections, and several beds of good quality and thickness are unrepresented.

The lignites all contain, when in the bed, a very considerable percentage of hygroscopic water, and even those which are very hard and tough under the pick at first, when exposed to the air tend from the loss of water to crack into angular fragments or split up along the layers of deposition. The same phenomenon has been observed with similar lignites mined on the Union Pacific R.R., and it is found necessary to prevent loss from this slacking to convey them to their destination as soon as practicable after their extraction from the mine. The lignites generally present a rather unpromising appearance in the banks where they crop out, from the fact of their having undergone superficially a certain amount of fissuring and the interstices being filled with clay from above. When followed inward a few feet however, they usually become quite solid and compact. They vary a good deal in appearance, some beds having a dull lustre almost like that of cannel coal ; others, and this is perhaps the most common form, have the same black colour on faces of fracture, but tend rather to split parallel to planes of deposit andshow on careful examination distinct traces of the medullary rays and rings of growth of the component wood. Other samples have almost a shaly appearance, caused by numerous layers of mineral charcoal, which is present in small quantities in nearly all the beds. Amber spots are common but generally quite small. The lignites do not soil the fingers like ordinary bituminous coal. Their powder is generally a dark shade of brown but sometimes quite black.

They all yield easily a dark brown solution when treated with caustic potash. The lignites from various beds might be designated by such names as *pitch coal*, *brown coal*, *lamellar brown coal*, &c., but it seems better, as they pass by easy gradations from one variety to another, to class them under the generic term lignite.

In this connection it should be mentioned that though some authors have persistently used the term *coal* for the fuels of the Tertiary formations further south, the name is mineralogically inapplicable, from their composition, to all but one or two which appear to have been altered by local outbursts of igneous rock.

Though giving below the actual amount of hygroscopic and combined water as found by analysis, it must be premised that it depends entirely on the conditions to which the lignites have previously been subjected, and that, by prolonged exposure to dry air, it might have been in many cases very considerably reduced. I have, therefore, thought it advisable in

another place to reduce the results of all analyses to correspond to a certain percentage of moisture, that they may be better compared with each other and with foreign lignites. The high percentage of volatile combustible matters renders the difference due to slow and rapid coking in some cases very marked.

Souris Valley. Section 6. Lowest lignite, two feet three inches thick. Conchoidal fracture with rather dull surfaces and resembling cannel coal, ash reddish-white.

		By rapid coking.
Water	12.07	
Fixed carbon	45.44	38.90
Volatile matter	39.74	
Ash	2.75	
	100.00	

Souris Valley. Section 2. *Layer* 19. A weathered specimen separating into laminæ horizontally. Clay from overlying bed filling fissures. Ash yellow-brown.

		By rapid coking.
Water	13.94	
Fixed carbon	45.27	38.35
Volatile matter	35.00	
Ash	5.79	
	100.00	

Souris Valley. Section 2. *Layer* 17. Weathered specimen. Black, compact, with shining faces. Ash yellowish.

		By rapid coking.
Water	12.67	
Fixed carbon	31.39	28.01
Volatile matter	49.52	
Ash	6 42	
	100.00	

Souris Valley. Section 2. *Layer* 10. Lustre dull, separating along horizontal planes. Ash light yellowish.

		By rapid coking.
Water	14.90	
Fixed carbon	36.94	36.68
Volatile matter	42.98	
Ash	5.18	
	100.00	

Souris Valley. Section 2. *Layer* 2. A weathered specimen soft and crumbling. Ash greyish-white.

		By rapid coking.
Water	17.97	
Fixed carbon	32.86	30.10
Volatile matter	44.56	
Ash	4.61	
	100.00	

Souris Valley. Section 5. Black compact lignite with much woody structure apparent. Ash yellow.

		By rapid coking.
Water	14.73	
Fixed carbon	42.48	34.07
Volatile matter	39.99	
Ash	2.80	
	100.00	

Souris Valley. Section 4. 7 *foot seam.* Hard compact black lignite, breaking with pseudo-conchoidal fracture, and showing traces of structure of wood. Ash yellowish-white, light.

		By rapid coking.
Water	15.11	
Fixed carbon	47.57	41.67
Volatile matter	32.76	
Ash	4.56	
	100.00	

Section 8 *Lowest Lignite.* Weathered specimen, crumbling. Ash grey.

		By rapid coking.
Water	18.74	
Fixed carbon	35.69	30.04
Volatile matter	40.54	
Ash	5.03	
	100.00	

Section 8. *Middle Lignite.* Weathered specimen. Soft, breaking into layers along deposition surfaces. Largely composed of comminuted charcoal-like fragments.

		By rapid coking.
Water	16.28	
Fixed carbon	46.25	29.18
Volatile matter	33.19	
Ash	4.28	

Section 8. *Upper Lignite.* Out-crop specimen. Crumbling. Tends to break into layers parallel to deposition planes.

		By rapid coking.
Water	15.20	
Fixed carbon	34.45	27.61
Volatile matter	44.43	
Ash	5.92	
	100.00	

Section 9. Out-crop specimen. Brownish. Fracture almost conchoidal. Ash yellowish-white.

		By rapid coking.
Water	15.51	
Fixed carbon	37.12	28.44
Volatile matter	42.65	
Ash	4.72	
	100.00	

Section 12. *Lower part of* 18 *foot seam.* Tough, compact lignite, separating into horizontal layers. Much amber in small spots, a good deal of woody structure apparent and some mineral charcoal. Ash light-grey.

		By rapid coking.
Water	12.05	
Fixed carbon	46.18	41.03
Volatile matter	35.12	
Ash	6.65	
	100.00	

Section 12. *Upper part of* 18 *foot seam.* Out-crop specimen, crumbling. Ash white.

		By rapid coking.
Water	16.87	
Fixed carbon	34.32	24.30
Volatile matter	37.51	
Ash	11.30	
	100.00	

The lignites, it will be observed, are on the whole uniform in composition and contain an average amount of over 40 per cent. fixed carbon, when the water content is estimated at 12 per cent. They thus fall somewhat behind the lignites given in Table II, from Wyoming, Utah, &c., and which are found in proximity to the Rocky Mountains and parallel ranges, and have probably been somewhat improved by metamorphism simultaneous with their elevation. The lignites here described, however, gain some advantage in a practical point of view from occurring in a horizontal position and out-cropping in the sides of valleys in such a way that they might be worked by simple adits, avoiding the expense and trouble necessary when vertical sinking has to be resorted to in the first instance, as in the case of some of the other localities named, where the beds are often highly inclined or nearly vertical.

It is a disadvantage, however, that none of those yet found yield a coherent coke, as is the case with one or two of those of nearly the same age in the United States.

The lignites examined merely shrink somewhat in size during the expulsion of the volatile combustible matter, and turn out of the crucible in a dry incoherent powder. The volatile matter is, as might be expected, comparatively poor in luminous gases, and the lignites would, consequently, be of little use in the manufacture of illuminating gas.

The ash is generally of pale colours; grey and white, passing into yellowish-white, being the prevailing shades. One or two only yield a deeply-coloured ash, wihch is then of a brick-red colour. It is small in amount in most of the specimens, and does not usually appear of a nature to form

troublesome clinker. The lignites when burning yield a peculiar empyreumatic odour but no smell of sulphur, and indeed, as might be foreseen from the nature of the ash, the quantity of sulphur present is very small.

In the table below the analyses of all the lignites are calculated to correspond with a quantity of water, combined or hygroscopic, equal to twelve per cent., which, may I think, be accepted for the samples examined as the practical limit of desiccation in dry air at ordinary temperatures. This will allow of a more accurate comparison of the value of those from different parts of the series.

TABLE I. RESULTS OF ASSAYS OF LIGNITES, WATER BEING ESTIMATED AT AN AVERAGE OF 12 PER CENT.

	Locality.	Miles West of Red River.	Thickness of bed.	Water estimated at 12 per cent.	Fixed Carbon.	Volatile combustible matter.	Ash.	Remarks on ash.
1	Souris Valley. Sect. 6...	255	2′ 3″		45.48	39.77	2.76	Reddish-white.
2	" " " 2...	263	3′ 2″		46.18	35.90	5.92	Yellow brown.
3	" " " 2...	263	1′ 5″		31.51	50.02	6.47	Yellowish.
4	" " " 2...	263	1′ 0″		38.08	44.57	5.35	Light Yellowish,
5	" " " 2...	263	6′ 6″		34.82	48.30	4.88	Greyish-white.
6	" " " 5...	262			43.72	42.40	2.88	Yellow.
7	" " " 4...	263	7′ 3″		49.31	33.98	4.71	Yellowish-white.
8	Big Valley. " 8...	344	a few inches		38.65	43.92	5.43	Grey.
9	" " " 8...	344	5′		48.61	34.90	4.49	Grey.
10	" " " 8...	344	3′		36.92	44.95	6.13	White.
11	" " " 9...	346	4′		38.63	44.48	4.89	Yellowish-white.
12	Porcupine Valley Lower part..... " 12....	390	18′		46.20	35.14	6.66	Light grey.
13	Upper part..... " 12...	390	"		36.33	39.97	11.70	White.
	Average.....				41.1	41.41	5.55	

It should be stated that, with the exception of two or three specimens, all those analysed were mere out-crop samples, and, from the facility with which these lignite coals deteriorate under atmospheric influences, show a

result much inferior to that which would be obtained from the same beds at some depth. Nos. 1 and 12 with one or two others were obtained from portions of the beds recently exposed by slips of the bank, and probably represent more fairly the quality of the better class of lignites. The total percentage of carbon, inclusive of that which passes off with the volatile matters, varies probably between 60 and 70 per cent. The lignites do not appear to be suited for smithy purposes, and the smiths who tried them reported it difficult to obtain a welding heat. The same fault has been found, I believe, with even the best classes of similar fuels found in the vicinity of the Union Pacific Railway, and arises, no doubt, from the great proportion of volatile combustible matter to fixed carbon, and the quantity of hygroscopic and combined water. As the lignites do not coke, they would appear to be unsuited for the smelting of iron in the blast furnace, though it is possible they might be economically employed for this purpose in the raw state, especially if mixed with a proportion of wood charcoal and burned in furnaces of not too great height.* They are perfectly suited for puddling iron, and the metallurgical treatment of various ores, if burned in gas furnaces. Similar fuels have already been extensively employed in this way at Golden City and other localities in Colorado, and in the mining districts of the Southern Rocky Mountain region, and appear several years ago to have commanded prices ranging from $2.00 to $4.00 per ton at the pit's mouth. Similar and even inferior lignites are extensively used for steam purposes in various parts of the world, and in Wyoming, Utah, &c., are employed on the railways, though locomotives to properly burn these fuels, in order to give satisfactory results, must have, compared to those worked on bituminous coal, larger grates and fire-boxes, and larger boiler-tubes, giving a greater heating surface compared with the horse-power.

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* Excellent charcoal is, I believe, made from similar Lignites in Germany, by treating them in coking ovens in the state in which they are extracted from the mine.

TABLE II. SHOWING COMPOSITION OF LIGNITES AND OTHER FUELS FOR COMPARISON WITH LIGNITES IN TABLE I.

Locality.	Water.	Fixed carbon.	Volatile matter.	Ash.	Colour of ash.	Analyst.
1. Wood, a verage of air-dried..	18.55	25.69	53.99	1.77		
Lignites, United States,						
2. Golden City, C.T.....	13.43	45.57	37.15	3.85	Grey.	J. T. Hodge.
3. Carbon Stn., W.T.....	6.80	49.72	35.48	8.00	Light grey.	"
4. Evanston, Utah.....	8.10	47.67	34.60	9.67	Grey.	O. D. Allen.
5. Murphy's, Ralston Cr. C.T.	13.83	44.44	35.88	5.83	Orange.	J. T. Hodge.
6. Chesnut R., Near Boyeman, Montana...	3.00	43.50	41.50	12.00		A. C. Peale.
7. Marshall Mine, Boulder City C.T., average of 5.	16.00	41.50	38.00	4.50		A. L. Ford.
8. Van Dyke, W. T.....	8.12	53.23	36.65	2.00	Light grey.	J. T. Hodge.
European Lignites.						
9. Zsemle, Hungary	12.60	55.20	27.85	4.35		Schrotter.
10. Wildsthut, Upper Austria	26.15	39.12	19.15	15.58		Regnault.
11. Dax, France.....		44.11	50.80 with water	4.99		Schrotter.
12. Utweiller, Rhine.....	----	67.3	31.80	0.90		"
13. Minerve, L'Aude.....	———	32.6	57.40	10.00		"
Bituminous Coals.						
14. Nottinghamshire (coking).	3.50	59.18	33.32	3.90		
15. St. Helen's Lancashire. (non-coking).	3.23	60.33	31.27	5.17		
16. Sidney, C. B.....	———	67.57	23.81	5.49		W.R.Johnson.
17. Pictou, N.S.....	1.75	61.95	25.87	10.42		J. W. Dawson.

No. 1, from Tables in Percy's Metallurgy. Nos. 2, 3, 5, 7, 9, from Geological Survey of Territories for 1870. No. 4, from Hague and King's Mining Industry of 40th parallel. No. 6, from Geological Survey of Territories for 1872. Nos. 9, 10, 11, from Percy's Metallurgy. Nos. 12 and 13 quoted by Hodge in Geological Survey of Territories for 1870. Nos. 14 and 15, Percy's Metallurgy. No. 16, from Coal Trade of British America, W. R. Johnson. No. 17, Acadian Geology.

o. 8 from VanDyke, together with another lignite of similar composition

from the neighbouring locality of Rock Springs, are considered by Mr. Hodge the best lignites in the Rocky Mountain region.

The ironstones of this formation, though occurring very frequently in the same sections, and in close proximity to the coals, have not been observed in any place to attain a considerable thickness. They generally run in nodular sheets of only a few inches thick, through the clays and argillaceous sands. Externally they weather to various shades of chocolate-brown and reddish-brown, but are hard and compact in structure and within preserve their original bluish or yellowish-grey colour. They ring beneath the hammer, and break off in conchoidal chips. Considerable quantities of this material might be gathered from the surface in some localities, and it is probable that further search might bring to light localities in which so many layers of ironstone occur in the same section as to render it profitable to work over the entire bank. Should these ores ever come to be worked, limestone for use as a flux could be obtained in considerable quantities from the boulders of Silurian age which strew the plains in many places.

Clay Ironstone from Souris Valley. Section 2.

Protoxide of iron	49.00
Water lost at 115° C	1.21
Carbonic Acid lost on ignition	28.57
Siliceous matter insol. in HCl	17.04
Sulphuric Acid	0.26
Phosphorus	*Trace*
Metallic iron per cent, in raw ore	38.11
Metallic iron in calcined ore	54.27

Clay Ironstone from 345 Mile Valley. Section 9.

Protoxide of iron	46.72
Water lost at 115° C	3.57
Carbonic Acid lost on ignition	21.23
Siliceous matter insol. in H Cl	8.72
Sulphuric acid	0.30
Phosphorus	0.03
Metallic iron in raw ore	37.53
Metallic iron in calcined ore	49.90

A small quantity of iron is present as peroxide in each ore, but I have not thought it necessary to make a separate estimation of this.

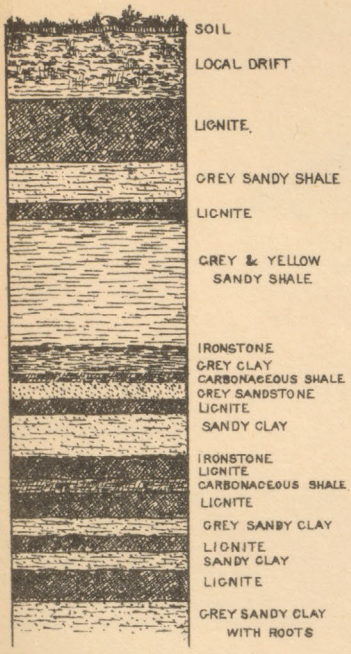
A third specimen from the 345 Mile Valley, section 8, examined for iron, gave a percentage in the raw ore of only 37.95.

The percentage of iron in the specimens examined is very good for the class of ores to which they belong. The average percentage of iron of several good English clay-ironstones amounts to 33.84; of several samples

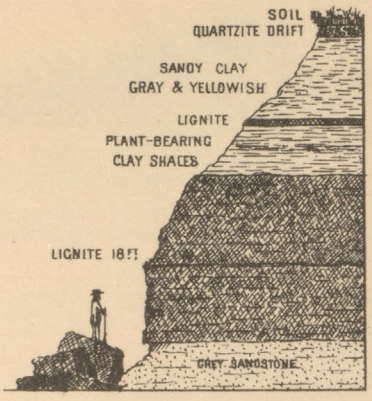
of black-band ironstones to 35.39. Where these ironstones are unweathered, the whole of the iron appears to be in combination with carbonic acid. The quantity of sulphur present is small, and it is entirely as sulphuric acid and in combination with lime. Phosphorus is also present in very small quantities.

The clays and argillaceous sands accompanying the lignites are in many places of the nature of fire clays, and contain but very small quantities of iron or lime. It is probable that many of them would make very refractory fire bricks. Clay of sufficiently good quality for the manufacture of ordinary bricks and pottery is present everywhere in close connection with the lignites.

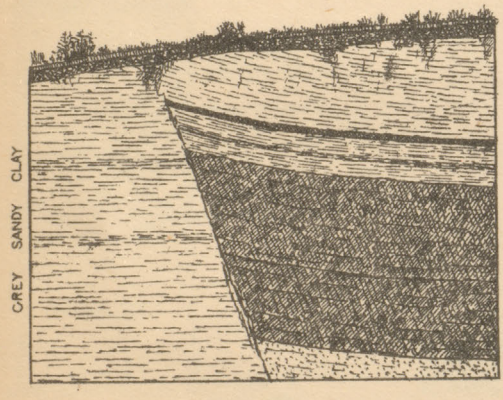
REFERENCE TO SECTIONS.



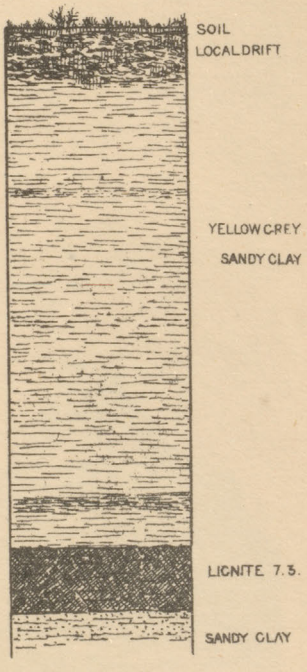
SECTION 2. SOURISVALLEY



SECTION 12. 18FT LIGNITE. PORCUPINE CREEK.



FAULT AFFECTING 18FT LIGNITE.



SECTION 4. SOURIS VALLEY.

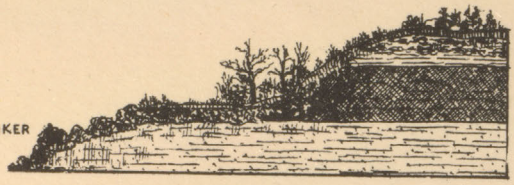
20 FEET

G.M.Dawson Delt.

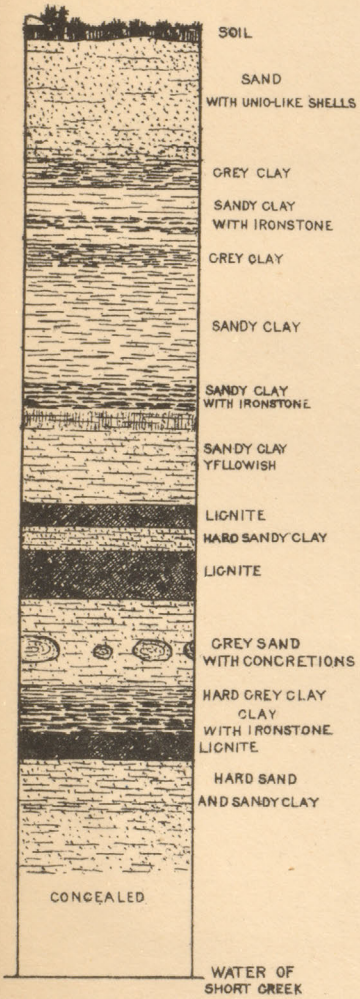
The Desbarats Litho. & Publg. Compy. Montreal. Lith.

SECTIONS TERTIARY LIGNITE FORMATION.

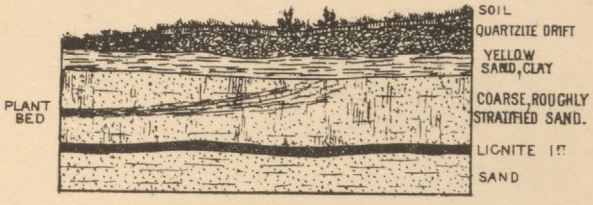
FORTY-NINTH PARALLEL.



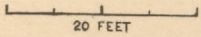
SOURIS VALLEY
LIGNITE BED BURNED AT OUTCROP

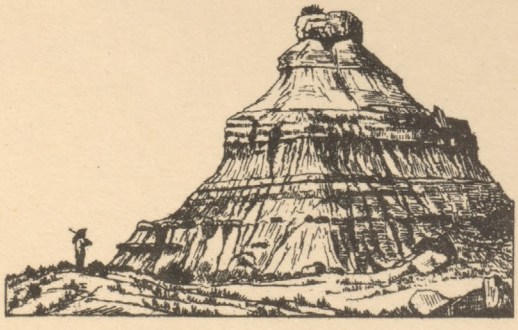


SECTION 7. SHORT CREEK



SECTION IN PORCUPINE CREEK





SECTION 8. [LOWER PORTION]

G.M.Dawson Delt.

The Desbarats Litho & Publg. Compy Montreal. Lith.

SECTIONS TERTIARY LIGNITE FORMATION.

FORTY-NINTH PARALLEL.