RECONNAISSANCE FROM CARROLL, MONTANA, TO YELLOWSTONE NATIONAL PARK.

GEOLOGICAL REPORT.

BY

EDWARD S. DANA AND GEO. BIRD GRINNELL.

LETTER OF TRANSMITTAL.

YALE COLLEGE, NEW HAVEN, CONN.,
June 1, 1876.

SIR: We have the honor to hand you herewith a report on the geology of a "Reconnaissance from Carroll, Montana, to the Yellowstone Park, and return," made under your command during the months of July, August, and September, 1875.

In submitting the narrative of our examination of the country passed over, we wish to express to you our grateful appreciation of your uniform kindness, and constant willingness to facilitate our investigations by every means in your power. To Lieut. C. F. Roe, who commanded our escort from Carroll to Camp Baker, we are under obligations for many kindnesses. At Camp Baker, Fort Ellis, and Camp Lewis, we were the recipients of most generous hospitalities from the officers of those posts; and our brief delays at those points are remembered by us as being among the pleasantest days of the trip.

The vertebrate fossils collected during the summer were submitted to Prof. O. C. Marsh, and by him identified. The invertebrates were examined by Mr. R. P. Whitfield, of Albany, and his identifications, with occasional comments on the specimens, will be found in the body of the report. A paper by Mr. Whitfield, describing such new forms as were discovered during the summer, accompanies our report. To both of these gentlemen our thanks are due for the many favors that we have received from them.

We remain, sir, very respectfully, your obedient servants,

EDWARD S. DANA.
GEO. BIRD GRINNELL.

Col. WM. LUDLOW,
Chief Engineer of the Department of Dakota,
Saint Paul, Minn.

GEOLOGICAL REPORT.

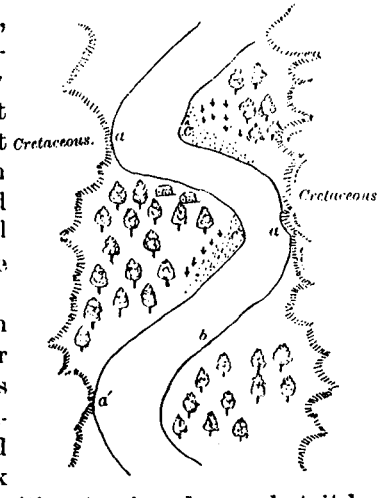
By Edward S. Dana and Geo. Bird Grinnell.

PRELIMINARY REMARKS ON THE ALLUVIAL DEPOSITS OF THE UPPER MISSOURI RIVER.

The town of Carroll is situated in the alluvial bottom of the Missouri, which is at this point quite extensive, and well timbered with a fine growth of cottonwood. The course of the river-valley is here easterly, and it continues for a considerable distance with but little change in general direction, though the valley varies very considerably in width between the high walls of Cretaceous clays which rise on either side of it. The river sometimes winds along through a bottom two or three miles wide, and again is confined to a narrow passage between the steep washed bluffs several hundred feet in height.

The alluvial phenomena are those which are always observed under similar circumstances, though they take place here more rapidly and on a larger scale than is often the case, in consequence of the vast amount of solid matter which the river is constantly carrying down. On this account, the "muddy Missouri" offers peculiar advantages for the study of alluvial changes; and, could a series of observations be carried on at a few points during two or three seasons, a large amount of data might be collected which would lead to interesting and valuable conclusions. At Carroll, we have an example of a condition of things which may be observed at almost any point in this part of the river, and a few words of explanation may consequently not be out of place. At *a*, on the outer bank of the river, the current is strong, and has forced itself close up under the high bluffs, whose top forms the border of the broad prairie above. The older deposits, at points such as this, are directly acted upon by the running water, and are thus gradually undermined and worn away, the material being carried on by the current. Upon the opposite side of the stream, at *c*, the current is weaker, the water shallow and eddying, and the shore runs out to meet the water in a long low sand-bar. At *b*, there is a high bank of alluvial clays, 10 feet or more above the stream, deposited long before in time of flood, but now being rapidly torn away. Still again at *a'* the water washes at the foot of the older bluffs, while opposite is the never-failing sand-point.

Fig. 1.



Thus the river winds on its course, touching the hills, which form the true limit of its valley, only here and there. For the greater part of its course, it is confined between the alluvial banks. It is safe to say that, except in the spring, the river deposits comparatively little solid matter, and this, chiefly on the sand-spits and bars, where the force of the moving water is small. The work of the river is at this season one of destruction more than deposition, tearing down what it has

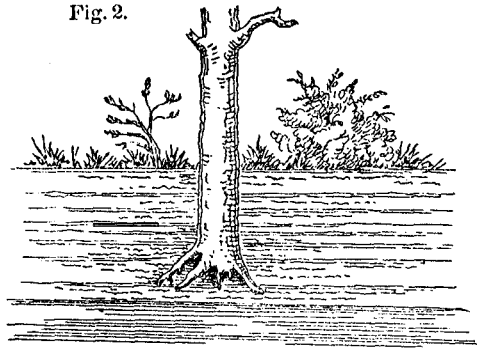
itself previously built up, and also to a less extent carrying away the older deposits. It acts alone, unaided by any minor tributary streams; for they are dry except in the early season. Even during the summer, however, the channel is constantly changing. The mud-and-sand bars which are everywhere formed do not long retain their positions, but are moved on down the river and heaped up again in other places. Thus the process is one of gradual transferral down the stream; the solid matter going to make one alluvial bank after another until it is finally deposited in the Gulf of Mexico.

It is interesting to note, in this connection, the explanation recently given by Prof. James Thomson (Proc. Royal Society, 1876) of the origin of the windings of rivers in alluvial plains. He shows that, upon hydraulic principles, the velocity of the stream must be greater on the inner bank than on the outer, and yet, as shown here, the wearing away takes place upon the outer bank, and the deposits are made on the inner bank. This is in part due to the centrifugal force, which tends to make the surface-water move away from the inner bank, while its place is taken by a partial upward current of the bottom water retarded much by friction. This current moves obliquely toward the inner bank, and serves to protect it from the rapid scour of the stream-line. On the outer bank, however, there is a tendency of the rapidly-moving surface-water, unimpeded by friction, downward against the solid bank; this it tends to wear away, the worn substance is carried down to the bottom, where the oblique current spoken of carries it toward the inner bank. Sooner or later it will reach this point, and more or less of it will find a resting-place.

These principles find an application in the flow of the Missouri through its alluvial plain. It is on the outer bank of the successive curves of the river that the wear is greatest, and that the river has forced its way up to the older bluffs, while on the inner bank the deposits are being made, more or less, all the time, sand or mud, or both, according to the relative velocities of the different parts of the stream.

As has been remarked, the work of the river in summer is destructive, and no additions are made at this time to the height of the alluvial banks. In spring, the case is very different, and it is at that time that the chief deposits of alluvium are made. The river is then full, the snows all over the wide area drained by the Missouri are melting, rains are frequent, and a vast amount of material is brought in from the surrounding country. The amount of solid matter held in suspension at this season is enormous. In floods, the waters rise many feet, overspreading the lower alluvial ground, and in subsiding and evaporating they deposit their load of sand and clay, sometimes covering a well-grown and fertile plain with a bed of alluvium a foot and more in thickness. This sometimes takes place for a number of successive years at the same points, as is shown by the fact that the roots of trees which must have been close to the surface of the ground when they commenced to grow were often seen buried beneath from four to six feet of alluvium. We could of course only observe this on the very edge of the bank, where the water had removed a part of the old alluvium, exposing to view the roots, and that part of the trunk which had been buried. Some of these trees were quite small, not more than 3 or 4 inches in diameter, and most of them were still living; thus indicating how rapidly such deposits as those referred to are made. The trees were mostly cottonwoods and elms, species of rapid growth. That these deposits are made very rapidly is also shown by the thick layers to be noticed in any section of a bank so deposited, sometimes a foot or more, perfectly homogeneous. It is interesting to note the great variation in the height of the perpendicular alluvial banks. From point to point, in some cases, it is only three or four feet; in others twenty-five feet or more. This depends obviously on the strength of the current, and the extent to which the water is backed up. It bears upon the general subject of river-terraces. Not infrequently we observed a second terrace above, or rather a long line of high cut bluffs separated from the stream by another alluvial plain (see figure 3). This is all of recent origin, and merely means that the river stopped washing away the bluffs here, and commenced to fill up at its foot.

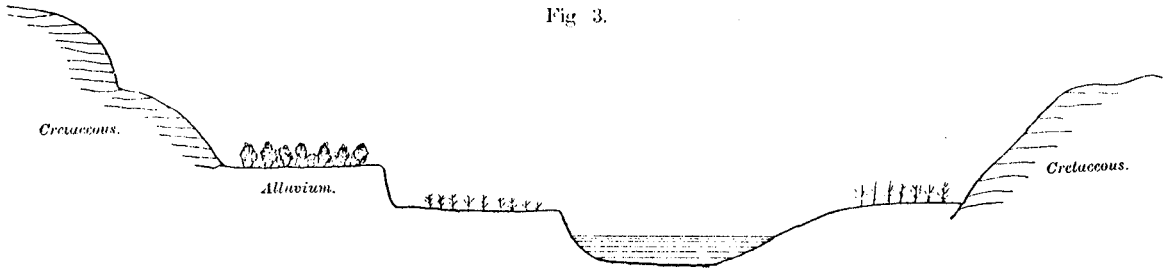
Fig. 2.



The energy of the stream is at all times directly proportional to the amount of the descending

water; and hence is immensely greater in spring than in summer. This energy is probably all expended in overcoming friction, and in carrying the load of solid matter. The difference in the amount of detritus held in suspension by the stream in early July and in late September was very marked—at the latter time the stream seemed to have to a great extent cleared itself. This is doubtless due to the diminished volume of the water, in consequence of which the carrying power of the stream was so much diminished. A river of this character seems to act as a destructive agent rather through the weight and moving force of its own water than by means of the abrading power of the solid matter it carries with it.

Fig. 3.



A true upper terrace was not observed at any point above the mouth of the Yellowstone. At points below, it was not uncommon to see one hugging the lignite bluffs, and separated from the river by a wide alluvial plain. Whether it be a true terrace or only a recent deposit is doubtful. Such a place was noticed a short distance below Fort Buford, where the water must once have spread over an immense area, pointing to the time when the Missouri was a much larger stream than it is at present.

Above Carroll, the river-bottom becomes much less wide, and, although sometimes flowing through valleys more or less broad, the stream generally passes along between and close beneath frowning banks of washed clays and sands. The undermining of the banks takes place here in the same manner as where they are alluvial; but, owing to the greater hardness and thickness of the older rocks upon which the water acts, the process is much more slow. It goes on constantly, however, so that at last a great mass of the rock above, perhaps a hundred feet in thickness, deprived of its support, slips down into the water. This has occurred at many points, and gives to the rocks, as viewed from the river, a great variety of dip, which has been considered by some observers as indicating an extensive disturbance of these beds, due to the elevation of the mountain-ranges of this section of the country. We cannot doubt, however, that all these apparent disturbances are purely local, and have been caused by the action of running water.

FROM CARROLL TO BOX ELDER CREEK.

Fort Pierre Group of the Cretaceous.

The clay bluffs at Carroll rise abruptly above the alluvial bottom on both sides of the river. They belong to what Dr. Hayden has called the Fort Pierre Group, Cretaceous No. 4. These bluffs consist of a dark-blue to purplish-black laminated clay, occasionally stained with iron, and sometimes containing very thin layers of white sand. They are remarkably constant in character from top to bottom. Dr. Hayden has stated in general that the clays of No. 4 are *not* laminated; but this is not true of those which came under our observation.

The characteristic features of this clay are (1) the large calcareous concretions, which will be spoken of more particularly in connection with Crooked Creek; (2) the plates and crystals of transparent gypsum, or selenite; and (3) the alkaline deposits.

The selenite plates are quite conspicuous, as they lie on the surface of the ground, and glisten brilliantly as the sun strikes them. In general, they are irregular crystalline fragments; but occasionally perfect crystals are found of the form common in the clay of Poland, Ohio. The surface of all these fragments is roughened and etched by the solvent action of the water which has flowed over them. These etchings are most distinct on the clinopinacoid, and are similar to those described by Baumhauer as having been produced artificially by the action of caustic potash. The

selenite plates are found most abundantly near the level of the river, having been washed together here, but they occur also more or less frequently on the plains, twenty-five miles from the river, at a level nearly 1,000 feet above.

The alkaline deposits seem to be particularly abundant in some layers, exuding from the bluffs along the river in long white lines. Considerable deposits of it are seen at various points on the banks of the river, and all the little dry creek-bottoms leading into the Missouri are white, as if frosted with it. The following is an analysis of a particularly-pure specimen of the alkali collected near Carroll. For this analysis we are indebted to Mr. Fred. P. Dewey, of the Sheffield Scientific School of New Haven, and we would here express our acknowledgments to him:

	I.	II.	Mean.
MgO	11.69	11.91	11.80
Na_2O	15.81	16.20	16.00
CaO	0.53	0.68	0.60
Li_2O	0.88	0.88	0.88
SO_3	44.09	44.12	44.10
Cl	trace	trace	trace
H_2O	23.09	23.00	23.05
Insoluble	3.29	3.27	3.28
	99.38	100.06	99.71

As will be seen from this analysis, the alkali consists essentially of the sulphates of sodium and magnesium; in fact, the amount of sulphuric acid given is almost exactly what is required to unite with the several bases. The presence of the lithia is also to be noticed.

This alkali is a constant attendant of this member of the Cretaceous, wherever observed in the West, and is one of the causes of its barren character. The water of the Missouri is so entirely derived from pure mountain-sources—even the large rivers, as the Musselshell, which flow through the alkaline prairie, being nearly dry at their outlets—that it is little affected by the salt which is brought into it, though the white deposits on the alluvial banks show that the quantity is not small.

These Cretaceous clays have a laminated shaly structure wherever exposed: they weather down so readily, however, that often only the rounded beds of clay are seen. These are so soft and yielding, that the foot sinks deeply into them, and they have much the feeling of a bed of ashes. In the neighborhood of Carroll, there is more or less of a scanty vegetation; but farther down the river, perhaps one hundred and fifty miles, there seems to be no vegetation whatever, and the appearance of these black clay-beds is desolate in the extreme.

The height of the Cretaceous bluffs above the river is quite variable as viewed from the water; but, when we examine the total elevation attained in passing back from the river, we find that it is remarkably constant. The Helena road at Carroll rises in two or three very steep pitches the greater part of its final ascent, and, within two or three miles of where the road leaves the valley the high plateau is reached, which is kept, with little change of level, beyond Crooked Creek. The height here, as given by an aneroid, is 665 feet. On the other side of the river, the height of the corresponding plateau is 680 feet; though in this case the final elevation was found a little farther from the river, the rise of the plain being more gradual after the first steep ascent had been made.

The appearance of the surrounding country, as viewed from the top of the bluffs back of Carroll, is very forbidding. The whole landscape is of a somber, gray tint; the color of the soil and the sage-brush sparingly relieved by the dark green of the stunted pines that grow here and there on the summits of the bluffs and along the little ravines. There is little vegetation, except the *Artemisia*, and, altogether, the region seems incapable of affording sustenance to man or beast. Notwithstanding its uninviting appearance, the neighboring country abounds in game. This region has been, and still is, though to a less extent than formerly, the favorite feeding-ground of a portion of the great northern herd of buffaloes: antelope are numerous on the plains, and mule-deer and elk are found in the pine-timbered ravines. Farther back from the river, in the hill-country, the big-horn, or mountain-sheep, and the grizzly bear occur, though nowhere numerous.

On both sides of the Missouri, the high bluffs are cut into numberless ravines, which divide

and subdivide again to a wonderful extent, thus carrying the surface-drainage back into the river. These ravines are often quite well wooded, and some of them contain a little strongly alkaline water.

As has been remarked, the height of the plateau varies but little as we proceed away from the river, though we soon pass over the divide which separates the immediate drainage of the Missouri from that of Crooked Creek, a tributary of the Musselshell River.

Little Crooked Creek, thirteen miles from Carroll, retains water in holes until midsummer, when it generally dries up entirely. Five miles beyond, a branch of Crooked Creek also affords a little poor water in the early summer; but, late in the season, the only water on the route is found in pools in the bed of Crooked Creek, and this is decidedly unpalatable. All these creeks, with their many dry branches, certainly contain swiftly-running water in the early season, when the spring rains unite with the melting snows to swell the streams. This is plainly shown by the high, cut banks and the large accumulations of drift pebbles in the turns in the creek-beds.

The surface of the prairie from Carroll to Crooked Creek (twenty-one miles) and beyond, though this point is only about fifteen miles from the river in a direct line, is scattered with drift deposits. These are of two kinds: (1) large, mostly angular, blocks of syenite and other hornblendic rocks, with occasionally some semi-crystalline limestone; and (2) small, smoothly-rounded pebbles, consisting to 90 per cent. of a brown quartzite or jasper. Some fragments of fossil wood may here and there be found, and a large variety of pebbles of various kinds of rocks in small quantities. This drift is entirely *superficial*, no proper deposits having been observed at any point. The lithological character of the drift will be described more in detail hereafter, when it will be connected with observations made north of the Missouri River (p. 135).

At Carroll, in the lower levels of the Cretaceous No. 4, the only fossils observed were *Baculites ovatus*, Say, and a large *Inoceramus*. At Little Crooked Creek, where we made our first camp (July 13), we had more opportunity for search, and here, and farther on, at Crooked Creek, we found:

1. *Lucina ventricosa*, M. & H.
2. *Lucina occidentalis*, Morton.
3. *Mactra*, sp.?.
4. *Inoceramus tenuilineatus*, H. & M.
5. *Anchura*, sp. (specific features not shown).
6. *Ammonites Halli*, M. & H.
7. *Scaphites nodosus*, Owen.
8. *Baculites ovatus*, Say.

Inoceramus tenuilineatus, H. & M., *Ammonites Halli*, M. & H., and *Baculites ovatus*, Say, were extremely abundant at these localities, and the specimens secured comprise individuals of all ages.

These fossils, as far as our observations go, are found only in the concretions previously mentioned in connection with these beds. These concretions occur in great numbers from the level of the river to the highest point above it where these clays were seen. Those which contain fossils seem to be much more abundant in the upper layers than in those nearer the water's level. Fossils were occasionally found in concretions from the lower ravines; but such concretions were not seen in place. They were generally found imbedded in the loose, washed clays of the ravine, and had the appearance of having been carried down from some point above. The concretions are quite compact when found in place in the cut bank, though they yield readily to a blow of the hammer. Whenever exposed for any length of time, however, to atmospheric influences, they separate into hundreds of angular fragments; and here and there over the prairie may be seen the little piles of these blocks, a conspicuous feature among the low cactus-plants.

The concretions are generally a foot or two in diameter, though sometimes much larger, and are extensively cracked; the seams having been filled with crystallized calcite and sometimes with gypsum. One fine specimen of an *Ammonite* was found, the interior of which was lined with exceedingly delicate crystals of the selenite. The concretions, as a rule, are not distributed at random through the clays, but lie in layers, sometimes closely contiguous, so as to form an almost uninterrupted stratum. The large majority are destitute of fossil remains; but occasionally they are met with, containing large numbers of the shells, a considerable number forming the nucleus of a single

concretion. It is to be noticed that these fossils, as a rule, are not clustered together in the center of the concretion, but lie in a single layer; and it is not uncommon to see this layer continued in line from one concretion to the others lying immediately adjoining it. This fact indicates the relation in point of time between the deposit of the shells and the formation of the concretions.

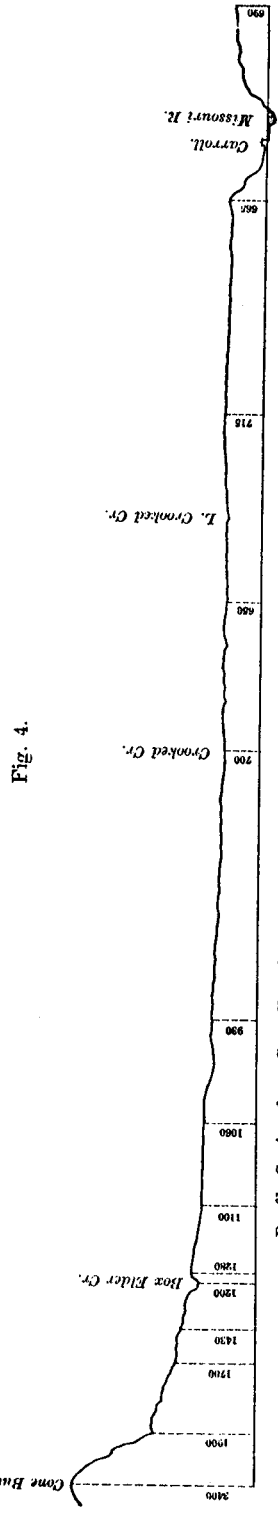


Fig. 4. *Profile Section from Carroll to Cone Butte, Judith Mountains. Course from Carroll to Box Elder Creek S. 55° W.; from Box Elder Creek to Cone Butte S. 30° W. Distance direct about 40 miles.*

The most common fossil in this association, and one which is met with almost everywhere on the prairie, is the *Baculites ovatus*, Say. These remains are often called "fossil fish", "fossil ferns", &c., by the white inhabitants of that section of the Territory; and, as they are so well known and so often spoken of, it may not be amiss to make a remark in regard to them for the benefit of the unscientific. They are not fish-skeletons, but are simply the shell of an animal somewhat allied to the present *Nautilus*, but having the shell straight and tapering instead of curved in a spiral. The delicate lines on the shell show the divisional walls, or septa, of the successive chambers in the shell.

During a delay of a day at Crooked Creek, we were enabled to follow along the dry bed of the stream for several miles. This bed is filled with alluvial deposits of the black clay deposited by the stream, and through which it has again washed out its path, leaving steep walls three feet or more in height. The banks on either side show evidence of having been washed over, looking white, and a little sandy, and with the drift-pebbles collected in large numbers. Here and there the Cretaceous clays are exposed in high bluffs on either side of the creek-valley. These bluffs have sometimes a height of 50 to 75 feet above the stream-bed. The clays are not to be distinguished from those forming the immediate banks of the Missouri. They are blue-black or slate-colored, shaly, the layers being very distinct and everywhere characterized by the concretions. The layers of the clay are pretty uniformly horizontal, though an occasional slight dip is to be observed. At one point, we noticed a very low synclinal fold followed by a fault; the strata being displaced some 15 or 20 feet. This and other similar disturbances observed in this neighborhood we decided were undoubtedly local, being due to slips in the loosely-laminated clays, through the influence of running waters. Many similar disturbances were observed along the river which were obviously due to a similar cause (see p. 125).

From Crooked Creek, the road runs on nearly southwest, rising slightly till a point some few miles from Box Elder Creek is reached, when there is a more sudden rise of 50 feet up to a plateau, which on top, is very level, and the northern edge of which can be distinctly seen extending some distance in both directions.

The following cut (fig. 4) gives an ideal section* from Cone Butte to the Missouri along the line of the road, as obtained from measurements made by an aneroid. It is to be observed that the line runs obliquely, making the distance somewhat farther than in a direct line, as will be seen by reference to the map.

The highest point at which the undisturbed Fort Pierre Group was observed was 1,060 feet above the river; and deposits of this age were seen at various points along the Helena road until Camp Lewis was reached. The last point at which they were noticed was near the crossing of Warm Spring Creek, south of the Moccasin Mountains.

*The vertical distances are increased nine times to admit of being brought within the limits of the page. The horizontal scale is (as on the map) 6 miles to the inch; the vertical scale is ½ mile (3,520 feet) to the inch.

The rise of the land continues until we reach Box Elder Valley, where the high plateau is seen extending east and west, and here a descent of 80 feet is made to the level of the stream.

Box Elder Creek takes its rise in the Judith Mountains, and, after a northerly course of about seven miles, turns easterly and then southeasterly, finally reaching the Musselshell River. At the stage-station, where we camped for several days, its course is nearly east and west. It is a running stream and furnishes fair water. Our delay at this point gave us an opportunity to explore to some extent the Judith Mountains.

In the neighborhood of Box Elder, we pass from the Fort Pierre clays, Cretaceous No. 4 of Hayden, to the sandstones of the Fox Hills Group, or Cretaceous No. 5, overlying them. At a locality lying nearly south of Box Elder station and distant from it about a mile, we observed a ledge of sandstone containing some tolerably-preserved shells. The rock is a yellow ferruginous sandstone in rather thin beds, but quite firm. Occasional calcareous layers contain fossils similar to those in the sandstone, but much better preserved. The thickness of this yellow fossil-bearing sandstone is small; and beneath it is a friable white sandstone, easily rubbed into powder with the fingers. The dip of the exposed strata is slight, toward the northeast. The fossils found at this locality are as follows:

1. *Sanguinolaria oblata*, Whitf. (n. sp.).
2. *Liopistha* (*Cymella*) *undulata*, M. & H.
3. *Tellina isomma*, Meek.
4. *Tellina scitula*, M. & H.
5. *Mactra warreniana*, M. & H.
6. *Mactra maia*, Whitf. (n. sp.).
7. *Tapes montanensis*, Whitf. (n. sp.).
8. *Ostrea congesta*, Con.???.
9. *Lunatia concinna*, H. & M.
10. *Inoceramus*, sp.
11. *Fusus Galpinianus*, M. & H.

Sandstones of a similar character to that mentioned may be seen at a variety of points where the excavation of the deep coulées has laid bare the rock beneath. One striking locality was visited some four miles east of the station, where, on the east bank of a deeply-cut coulée, the sandstone is exposed at a height of 200 feet above the creek-bottom.

The section was as follows:

Two feet of a white sandstone, in thin layers;

Thirty feet of a white, soft, thickly-laminated sandstone, underlaid by an uncertain thickness of rusty-yellow sand-rock.

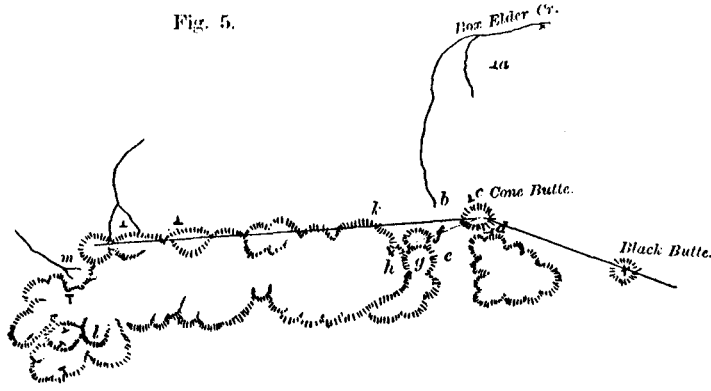
No fossils were found here, though they were searched for with care.

JUDITH MOUNTAINS.

Our examination of the Judith Mountains was hasty and incomplete, owing to lack of time at this point; and our movements were still further embarrassed by the necessity of taking some precautions against the hostile Sioux, known to be in the vicinity at the time.

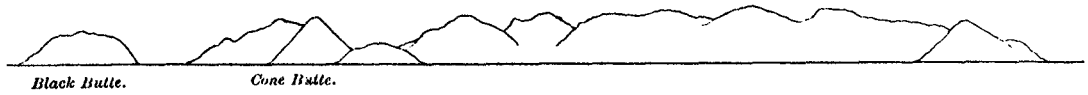
The following cut (fig. 5) will give some idea of the extent and bearings of the Judith Mountains,

Fig. 5.



although it makes no pretensions to topographical accuracy. The few bearings which were taken from Cone Butte are indicated. It is to be noticed that these mountains do not lie north and south on the east bank of the Judith River, where they are generally represented on the maps of this region. On the contrary, their trend is essentially east and west, so that the axis of the range lies almost at right angles with the course of the river. The general appearance of the range as viewed from a point to the northeast is shown in figure 6.

Fig. 6.



In the neighborhood of Box Elder, we pass, as has been stated, from the Fort Pierre clays to the sandstones of the Fox Hills Group overlying them. The rocks of this group extend widely east and west from this point, and from the hills which slope up to the foot of the Judith Mountains.

Near Box Elder station, the sandstone shows itself nearly on the level of the stream at a point hardly a mile distant from it to the south. This is the locality where the fossils above mentioned were found. From this point, in approaching the hills, we took a course nearly south up a coulée, then dry, but which had been deeply excavated by running water, and which in the spring is no doubt a considerable tributary of Box Elder Creek. The eastern bank of this coulée is quite high above the bed, perhaps 200 feet, and all the way has a very uniform slope up to the mountains. On the west side the terrace is quite low, but has also the same gradual slope upward; the surface being for the most part remarkably level. The slope is about 50 feet to the mile. The sandstone of No. 5 is seen at a number of points, both in the bed of the coulée and above in the high eastern bank just referred to. The slope upward on the east continues until within a mile or so of Cone Butte, where the sandstone strata are more upturned and the surface of the hill is more broken. Close to Cone Butte, at its foot (at *c*, fig. 5), we observed the sandstone, elevated 750 to 800 feet above Box Elder. It was here whitish, compact, weathering out into peculiar forms, with irregular layers of ferruginous sand; dip, 10°; strike north 80° west.

The thickness here, as elsewhere, is difficult to estimate, because of the insufficient exposure. It must be two or three hundred feet, or perhaps more. It may be mentioned here that the hills and terraces are so much covered with grass and soil that exposures of rock are rare. Below this point (at *b*, see map) is an exposure of blue laminated clays, with abundant concretions, probably the Fort Pierre Group again, though here 600 feet above the highest exposure observed below, and 400 feet above the sandstone identified as No. 5 (*a*, on map). The elevation is due to the upturning of the mountains, involving both members of the Cretaceous alike.

From here we made the ascent of Cone Butte. The immediate foot-hills, and indeed those at some distance from the peak, are made up of the talus from the mountain as far as the surface-exposure goes. Loose blocks of the trachyte, which forms the mass of the mountain, have been spread over the surrounding country to a remarkable extent, and the smaller fragments were found abundantly within a mile or two of Crooked Creek; that is, having crossed Box Elder Valley. Cone Butte is, as has been intimated, a trachytic hill, and according to the readings of our aneroid it is 2,200 feet above Box Elder, and 3,400 above the Missouri River. This is about the average height of what are called the Judith Mountains, though there are several points which are probably a little higher.

The summit of Cone Butte commands an extensive view over the prairies to the north. The Little Rocky Mountains and the Bear's Paw Mountains, though far in the distance, are the most conspicuous points to be noticed. Its commanding position is well appreciated by the Indians who use it as a lookout, for which it is most conveniently situated. A shelter which we found on the summit, formed of large flat blocks of trachyte resting upon the spreading branches of a stunted pine-tree, had doubtless been used as a resting-place by many an Indian scout.

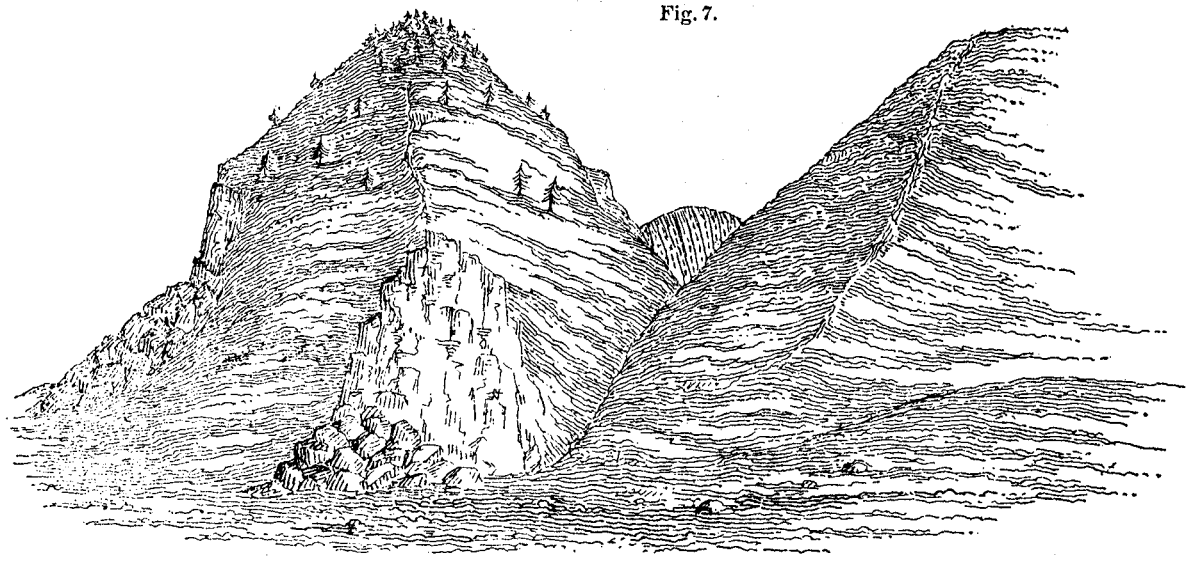
Cone Butte is itself a conspicuous object from all the surrounding country, even as far north as the Little Rocky Mountains; its perfectly conical shape being very striking from any point on the Carroll road. Viewed from the west, the sides of the cone are broken, and not so symmetrical as shown in figure 6. The slopes are covered with loose blocks of trachyte, and at some points are

precipitous. The angle of the cone is about 40° or 41°; indeed, it is so steep, and the loose blocks of trachyte furnish so insecure a foot-hold, that, were it not for the trails made by the mountain-sheep ascending and descending, it would be no easy task to climb it from the west side.

The mineralogical character of this trachyte deserves to be described a little in detail, as it may be taken as a type of the variety which occurs most widely in these mountains. It is in general of uniform texture, hard and firm, though occasionally showing minute cavities containing quartz crystals as a secondary product. It breaks on weathering into the large thin slabs which cover the sides of Cone Butte. The main constituent of the rock is a triclinic feldspar, as revealed by a thin section under the microscope, though occasional crystals of orthoclase of greater size may be observed. Hornblende follows next in order, the crystals being very distinct; and, further than this, magnetite plays an important rôle—this is distributed more generally than is common in similar rocks, and is seen by the microscope as extremely minute grains, whose metallic character is revealed only in reflected light. These particles of magnetite have suffered alteration to a considerable extent, and the feldspar is often stained red and yellow in a ring about them by the oxidized iron. It is to this alteration that the peculiar red color of the talus on the sides of the hills, as seen from a distance, is undoubtedly due. A critical examination shows that a little quartz is also present; but, as it was often otherwise noted in minute cavities, it may be questioned whether it is not merely a secondary product.

The descent from Cone Butte was made by way of the deep ravine which separates it from the trachytic hills to the south. The white trachyte is carried down nearly to the gap, where (see fig. 7) we passed a transverse dike, east and west in direction, of a hard green trachyte, with a cubical fracture breaking into large angular blocks, in striking contrast with the loose slabs of the other trachyte which cover the slopes of Cone Butte. This is probably a later dike, subsequent to the formation of the other hills. This trachyte, as well as that of Cone Butte, was found in fragments abundantly over the prairie, even to a distance of fifteen miles from the mountains. It is characterized by large crystals of a glassy orthoclase, which give it a porphyritic structure. Under the microscope, these crystals are found to be more or less clouded, in consequence of incipient alteration: this is also shown by the indistinct colors obtained in polarized light. Accompanying the large crystals of orthoclase are smaller thin-bladed crystals in large numbers. The other essential constituent is the hornblende, which is seen in simple distinct prisms: it has a deep-green color, and is strongly dichroic. No quartz was observed. The most interesting feature of the rock

Fig. 7.



is the green base, which, under a low magnifying power, seems to be without structure, but, when magnified highly, is resolved into countless minute, acicular crystals, jumbled together in a con-

fused mass. They show very little color in polarized light. They may be zeolitic; but a chemical analysis, which the circumstances do not now admit of, would be required to settle the point.

In the ravine spoken of, 355 feet below the summit of Cone Butte, we were surprised to find a series of slates and sandstones. The cut (Fig. 7) will give some idea of the relations of the rocks, it being a sketch taken from a point below to the west. The total width of the gap is about 70 yards; the trachyte rising abruptly on both sides. The trachyte of the hill to the south is quite similar to that of Cone Butte. The section in the gap is as follows:

Coarse ferruginous sandstone, vertical	3 feet.
Fine blue shale, vertical	20 feet.
Slate, sometimes shaly, sometimes a good slate, and very sandy, in layers; color whitish and yellowish; dip 70° south	180 to 200 feet.

The strike of these slates is east and west.

The age of these rocks is uncertain, as the only fossils found in them were some cycloidal fish-scales, with occasional impressions of fish-vertebræ and spines, which were quite numerous in some layers in the slate. It is hardly to be doubted, however, that they are Cretaceous; and the position of some rocks, also containing fish-scales and probably identical with these, observed at another point, as noted below, suggests that they are probably Upper Cretaceous, perhaps No. 5.

The present position of these slates is very remarkable: they lie far above (about 600 feet) the rocks visible in the hills below, and doubtless owe their elevation to the eruption of the trachyte, having been squeezed up between the two great masses of igneous rock. They show little trace of the influence of heat upon them.

The hills to the south and east, forming the eastern extremity of the Judith Mountains, are, as far as observed, trachyte. Black Butte, or Buffalo Heart Mountain, was not visited; but its position and similar appearance show that it is also eruptive, probably exclusively so. The sandstones dip away from it even more distinctly than from Cone Butte. It may be remarked here that the trachytic hills are very distinctly marked in appearance, and may be recognized with certainty even at a considerable distance. Their sides are covered with the loose blocks of the rock, and have a distinct reddish color, due to the oxidation of the iron which exists in considerable quantities in the trachyte (see description), which is quite conspicuous and characteristic.

West of Cone Butte (see *e*, fig. 5), there is a break in the hills, and a low pass called "Ross's Cut-off" gives passage to frequent Indian parties. It is free from timber, and of gradual slope, so that upon one occasion wagons were brought through without serious trouble. It is from this low pass that Box Elder takes its rise.

In this gap, the observations made were unimportant; the rocks being mostly covered up with soil and grass. It was interesting, however, to note that the even, gradual slope of the terrace before mentioned extends quite into the pass, with the same character well preserved. At *e*, (Fig. 5,) just on the edge of the hills which rise on the west side of the gap, a series of black shales were observed, vertical, and with a strike nearly north and south. These hills at *g* and to the south are all trachyte. We crossed them at one point, dragging our horses over the loose talus, much to their and our own discomfort, and found the height a little less than that of Cone Butte. On their western side, the trachyte shows itself in a series of columns, which are very regular and well formed; much more so than is common in this rock. This trachyte differs somewhat from the others described in the larger proportion of hornblende present. As before, the orthoclase appears in distinct crystals of large size, and the triclinic feldspar in thin-bladed fragments. The whole has a pasty base. A little valley, in which rises a small stream of cool water, lies just to the west, and on the other side is a high limestone hill (at *h*), the only exposure of the older sedimentary rocks which we met with in this part of the hills.

This limestone rises in a series of sharp ridges, very distinct, and seen from a distance as a number of white lines running up the sides of the hills. It dips 50° northeast; the strike being northwest. The upper layers are white, semi-crystalline, and very profuse in flinty fragments. These are exposed by the weathering, and, on the surface, the rock has quite a coralline aspect. Lower layers are firmer, blue, and also cherty, though not to the same extent as those above. A very careful search showed that fossils were very rare, though a few were found, enough to deter-

mine the age of the rock to be Carboniferous. The following is a list of the fossils obtained at this point:

1. Crinoidal remains too indistinct to be identified.
2. *Terebratula* or *Cryptonella.*
3. *Spirifera* (*Martinia*) *lineata*, Martin.
4. *Spirifera centronata*, Winch.
5. *Orthoceras???*, possibly filling of outer chamber.

Spirifera centronata, Winch., was the most abundant and characteristic form noticed here.

The thickness of these limestone beds must be very considerable; at least 300 or 400 feet were seen on this side of the hill, but as we were unable to follow them farther, we cannot venture to estimate their whole extent. This limestone is intersected at one point by a ridge of hard trachyte. On the other side of the little creek valley, the limestone also appears, containing here only a few imperfect crinoidal stems. Here it is apparently overlaid by a sandstone which has all the appearance of dipping under the hill, or, in other words, is overlaid by the trachyte. The outlying hill, *f*, is made up of sandstone, or a sandy slate; its summit is 1,200 feet above Box Elder, and hence a thousand feet lower than the adjoining trachytic hill. The observed thickness of this slate is 200 feet; dip 10° a little east of north, and strike nearly east and west. It can hardly be conformable to the limestone described; but the eruption of the trachyte, which doubtless accompanied the elevation of the mountains, has very much complicated the relations of the beds..

This slate contained large numbers of poorly-preserved fish-scales, which would seem to show its probable identity with the elevated slates in the ravine behind Cone Butte. Further than this, its position seems to suggest that it may be nearly parallel with the sandstones near Cone Butte, which are, as has been stated, Upper Cretaceous. No trace was seen at this point of any rocks between the Cretaceous and the Carboniferous limestone.

FROM BOX ELDER TO CAMP LEWIS.

The road from Box Elder to Camp Lewis follows along the foot of the mountains, but at such a distance from them that very few observations could be made. The character of the country is much better than that nearer the Missouri, but cannot be very highly praised. The Judith Mountains give rise to several running streams, which occupy wide valleys, and the region seems well adapted for stock-raising. Near Armell's Creek, a mile to the north of the road-crossing, gray clays are conspicuous, forming high bluffs with perpendicular faces, quite different from anything seen near Crooked Creek. This exposure was visited later, on the way to the mouth of the Judith River, but yielded no fossils, and its age is therefore uncertain. It is probably, however, near the top of the Cretaceous.

Our road approached quite near the mountains at Bald Butte (see *m* on map), and here, and at several points beyond, we observed a considerable thickness of a soft white sandstone, fine-grained and even-textured, but without fossils. It is in very thick beds, and weathers out in vertical walls, taking fantastic shapes, which are like those of the "Quader Sandstein" of the Saxon Switzerland. This is undoubtedly Upper Cretaceous. From this point, the road bears away from the hills again, crossing the divide between the Musselshell and Judith Rivers, and passing between the Judith and Moccasin Mountains. As has been before remarked, the dark clays of the Fort Pierre Group are seen again south of the Moccasin Mountains and just before reaching Warm Spring Creek. At this point, there was a considerable exposure of these beds, and, although no fossils were collected here, the characteristic features of the deposit were unmistakable. Farther on, a cut bank on the creek gave the following section:

Yellow clays, somewhat sandy	20 feet.
Hard gray shaly clays seen	20 feet.

These beds had a very slight dip a little east of north.

The Moccasin Mountains we were unable to visit; but their appearance, as viewed from various points on the road, and again from the northeast, indicated that, like the Judith Mountains, they are largely trachytic.

Camp Lewis is situated on Trout Creek, or Big Spring Branch, as it is sometimes called, which

is the largest branch of the Judith River. This is a wide stream of clear, very cold, water, which takes its rise in a spring about five miles from where the camp is situated. The immediate valley of the stream is covered with excellent grass, and when the country becomes safe from the incursions of hostile Indians—far from being the case at present—it must prove of high value for settlement.

About Camp Lewis there are considerable deposits of red clay. This is the case on both sides of the stream, but most conspicuously on the east bank, where the bluffs for a considerable distance are of a deep-red color. It is rare to find any exposures of the beds which give rise to these red slopes. In general, they are so washed down that only the red surface-deposits are seen. In some ravines, however, on the east bank of Trout Creek, we found the hardened red clays in place. No fossils could be discovered, though they were searched for with care. These beds seemed to be somewhat irregular and of rather local character. In the place where opportunities for observation were most favorable, we found 10 feet of red laminated clay, underlaid by a gray shale and overlaid by a sandy slate of a brown color. A little farther north, other layers of sandstone were observed, and beneath these some very thick bedded sandstone deposits; the red clays running out entirely. There was nothing to settle positively the age of these deposits. Except in color, they do not resemble the "red beds" of the West, generally referred to the Triassic; and as similar deposits were seen on the slopes of the Snow Mountains, twenty-five miles distant, overlying sandstones containing Cretaceous fossils (the same was true elsewhere), as noted later, it is more than probable that they are all Cretaceous in this vicinity. From this point, on our return journey, we made a detour and crossed the west end of the Judith Mountains; and, as we have just stated our observations in the neighborhood of Cone Butte, it may be interesting to add the others in this place.

Passing on from the red beds just mentioned, we crossed a low divide, and came down into the wide valley of a branch of Trout Creek, passing over some more red clays at a little higher level than those seen before. From here, our course was about north; our objective point being some white limestone bluffs conspicuous on the summit of the range. The foot-hills first passed over consisted, as indicated by one or two rock-exposures, of a brown, firm sandstone, in which no fossils were found. It had a dip of 20° away from the hills. These hills, in both directions, are covered with timber and grass, and the rock is rarely seen on the surface.

The limestone bluffs (*l*, fig. 5) were reached without much clue to the structure of the intervening country having been gained. This limestone stands up in a series of high buttresses, which, with their vertical fronts, are quite conspicuous objects. They show no evidence of stratification or structure. The rock contains occasionally masses of flint, though they are not so conspicuously cherty as those seen near Cone Butte. Some few fossils show that the rock is of Carboniferous age.

The following is a list of those obtained:

1. *Zaphrentis centralis*, Ev. & Shum.
2. *Syringapora mult-attenuata*, McChes.
3. *Stictopora*, sp.
4. *Spirifera centronata*, Winch.

On the hill to the west of this, a broad band of stratified limestone is exposed, in which some similar fossils were found. This same band apparently appears again on the north side of the hill, but here with a changed dip, northwest instead of southwest, pointing to a fold over at this point.

We crossed the higher ridge here, from which we could see off to the east, noting, as before, that the hills to the north are mostly trachyte, while those behind them to the south are as uniformly limestone. Near the source of Deer Creek, we descended into a broad, green meadow, quite surrounded by the hills. At one point, a patch of bright-red soil suggested a return to the red clays before seen. Crossing over by Bald Butte, a hill of trachyte, we reached the road again. The excursion was not altogether a satisfactory one, though showing the presence of the limestone at this point, but, as an investigation into the further structure of the hills, it was not successful. The difficulty lies in the fact that the hills are principally of igneous origin, and the thrusting in of the trachyte between the sedimentary rocks has destroyed the regular succession in the strata

which would otherwise exist. Further than this, while the trachytic hills are mostly bare and rocky, the other hills are, with the exception of the occasional sharp ridges of limestone, covered with grass and timber, so that little can be seen by one who must hurry on and make few stops. Probably two-thirds of the area of the hills is covered with trachyte, of which that found at Cone Butte may be taken as the type.

CAMP LEWIS TO THE JUDITH GAP.

From Camp Lewis, the road passes on thirty miles to the Judith Gap, crossing a portion of the country which has some promise of becoming valuable in time. Quite a number of running streams pass through it, of which Cottonwood Creek, Little Trout Creek, and Buffalo Creek are the most important. The latter becomes dry late in the season. Little Trout Creek is famous for the number and beauty of the trout which it contains. In the immediate vicinity of the streams, the grass is excellent; but, on the higher prairie, it is rather thin. The streams flow fresh and cold from the neighboring Snow Mountains, and could doubtless be used extensively in irrigation. This Judith Basin is a region that has been highly spoken of, and it will no doubt in time furnish farms for hundreds of settlers.

Very little opportunity for geological work is afforded over this portion of the route; for the prairie is much of it almost level, sloping away to the northwest to the Judith River, and giving no exposures of the underlying rocks. Considerable surface-drift is found here, which is entirely local, consisting, for the most part, of pebbles and masses of a blue limestone, some of them containing Carboniferous fossils. The source of this limestone is to be found in the Snow Mountains, which rise ten or twelve miles to the east, and from which it has been very abundantly carried off.

A short distance before reaching Ross's Fork, a bluff was examined, of a black shale, containing many reddish iron concretions, but no fossils; and a little farther on, to the left of the road, were seen some washed exposures of light-gray shales, also without fossils. Not far beyond, the soil becomes red again; and, for a distance of several miles up to the Judith Gap, the presence of beds of red clay is indicated. Associated with them was a limestone, impure and knotty, with many veins of calcite. These red-clay beds appear also at the foot of the Snow Mountains, and, as has been said, also at the foot-slopes of the western end of the Judith Mountains. Their thickness seems to be small. They appear to belong to the Cretaceous, which doubtless extends under the grassy prairie from Camp Lewis to the Judith Gap.

SNOW MOUNTAINS.

From Buffalo Creek, ten miles before reaching the Judith Gap (that is, north of it), we made a short detour, to examine the west end of the Snow Mountains. This range extends in an approximately east and west direction for a distance of some twenty miles. It is low, like all the other minor ranges. The average height can hardly be more than 2,000 feet above the surrounding prairie. Buffalo Creek takes its rise in the north side of the west end of the range. Following up the stream for a mile and a half from where the road crosses it, we found some outcrops of sandstone, with indistinct vegetable remains, undoubtedly Upper Cretaceous. A little farther—this on the north side—on the hill-tops, there was a gray sandstone, and below it, on the hill-side, a sandstone of a deep yellow color. Both of these broke into irregular, wavy fragments. Dip 10° westerly; strike north 20° east. These, which are in thickness perhaps 60 feet, are probably Upper Cretaceous.

On the opposite (south) side of the stream appears a thinly-laminated sandstone, with a southwesterly dip of 10°, but a strike north 30° west. Beneath this followed the slopes of red soil, pointing to the presence of thin beds of clay beneath, like those at Camp Lewis. Following and underlying this was a firm, thick sandstone, breaking into massive slabs, which covered the top and sides of the hill, giving it much the appearance of having been paved; the strike was as before. Beyond, also south of the creek, a hard, gritty sandstone was noticed, with layers containing a large number of poorly-preserved shells. These were not specifically recognizable, but have been identified as Cretaceous by Mr. Whitfield. Beneath this was what seemed to be a second deposit of the red-clay beds. These last are visible, though not so distinctly, on the opposite side of the creek,

where they are followed by about 5 feet of a firm limestone, and that by a considerable thickness of green and black shales, which last may be traced for a short distance on both sides of the stream. It is to be noticed that the strike and hence the dip of similar layers on both sides of the stream is quite different; and, though further study is needed to make out all the facts, we think it can hardly be doubted that at this western end of the mountains there is a distinct fold; the axis probably running a little north of west.

Continuing up to the source of the stream, we found the limestone here with a very slight dip to the northwest; strike northeast. The final point which we reached was a little cañon, with high and bold limestone walls, from which we obtained a few not very perfect Carboniferous fossils, viz:

1. *Zaphrentis centralis* (?), Ev. & Shum.
2. *Streptorhynchus Keokuk*, H.
3. *Spirifera centronata*, Winch.
4. *Stictopora*, sp.

To reach these Carboniferous rocks, we had doubtless passed over in succession the Cretaceous rocks, having perhaps a thickness of 900 feet, and also the Jurassic, if it exists here. We found no fossils belonging to this age, and doubt the existence of any considerable thickness of Jurassic beds. The limestone with the green and black shales noted above may possibly belong here.

Leaving the ridge, we turned at right angles to it; that is, nearly north. Here we passed over, first, the limestone dipping northwest, then successive beds of sandstone with beds of red clay interstratified. Near the foot of the hill, a reversal of the dip occurs in the sandstones, pointing to a minor fold parallel to the general course of the range. No older rocks than the Carboniferous limestone were observed; and from the numerous limestone pebbles containing Carboniferous fossils, picked up at different points along the sides of the mountains, it is safe to conclude that the range, as a whole, is made up of Carboniferous limestone; the younger rocks lying on its outer slopes. No evidence of any older rocks than the Carboniferous was noted; certainly not of any crystalline rocks. The trachyte, so common in the neighboring Judith Mountains, seems to be almost or entirely absent.

LITTLE BELT MOUNTAINS.

The Judith Gap is the divide between the Judith and the Musselshell Rivers. At this point the Little Belt Mountains and the Snow Mountains approach one another quite closely. The former are quite an extended and somewhat irregular range, reaching for a long distance north and west. Of its general geology, we can say little, as we can speak only of a few widely-separated points where we were able to visit it. One of these points was the extremity of the range at the Judith Gap. Near the Gap, we have already spoken of finding, on the north side, beds of red clay, which are associated with a little limestone, and nearer the hills with an underlying sandstone. Crossing the hills, which form the extreme eastern end of the range, perhaps a mile west of the Gap, we found a bed of yellow sandstone, which contained *Ostrea congesta*, Con.; then, some distance up the slope, a limestone containing corals, and dipping in a northerly direction; then some thin layers of limestone containing *Productus*.

The fossils found here were as follows; the identification by Mr. Whitfield:

1. *Ostrea congesta*, Con.
2. Cyathophylloid coral.
3. *Campophyllum torquium*, Owen??.
4. *Spirifera centronata*, Winch.
5. *Spirifera*, sp. May possibly be *Spiriferina Kentuckensis*.
6. *Productus*, sp. Resembles *P. Wortheni*, H.; but perhaps more nearly related to *P. multistriata*, Meek.
7. *Schizodus*, sp. Nearly or quite *S. Rossicus*, (DeVern.,) M. & W.

Here were seen 20 feet of green and black shales, dipping 50° northeast. From here, as we go up and across the hills, the strike gradually changes, and with it the dip, so that on the south side of the hill we have strata dipping southeast instead of northeast. The succession observed here is from below up:

Limestone, dip 65° south, strike north 70° east ..... 2 feet.
Red clays, with purple slates underlying it ..... 10 feet.

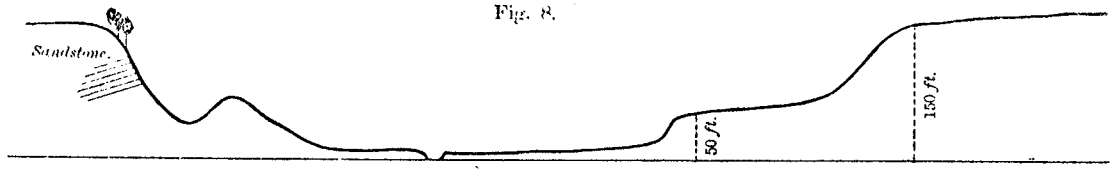
These beds bend around some 50°, so that in a vertical section they describe a quarter circle. The upper and central part of the hill consists of limestone, overlaid by a considerable thickness of slates and sandstones, dipping mostly east-southeast. The hill alluded to forms the extremity of this portion of the Little Belt Mountains. Farther along to the west, in the main range, is a limestone which has every appearance of dipping under all the rocks thus far mentioned; it probably corresponds to the firm limestone which forms the lower portion of the Carboniferous as developed in this region. The structure of this hill, thus imperfectly made out (a hasty run across it while the party was going round being all that circumstances admitted of), may be better understood upon the statement that it is an anticlinal fold; the axis pointing about north 30° west, and somewhat elevated in this direction. The south side of the fold is apparently the steeper.

JUDITH GAP TO THE MUSSELSHELL CAÑON.

From the Judith Gap to the Musselshell Cañon, a distance of rather more than forty miles, the underlying rock belongs for the most part to the Upper Cretaceous; the only fossils found having been referred by Mr. Whitfield, as stated below, to No. 5. This district is remarkable, perhaps more so than any other seen by us, for the deep and wide valleys which have been cut through the nearly horizontal rocks, and which lead away from the neighboring range, the Little Belt Mountains. There are now no streams running from the mountains, with the exception of Haymaker's Creek near the Forks of the Musselshell, and yet the otherwise remarkably level prairie is broken by a number of striking ravines or valleys. These are all alike in that they show no evidence of any important action by recent running water, but, on the contrary, point to agencies which must have done their work in glacial times. The beds of these valleys, and also, though to a less extent, the prairie above them, are strewn with pebbles and masses of limestone, whose source is in the mountains, only a few miles distant.

Three very conspicuous valleys, one of them a mile wide, with steep banks more than one hundred feet in height, are crossed before going twelve miles from the gap. Hopley's Hole is by far the most remarkable of these. A section is given in the following cut (fig. 8).

Fig. 8.



A Section across Hopley's Hole.

The width of the coulée at the top is about 1,000 yards. From the level of the prairie on either side, there is a steep plunge down; the total depth to the dry bed of the little stream being, according to aneroid measurements, 150 feet. On the west side, a second terrace of 50 feet in height is very distinct, while on the eastern slope a similar terrace, at about the same height, seems to be indicated; at present, however, there remains only a series of little conical hills all lying in a continuous line and presenting quite a peculiar appearance. This ravine is now dry, with the exception of a few springs of moderately good water on the west side. The water from these springs moistens the ground for a little distance about the point where they appear, but soon sinks out of sight. In the early part of the year, after the melting of the snow, more or less water evidently runs in the bed of the stream, which is dry in summer; but its erosive power is small, and there is nothing in the present relations which will explain the existence of such an extended valley. Hopley's Hole is important to those who pass over this road, not only as furnishing one of the few sources of water in this part of the route, but also because along the eastern edge of the valley there is here and there a little timber: a few straggling pine-trees which have ventured out into the prairie from the adjoining hills, and which show, by their appearance, that they have here a hard struggle for existence. The western slopes of this ravine, over which the limestone pebbles before mentioned are thickly scattered, are more gradual than the eastern; and, while the former are covered with thin grass, the latter shows a line of exposure of the sandstone which underlies the level prairie here. The upper

part of this is yellow and quite ferruginous; that below whitish and a little shaly. It varies somewhat at different points; in one place turning into a soft, dark-colored slate in very thin layers. The whole exposure may be 15 or 20 feet in thickness; the sandstone having a very slight southeasterly dip. No fossils could be found, and the rock seemed to be without any special characteristic features, with the exception of pipe-stem pieces of carbonate of lime, which were quite common. They occupied a vertical position, sometimes curving more or less, and were 6 to 15 inches in length; possibly they were holes in the sand made by borers and subsequently filled up.

West of Hopley's Hole, the plain is nearly level for a long distance, broken only by one or two gullies. The general slope of the whole is very gradual to the south toward the Musselshell River and far beyond. In this direction, there is nothing to break the view, and the eye wanders unrelieved over a vast range of dry, parched prairie, from which, at midday, the heated vapors arise, producing the illusive phenomena of the mirage.

Haymaker's Creek, twenty-five miles from the gap, offers another example of the extensive erosion which has taken place in this region. The stream at present carries very little water, and that quite strongly alkaline, especially late in the summer, at which time it barely moves at all. On the west side, the terrace is high and distinctly marked. It may be traced from the mountains to the Musselshell River with the same gradual slope noticed elsewhere; here also quite independent of the dip of the strata, which make a small angle with its upper surface. On the east side, the slope is very gradual; the final height not being attained for several miles.

A short distance below the road-crossing, the sandstone is exposed. For the most part, it is a fine-grained rock of even texture, and of a light-bluish color, becoming yellow on exposure to the weather. Much of this lies in exceedingly thin, paper-like layers. There are also a few layers of a blue, impure limestone, and toward the top a bed of coarse sandstone, almost a conglomerate, containing some indistinct plant-remains, shells, and a few sharks' teeth and vertebræ, which show the beds to be Cretaceous No. 5. The remains are too poorly preserved to be specifically identified. The genera are as follows:

1. *Gryphæa*, sp.
2. *Ostrea*, sp.
3. *Lamna*, sp. (teeth).
4. *Galeocerdo*, sp. (teeth).

The strata have a slight dip (5°) northerly; and a little to the north, where the thin-bedded sandstone only is visible, the beds are horizontal or dip slightly to the south. A mile or two farther, *i. e.*, west, we meet several outcrops of a dark ocher-yellow sandstone, in which some pipe-stem calcareous fragments suggested those found at Hopley's Hole. A few indistinct vegetable remains were also obtained, but nothing characteristic. The slight dip is reversed in a subsequent exposure, showing an extremely low fold, the meaning of which will be explained later. Following these are a series of bluffs, sandstones, or sandy shales, some of which we were enabled to visit. None of them afforded us any fossils. Over these, we noticed a few washed exposures of white and cream-colored clays.

These doubtless all belong to the Upper Cretaceous, though, in view of their very slight dip, it would require more time than we had at our disposal to make out their exact stratigraphical relations. In general, it may be said of these sandstone bluffs that they are more tilted as we approach the mountains, and seem to owe their position to the forces which threw up this range of hills.

On reaching the Forks of the Musselshell, we come into a more attractive region. From the Judith Gap to this point, the prairie is almost a desert, dry and parched, and the grass very thin. Both branches of the Musselshell River, however, are fine running streams, and at their union the alluvial country is wide and susceptible of profitable cultivation. Just before reaching the Forks, we passed a ranch where a system of irrigation had produced excellent agricultural results.

From the Forks our road took us along the north branch of the Musselshell River, and two miles beyond we entered the Musselshell Cañon. The open country here is rough, and is characterized by many step-like ridges of sandstone, on one side steep, showing the edges of the strata, and on the other sloping off gradually, and covered over with grass.

MUSSELSHELL CAÑON TO CAMP BAKER.

The Musselshell Cañon divides the Little Belt Mountains from what is called the Elk Range. It is a narrow mountain-ravine, with steep hills on both sides, which sometimes approach very closely together, and again recede, giving room for a little strip of green meadow-land on the border of the stream. It is, throughout its length of eight miles, very picturesque, especially near the eastern end, where the abrupt walls and buttresses of white limestone contrast strongly with the dark-green foliage of the pines and spruces. All together, it was a most delightful relief from the parched alkaline prairie on which we had made our camps for the preceding fortnight. The waters of the stream are clear and cold, and abound in what is apparently a species of *Coregonus*. This fish rose readily to a fly, affording to some members of the party fair sport, and furnishing a very agreeable variety to the sameness of our daily fare.

On leaving the open country and entering the cañon, we came abruptly upon the Carboniferous rocks. A band of red clay a few feet wide is quite conspicuous at its eastern opening, followed by several others less striking and quite narrow, all red or ocher-yellow. These are interstratified with a sandstone which contains great numbers of *Ostrea congesta*, Con., as identified by Mr. Whitfield. These dip west 50°. Immediately following these are successive layers of limestones and slates, and then several hundred feet of limestone.

From the former beds the following fossils were obtained:

1. Bryozoan (undescribed).
2. *Aulopora*, or bases of *Syringopora*.
3. *Zaphrentis centralis*, Ev. & Shum.
4. *Productus semireticulatus*, Mart.
5. *Productus muricatus*, N. & P.
6. *Productus*, sp., probably young of *P. punctatus*.
7. *Productus*, sp., approaches forms referred to *P. Prattenanus*.
8. *Productus multistriatus*, Meek.
9. *Athyris*, sp.
10. *Pinna Ludlovi*, Whitfield (n. sp.).

The overlying limestone-beds all dip like the others, a little south of west, 50° to 60°. These limestones form a number of high vertical walls and isolated towers, which are worn out into a variety of fantastic forms which have already been alluded to. These are especially conspicuous on the north side of the stream, though similar walls are seen too on the other side in the line of the strike. This limestone is very cherty, the fragments of flint being numerous; and it is to their presence that the rock owes the peculiar forms in which it now appears. The walls show no evidence of structure or stratification. They abound in little cavities and holes, often partially filled with stalactitic masses of carbonate of lime, showing the extent to which the solvent action of water has worked upon them.

A similar relation of the rocks was observed on the upper slopes of the Bridger Mountains; that is, the series of bright-red indurated clays, with a little Cretaceous sandstone, followed by thin layers of limestone full of Carboniferous fossils, and then 500 feet or more of a firm cherty limestone, weathering out into walls showing no stratification and rarely containing fossils. The limestones are overlaid by (Jurassic and) Cretaceous and underlaid by Silurian. The similarity in the succession of the beds makes it quite certain that the *underlying* rocks at the entrance of the Musselshell Cañon are really the youngest, forming the upper part of the Carboniferous series, while the rocks which follow and overlie, apparently conformably, are older, and, in part at least, Lower Silurian.

The later layers of the limestone, going west through the cañon, have a somewhat different look from those seen farther to the east, being darker-colored and more uniform in appearance. Leaving the limestone, we passed over perhaps a quarter of a mile without finding any rock in place, though on the hill-slopes to the south masses of a hard, reddish quartzite indicate the presence of this as a member of the series. The next exposure reached was an argillitic slate, with veins of quartz, also dipping westerly. The hills for a considerable distance are rounded and covered with grass, exposing no rocks within the limits that we were able to cover.

The prevailing rock, as we continue up the cañon, following the course of this branch of the

Musselshell, is a clay-slate, of which there must be a very great thickness, interstratified with some sandstone-beds. The central portion of the range is trachyte, which is very abundant, forming a series of high hills and seriously interrupting our observations in the succession of the strata. Occasional outcrops of sedimentary rocks, principally slates and shales, appear; but as they contained no fossils, and as their succession was everywhere interrupted by the trachyte, their relations to what had preceded remain very uncertain. On the whole, the cañon gives a very fair exposure of the successive rocks, and to one who could do more than take passing notes in riding through it would no doubt yield some important facts.

Leaving the cañon, we emerge into an open rolling country, covered with grass, and with few exposures of the underlying rock. This, as far as could be observed, was a yellowish fragmentary slate, with occasional veins of quartz and calcite. A number of openings have been made by individuals prospecting for metal, but only faint indications of copper were observed. At Copperopolis, a mine has been sunk some 40 feet into this slate, and some very fair copper-ore and a little silver ore are being taken out. The mine is being worked on a very small scale indeed, only two men being engaged in it; but the ore obtained is sufficiently valuable to pay its way to the East, where (at Baltimore) it is smelted.

Near this point we pass the divide, and descend rapidly to the valley of Deep Creek, leaving the Musselshell behind us, and striking waters that flow into the Missouri near Sun River; that is above Fort Benton.

The valley of Deep Creek, though here somewhat narrow, becomes rapidly wider as we follow it down to Camp Baker. It is a fertile alluvial plain, and is no doubt susceptible of successful and profitable cultivation. There is as yet, however, no market for cereals in the vicinity, and the grassy meadows are given up to large herds of cattle, which range at will over the valleys and foot-hills. Every settler owns some cattle and horses, and these require little or no care, even in winter. The inhabitants state that they cut no hay for the winter-consumption of their stock, nor do they build stables or shelters for them at that season. The animals are said to run out all winter and to keep fat on the standing hay. Montana beef has quite a reputation for excellence west of the Missouri, so that the raising of cattle is likely to prove the most profitable pursuit for the settler until railroads shall have supplied him with a market for other products. Deep Creek, like most of the streams in this neighborhood, abounds in delicious trout and grayling (*Thymallus*), both of which attain a large size, sometimes weighing three pounds and more.

To our left, as we come down the valley of Deep Creek, we have the Elk Range high above us, the summits of which consist of trachyte. This has taken many curious forms, as pinnacles and towers, which rise above the timber, and give to the hills a very castellated appearance. An outcrop of purplish-red slate to the left of the road, and dipping 40° southerly, deserves to be mentioned, as its exact counterpart was seen at Camp Baker, sixteen miles distant, there overlying the Potsdam limestones. To the right, that is west, were a series of limestone ridges with masses of trachyte interstratified. These beds of trachyte have all the appearance of sedimentary rocks at a distance, so entirely do they conform to the uptilted beds of limestone. These latter have a dip of 40° to the southwest. They have the appearance of the Potsdam limestone beds just spoken of as occurring at Camp Baker, and since, if continuing, their strike would make them appear there, it is hardly to be doubted that they too are Silurian.

The Sulphur Springs are about 17 miles from Copperopolis, and lie at the point where the road to Camp Baker turns at a sharp angle to the west. The springs have a temperature of 150° or thereabouts, and are strongly impregnated with sulphureted hydrogen. They are quite well known through the Territory, and are believed to have the beneficial effects generally ascribed to similar springs, and to be especially valuable in cases of rheumatism, a complaint very common among miners. Considering the vast trachytic upheaval which has taken place in that vicinity, the presence of hot sulphur springs can hardly excite surprise.

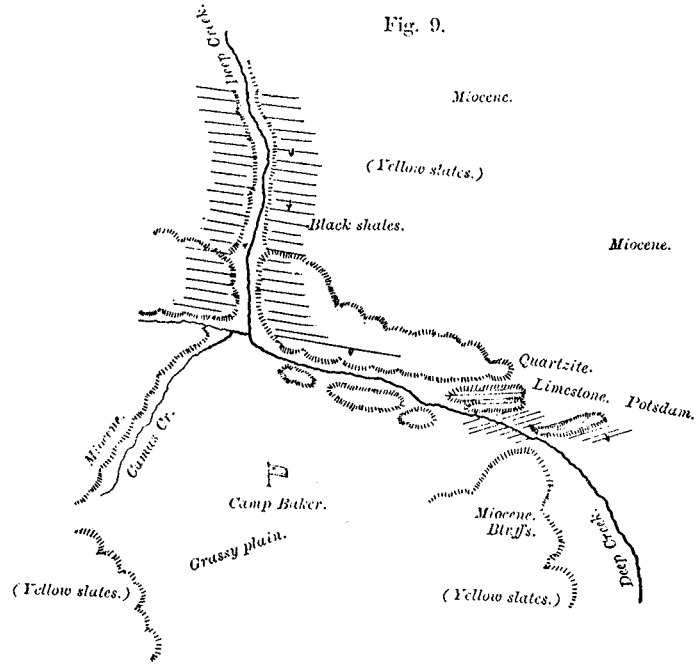
From the Sulphur Springs, the road continues west, at the foot of the Big Belt Mountains, crossing a wide grassy plain, which has an even, uniform slope up to the edges of the hills. The stream, some ten miles from the springs, where Newland Creek joins it, runs through a gorge of porphyritic trachyte with a distinct columnar structure. This rock borders the creek for some distance, and the dike runs across the road, continuing on in a northerly direction. From here a

march of seven miles took us to Camp Baker; the road passing along by bluffs of Miocene Tertiary, to be described later.

CAMP BAKER.

At Camp Baker, where we made a short stay, we were the recipients of most kind hospitalities from the officer at that time in command there, from whom also we received valuable information in regard to the surrounding country. During the time spent at this point, we were enabled to make an imperfect reconnaissance of the immediate vicinity. The descriptions given below may be better understood by reference to the following cut (fig. 9):

Fig. 9.



Camp Baker lies in a broad plain, which is surrounded on all sides by mountains, of which the Big Belt to the south are the most conspicuous and highest. We are here on the eastern border of the mountain-region, which extends far to the westward. The valleys of Deep Creek and its tributaries are filled with deposits of Miocene Tertiary. These consist for the most part of homogeneous cream-colored clays, so hard as to be with difficulty cut with a knife. The lower layers are generally more loose and homogeneous, while the upper beds are harder, firmer, and sometimes quite calcareous. Some of the upper beds are remarkable for the large number of white clay concretions which are found in them.

The beds are horizontal, and rest unconformably on the somewhat upturned yellow and red slates below; the clays of which they are formed resemble closely those of the Miocene beds at Scott's Bluffs near the North Platte River in Wyoming. The deposits at Camp Baker have been extensively denuded, and nowhere reach any very great thickness. At a point about three miles southeast of the post, some bluffs were noticed where the Miocene beds attained a thickness of 200 feet, and these were capped by 50 feet of Pliocene clays, both beds containing characteristic fossils.

We saw the first exposures of these beds a few miles west of the Sulphur Springs, just after crossing the high ridge of trachyte before referred to, through which Deep Creek flows. From here, the lake-bed was traced continuously along Deep Creek for a distance of fifteen miles. Beds of the same character, containing fossils, were found on Spring Creek to the east, on White-tailed Deer Creek, about seven miles to the north of Camp Baker, as well as on Camas Creek to the southwest. On Camas Creek, the beds are exposed for a mile or more in bluffs ranging from 20 to 25 feet in height. The exposures on White-tailed Deer Creek are much more extensive than those last

mentioned. Those on Camas Creek are in thick, rather indistinct, layers, and contain more or less bluish sand in irregular layers, and sometimes a little coarse gravel. Traces of this deposit, containing what appear to be remains of *Rhinoceros*, were also observed two miles or more south of Moss Agate Springs (to be referred to later), and at a considerable elevation above the creek-bed. With more time than we had at command, they could, no doubt, have been traced much farther, although in many places the beds have been washed out, or have been covered by the later local drift.

In the Miocene beds were found a species of *Rhinoceros;* several species of *Oreodon*, Leidy, and *Eporeodon*, Marsh; a canine tooth apparently of *Elotherium*, Pomel; and remains of Turtles. In the Pliocene beds, the principal fossils were a species apparently of *Merychyus*, Leidy; remains of an equine smaller than the modern horse; and Pliocene Turtles. These fossils have not yet been carefully studied, and, for this reason, their relation to the remains found in the other lake-basins of similar age cannot here be stated. The line of separation between the Miocene and Pliocene beds is, in some places, well marked. It consists of about six feet of hard sands interstratified with layers of very small, water-worn pebbles, soldered together into a hard mass. Each of these layers is about 6 inches in thickness. Immediately above these strata, the Pliocene fossils were found.

It is known that in the neighborhood of Fort Shaw, and near Helena, Pliocene deposits exist; and near Fort Ellis, and in the valley of the Yellowstone, we saw, but were unable to examine, gray sands and marls, which Dr. Hayden refers to the same age. No Miocene beds, however, have been identified at any of these localities. It seems probable that, in Pliocene time at least, the Baker Lake may have extended north to the Missouri River, and perhaps up that stream to the "Three Forks", thus connecting with the lake which existed near Fort Ellis. Indeed, it would seem that we just touched upon the southern edge of this basin, which may have extended far to the north and west.

An interesting point in connection with these deposits is the fact that, with the exception of one deposit in Colorado, they are at a much greater elevation than any other beds of the same age now known on the continent. The elevation of the White River beds is about 3,000 feet, and that of the Oregon basin somewhat less; while that of the deposits near Camp Baker is over 5,000 feet.

On the east side of the plain on which Camp Baker stands, the Miocene has entirely disappeared. It is to be noticed that these Tertiary beds were deposited after the elevation of the older rocks, and that most of the denudation now visible in these rocks must have been accomplished before the deposit of the Tertiary, as it is repeatedly seen filling the depressions and unevennesses in the slates, as also covering over the ridges of trachyte. Underlying the Tertiary, and tilted up at a small angle, appear a series of yellow slates and shales, which are quite generally distributed in this region, though not seen elsewhere. They are seen generally as a fine-grained slaty rock, friable and weathering readily, so that exposures of the rock in place are rarely found. Occasionally, there are observed in them immense black concretions of remarkable structure. In the interior, these consist mostly of a calcareous clay, very hard, and showing distinctly what is called the cone-in-cone structure. Outside of this, the lime is purer, though lying in concentric layers, and the exterior shell is made up of fibrous calcite half an inch in thickness. The clay cones radiate from the center of the concretions.

The slates are destitute of fossils, and their age is only a matter for conjecture. The most remarkable feature connected with them is that they have, in spots, a bright brick-red color; thus, in riding over the country, a patch of intensely red-colored soil will be seen here and there, strongly suggestive of the burned lignite beds of the Missouri River. The slate has at such points the appearance of burned pottery; the material being harder and firmer than the surrounding rock. In some cases the red color was uniform in the rock; but generally it was distributed in successive bands, as though produced by the action of hot water. The red patches are quite local, and seldom cover more than a few square yards, though in one case they were seen extending along a range of hills for a hundred yards or more. That the effect produced has been caused by the action of heat cannot be questioned, though under what conditions no attempt is made to conjecture. As has been said, these shales and slates are tilted up unquestionably; but their exact relations to the underlying rocks could not be made out without more opportunity for investigation than we had.

The difficulty in settling the matter arose from the fact that the loose shale seldom showed its true position.

We find this formation in the immediate vicinity of Camp Baker, both to the east, where it forms high hills 250 feet above the plain, also to the south and west, where it is intersected by some dikes of porphyry, and quite extensively below in the valley of Deep Creek, as well as along the valley of White-tailed Deer Creek. Its general distribution seems to conform to a certain extent to that of the Miocene Tertiary that is filling the valleys between the older rocks.

The older rocks alluded to form the ranges of hills conspicuous about Camp Baker. Immediately north of the post lies a range of hills, having an east and west trend, through which Deep River takes its course by means of a cañon, which gives an excellent section of the rocks of which the hills are composed. The rocks all dip south, and this dip continues the same for a mile or two to the north. South of the range alluded to, and close to the post, are several minor hills, and, at a distance, a series of others all singularly alike in appearance. The section of rocks alluded to is as follows:

Quartzite	20 feet.
A series of colored shales, chiefly red, but also green and blue, with a bed of trachyte interstratified	150 feet.
Two ridges of limestone, in all	80 feet.

These limestones show abrupt bluffs to the north, and dip southerly. In the northernmost of the ridges were found—

1. *Crepicephalus* (*Loganellus*) *montanensis*, Whitf. (n. sp.);
2. *Obolella*, sp.?;

identifying the formation as Potsdam, according to Mr. Whitfield. Following this is a quartzite, which forms the south side of the hill alluded to. The section is continued through the cañon: quartzite 40 feet, firm and solid, with a reddish tinge of color, breaking into massive blocks; underneath is a series of bright green slates, followed by a variety of clay-slates, mostly dark-colored, with occasional beds of hard solid quartzite and some thin layers of limestone. After half a mile, the ridge is passed, and the stream comes out into the open country. The rocks, for a mile or two, however, are mostly the same in dip, and are conformable. They are chiefly dark blue shales.

The appearance of the quartzite hills in this neighborhood is peculiar, as they all have a gradual slope to the south, but are nearly vertical toward the north, on which side there is at their foot a talus of large cubical blocks of quartzite.

We were unfortunately not able to visit the Big Belt Mountains.

CAMP BAKER TO FORT ELLIS.

From Camp Baker, the party marched to Fort Ellis; the road for a short distance being the same as that before traveled. The road passes to the right of the Elk Range. Twenty miles from Camp Baker, we reached the extremity of this range. At this point, we passed immediately from the grassy meadow onto the older rocks. Here we found first a red shale similar to that at Camp Baker, and also to that observed higher up, four miles the other side of the Springs. This was followed by a heavy massive quartzite, a little reddish and very firm; and overlying this was a considerable thickness of limestone. This last is well exposed just above Moss Agate Springs, and in some of the layers we found an abundance of fragments of *Trilobites*. The limestone is much of it very cherty, and in many places it formed the same abrupt and peculiar shapes noticed elsewhere. Just above Moss Agate, there is a little superficial synclinal fold in the limestone, the axis of which has an approximately northeasterly direction. Moss Agate Springs takes its name from the fragments of flint, chalcedony, and agate, which are common on the adjoining hills, and many of which, from the presence of the arborescent forms of psilomelane, are popularly called "moss agates".

These fragments of silica are evidently from the limestone, and are quite characteristic of it. Similar fragments of chalcedony, though without the moss effect, were found abundantly in some of the little hills just by Camp Baker. The limestone is evidently the same as that, as is moreover proved by its association with the quartzite and by the few fossils found in it; these were all of one species, a new *Trilobite*,—*Arionellus tripunctatus*, Whitf. (n. sp.).

The road from Moss Agate passes, it is true, more or less at the end of the hills, but at such a distance from them as to afford but little opportunity for observation. From a distance, it is observed to how great an extent the hills are made up of limestone, with the conspicuous trachytic prominences before mentioned. From the limestone, we pass immediately to a dark, somber sand, stone of granular texture and quite peculiar in appearance. This had a dip to the west, and contained some indistinct plant-remains.

On our return journey, we found time to touch at the southeastern extremity of the same hills near the source of Flathead Creek, and here we passed directly from sandstones resembling the one spoken of to the limestone exactly similar to those so often observed at various points in this range. It agreed in all respects with the other exposures. A few indistinct fossils were obtained from a loose block, which had evidently come from close at hand, and these show it to be Carboniferous. They were identified by Mr. Whitfield as *Spirifera centronata*, Winch.

The country near the branch of Deep Creek on the south side of the Elk Range is attractive and covered with good grass, supporting large herds of cattle; but, after passing the low divide which separates the above-named stream, a tributary of the Missouri, from Shields River, a branch of the Yellowstone, a more or less decided change is observed. The prairie is here dry and barren, especially to the south of Cottonwood Creek, and supports nothing but a thick growth of sage-brush. It is watered by several running streams beyond Sixteen-mile Creek, of which Cottonwood is one of the most important, in view of the fact that its banks are fringed with fine trees, from which it takes its name.

As we approach Bridger's Pass, the character of the country improves again, and the large numbers of cattle met with near this point indicate its capabilities in the way of grazing. Of the geological relations of this part of the road, we saw little on our way south. While returning, however, our opportunities for observation were better, and the results are presented immediately below. Bridger Pass is a high mountain-divide, thickly wooded, and with the high limestone cliffs of the Bridger Mountains overhanging it on the west side. The scenery is fine, and the change from the bare prairie to the grateful shade of the wooded mountain-side is gladly welcomed by the traveler Geologically speaking, the prevailing rock is the dark sandstone described later, and known to belong to the Upper Cretaceous. The position of the strata is nearly vertical. An occasional dike of igneous rock was observed, and one of these was conspicuous on the north side of the pass. It consists of a greenish basalt in spherical nodules, separating in the fracture into successive thin slabs. High above the road, as we approach Fort Ellis, we noticed the horizontal strata of the Pliocene Tertiary, which, according to Hayden, extends far away toward the west.

From Fort Ellis, the party extended their trip into the Yellowstone Park. We introduce here, however, the additional observations made on our return-trip through the country just mentioned.

BRIDGER MOUNTAINS.

On our return to Carroll from Fort Ellis, early in September, we encountered much trouble at first from the condition of the roads, which were almost impassable, owing to the unprecedented amount of rain that the country had recently received. We made use of the delay which this occasioned in the movements of the wagons, to make a little exploration of the Bridger Mountains, or East Gallatin Range, as it is sometimes called. These observations could not be extended beyond the east side of the range, and hence are only fragmentary. Considerable time was devoted to the same mountains by Dr. Hayden and his parties in 1871 and 1872, and reference may be made to his reports for those years for the facts observed by them.

This range of mountains is especially conspicuous as viewed from the east side, rising up steeply from the deep and narrow valley, and terminating in a nearly perpendicular white wall, with a sharp knife-edge for its summit. We ascended the ridge from two points: first, September 4, from a point in the valley below, about six miles from Fort Ellis; and, again, September 5, from our camp, a short distance to the north side of the divide in the Bridger Pass.

The rock of the valley, and indeed of the pass, as far as observed, is a sandstone of somber tints, gray, brownish, or greenish. The texture is generally granular and gritty, and the rock is more or less speckled with grains of quartz and feldspar. In general, it may be said to be a sand-

stone ma from poorly-assorted materials. It contains, in some layers, impressions, generally indistinct, of vegetable remains. It is referred, as a whole, to the "Coal Series", by Dr. Hayden; and he further estimates its thickness at 10,000 feet. This seems to us considerably to exceed the truth. We found the same series of sandstones extending in a number of wide folds over the prairie to the north; and this would make it probable that even if there be a thickness of 10,000 feet of vertical strata belonging here, it has been formed by the pressing together of an anticlinal fold parallel to the range of mountains. This is the more likely, as the strata of the beds all dip steeply, and are often overturned, the dip being reversed.

Ascending the hills from the point first mentioned, somewhat north of the Bridger Peak, we passed for a long distance through the timber, crossing, here and there, little open parks and valleys, up to the foot of the range proper. Up to this point, we had seen but few exposures of rock, and those similar to the sandstone already described. The section observed from this point to the summit is as follows: Red earth and clay, with occasional masses of indurated red clay, seldom showing any stratification; in all, 60 feet. Following this, and, in its present position, overlying, though, in fact, geologically, underlying it, is a thick-bedded sandstone, dipping 60° west; strike north 20° west. This rock was mostly yellow and ferruginous; its texture gritty, at times becoming a mass of coarse pebbles. Occasional layers were calcareous, and contained multitudes of indistinct Cretaceous shells (see list below). These often yielded to the weather, the rock becoming then rusty and cellular. The visible thickness of this deposit was 40 feet. Then, after a small interval, follows a firm, blue, compact limestone; the first layers containing a few Jurassic fossils, and those following the same in greater numbers (see list below). The thickness of this bed is about 60 feet. Following this is a sandy limestone; and then comes the Carboniferous limestone, which forms the remainder of the upper part of the hill for a distance of 700 or 800 feet, the total thickness of these strata being perhaps 500 feet. This limestone has the same massive and, on weathering, structureless character remarked elsewhere. Some layers seem to be a conglomerate of fragments cemented together by a calcareous paste. Thin layers of dark flint, two or more inches in thickness, are common, running irregularly through the limestone blocks, and also isolated masses of the same rock of greater or less size. At the summit, the dip is 70° east. Fossils were not common in this rock; those found were chiefly corals. Continuing along the narrow summit for some distance toward the north, all the time on the solid limestone, we found its dip varying considerably from east to west. On descending, a band of red clay was passed over at the foot of the compact limestone, and calcareous layers interstratified with it contained some Carboniferous fossils. The dip here was west. This is the same band noted on the succeeding day, and to be described farther on. In other respects, the return trip added nothing to what had been before observed.

On the following day, the ridge was ascended again from a point some eight miles beyond; but it did not yield us the complete section of the rocks that we had hoped for. The approach to the mountains was, for the most part, of necessity through the timber; the rock appearing but seldom, and this the dark-colored sandstone before noted. What was observed here would not enable us to do more than guess at its total thickness. Emerging into the open ground, high up on the range, we came upon a high ledge of a very massive, coarse sandstone, or rather a conglomerate. The strike was north and south, and the dip east 35°. The thickness actually exposed was small. Rising 500 feet from here, we found a series of limestone exposures mostly covered with grass. They yielded some Jurassic fossils, similar to those obtained the day before. The rock following was, as before, a white, sandy limestone, sparkling in the sun, and without fossils; then appeared the Carboniferous limestones.

The point we had now reached is conspicuous from all parts of the surrounding country, being marked by two lines of deep red, like bloody gashes, in the side of the mountain. These red bands, though narrow, may be traced along the east slope of the hills for a considerable distance north and south, and form quite a striking feature of the range. The lower bed, made up of an indurated red clay, was only 4 feet in thickness; but the color was very intense. Interstratified with these bands was a small thickness of variegated limestone, generally purplish, sometimes vermilion or greenish. This limestone abounded in Carboniferous fossils; not infrequently the shells occupied the center of little grayish circles in the reddish rock. These soft red bands have generally yielded

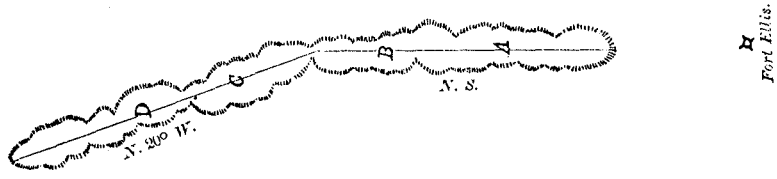
to denuding influences, and the point where we stood was a narrow neck of land with a deep gulf opening below us to the south and southeast.

From here to the summit, we were on the massive Carboniferous limestone containing corals and crinoidal plates, with here and there a *Spirifera*. The summit of the ridge attained here was considerably higher than that previously ascended, and was evidently as high as, or higher than, any neighboring point north or south. The aneroid barometer indicated that the height was in the neighborhood of 10,000 feet. The higher points of the summit were thickly covered with snow, on which were lying thousands of dead grasshoppers; and in many places we saw the tracks of the grizzly bears which had ascended the range to feed on these insects.

The prospect from this point is exceedingly grand and extended. The ridge, as has been remarked, is, at its summit, extremely narrow, coming to a sharp knife-edge, and the view is unobstructed in all directions. Nearly north and south stretch the irregular summits of this rugged range, while on either side the eye sweeps over the open prairie till arrested by the mountains which rise above the plain. To the east, the Crazy Woman's Mountains are most conspicuous; to the south, the ranges near the Yellowstone River; and westward, the rich Gallatin Valley extends to the "Meeting of the Three Waters"; and far beyond were the Bitter Root Mountains. At the foot of the abrupt cliffs on which we stood was a little mountain lake, far below us, though seemingly at our very feet. With its deep-blue waters, it was prettily set off by the white limestone cliffs above and the dark pines inclosing it on the farther side.

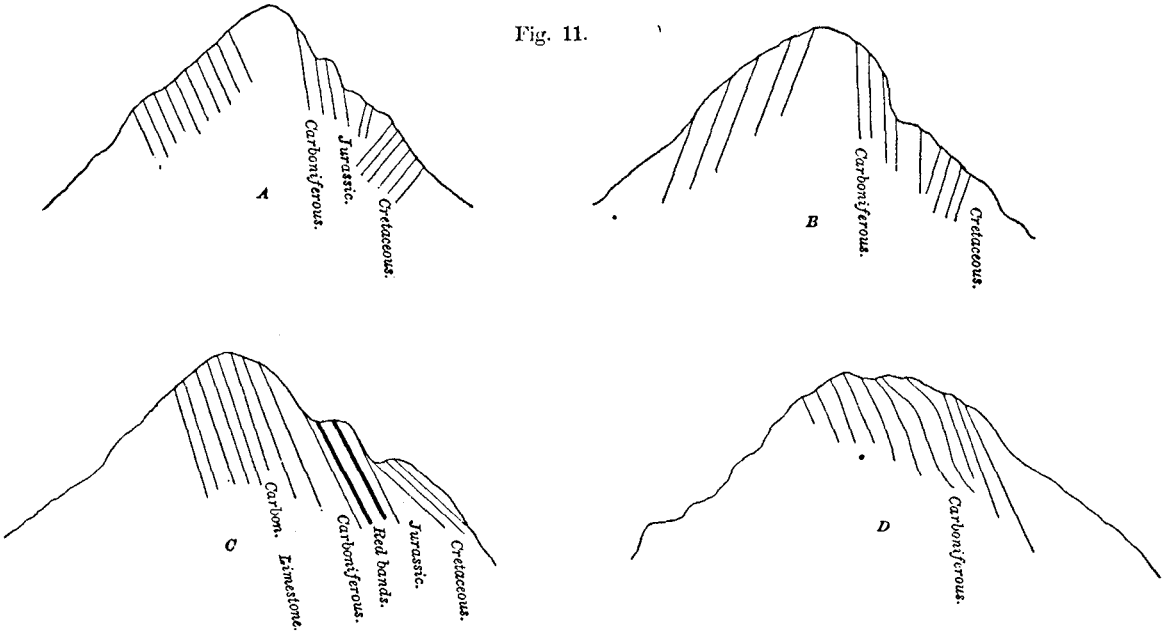
The following cut (fig. 10) will give some idea of the general trend of the summit of the range. The points lettered (A, B, C, D) refer to the cuts which follow, showing roughly the dip of the

Fig. 10.



strata where indicated. No special importance is attached to these, except as showing the irregularity which exists at different points. The younger rocks lie on the east side, the Carboniferous

Fig. 11.



limestones form the summit, and the older rocks are on the west, with a reversed dip. We were unable to extend our observations below the summit, and hence have nothing to add in this relation to what is given in the reports already referred to.

The following is a list of the fossils obtained during our examination of these mountains, as identified by Mr. Whitfield:

Cretaceous, September 4 and 5.

Ostrea congesta, Con., associated with fragments of carbonized wood.

Jurassic, September 4 and 5.

1. *Camptonectes extenuatus*, Meek.
2. *Camptonectes bellistriata*, Meek.
3. *Myacites (Pleuromya) subcompressa*, Meek.
4. *Myalina (Gervillia) perplana*, Whitf. (n. sp.).
5. *Gervillia erecta*, M. & H.
6. *Gervillia sparsaradiata*, Whitf. (n. sp.).
7. *Gryphæa planoconvexa*, Whitf. (n. sp.).

Carboniferous, September 4.

Summit.

1. Cyathopylloid coral.
2. Crinoidal plates.
3. *Platycrinus*, sp. ?.
4. *Spirifera centronata*, Winch.

Limestone interstratified with the red bands.

5. *Productus nebrascensis*, Meek.
6. *Chonetes mesoloba*, Norwood & Pratten.
7. *Athyris*, sp. ?.

Carboniferous, September 5.

Summit.

1. *Cystiphyllum*, sp. ?.
2. *Campophyllum*, sp. ?.
3. *Campophyllum torquium*, Owen.
4. *Chætetes*, sp. ?.
5. *Zaphrentis centralis*, Ev. & Shum. ?.
6. *Syringopora mult-attenuata*, McChes.
7. *Spirifera centronata*, Winch.

Limestone interstratified with the red bands.

8. *Spiriferina Kentuckensis*, Shum.
9. *Athyris planosulcata*, Phil. ?.
10. *Athyris subtilita*, (H.) Meek.
11. *Rhynchonella Osagensis*, Swall. ?.
12. *Streptorhynchus crassus*, M. & W.
13. *Productus punctatus*, Mart.
14. *Productus costatus*, Sow.
15. *Productus Prattenanus*, Norwood.
16. *Productus cora* ?, or perhaps *P. Prattenanus*, Norwood.
17. *Productus*, sp.; may be *P. nebrascensis*, Meek.
18. *Chonetes mesoloba*, N. & P.
19. *Chonetes granulifera*, Owen.
20. *Euomphalus*, sp.

FROM THE BRIDGER MOUNTAINS TO THE FORKS OF THE MUSSELSHELL.

We camped September 5 on Cottonwood Creek, and made from here a short excursion to the west of the road. The main valley of Shields River is a synclinal, lying between the Bridger Mountains and the Crazy Woman's Mountains, with an axis pointing in a direction about north 20° west. In the valley, the rocks are rarely exposed; but riding up the creek, two or three miles from the road-crossing, we find the rocks dipping 30° east, with the strike north 30° west. The exposures here show a friable sandstone, disintegrating readily. The rock has a dark, somber appearance, and is made up of a greenish or brownish base, with small grains of quartz and a little

feldspar. For a distance of two miles, the inclination remains the same; the rock standing up in a series of wave-like ridges, all having an abrupt side toward the west, and a gradual slope to the east. Looking from the eastern side, the existence of the abrupt rock exposures would hardly be expected, so gradual is the rise of the grassy slopes. From the west, on the contrary, the eye is immediately struck by the remarkable series of hills with precipitous fronts.

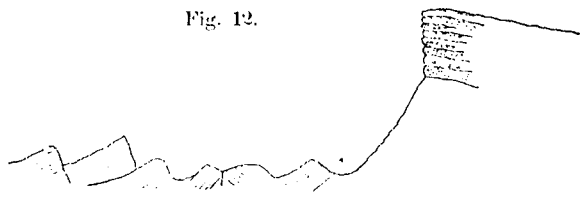
Some five miles from the road-crossing, there is a sudden change of dip, and as sudden a return to the easterly direction: this is very probably a local change, occasioned possibly by a dike of igneous rock noticed at that point. The rock is here generally a sandstone, answering more or less closely to the description given above, sometimes a sandy slate, sometimes a whitish-gray sandstone. At the headwaters of Cottonwood Creek, about six miles from the road, we found an exposure of a brown sandy slate, full of fucoidal remains, and containing a few indistinct shells. As this rock is apparently one of the lowermost layers in the group of rocks being described, these fossils are of interest as furnishing a clue to the thickness of the strata. The fossils are very poorly preserved, but have been identified by Mr. Whitfield as follows:

1. *Crassatella*, sp.
2. *Crassatella*, near enough to *C. vadosa*, Morton, to have come from New Jersey.
3. *Inoceramus*, sp.
4. *Pholadomya*, sp.
5. *Gryphæa*, sp.
6. *Panopæa*, sp., very near *P. occidentalis*, M. & H.
7. *Scaphites larvæformis*, M. & H.

Scaphites larvæformis is regarded as characteristic of Dr. Hayden's No. 2. Above this bed there must be 5,000 feet of rock belonging to the Cretaceous, though referred in part by Dr. Hayden to the Coal Group.

At the point mentioned we pass a deep grassy valley a few hundred feet in width, and on the other side rises a long range of high bluffs 100 feet above, and extending for a mile or more (see fig. 12).

Fig. 12.



The rocks are exposed for a height of from 10 to 50 feet in the perpendicular eastern front of the bluffs, and form a feature of the country quite conspicuous even from a distance. The rock is a brown and gray sandstone in alternate layers, with occasional slaty bands. The dip is here westerly, it being the under part of a very long and low fold. From the summit, quite a good view is obtained to the west; the bluff has an abrupt front both to the east and northwest. The valley alluded to occupies the position of the axis of the anticlinal, and the fold itself is a continuation north of the folding which took place in the Bridger Range.

Turning north from here, we crossed the divide a mile beyond, and came into a long valley which trends a little west of north. The rock observed here was a brownish-yellow sandstone, with a clay-shale underlying it, and is undoubtedly Cretaceous, though containing no fossils. The valley alluded to drains into Sixteen-mile Creek. We followed it for a distance of ten miles, keeping along with the strike of the rocks, and found it abundantly covered with thick grass, or rather at this season with hay cured in the ground, which could afford grazing for multitudes of cattle. Turning again easterly, across the strike of the rocks, we cross a long series of wave-ridges dipping east as before, and much resembling those previously observed. A very white fine-grained sandstone forms a series of bluffs not much west of the road.

The valley of the south branch of Deep Creek is wide and level. On the northeastern side, where the road to the Forks of the Musselshell turns off to ascend the divide, there is quite a high ridge, extending from the end of the Elk Range across toward the Crazy Woman's Mountains. This valley is obviously, like its continuation below, a synclinal, for the strata dip sharply to the west 70°, the strike being the same northwest. The same dark-colored sandstone forms the first layer: this is underlaid by a sandy slate with large clay cannon-ball concretions. From here on for a mile, the dip is continuously westerly, there being the same series of wave-ridges observed before,

only here the dip is reversed, and the abrupt side is toward the east. The strike remains the same, but the dip is gentler, averaging 40°. After some 5,000 feet of strata, the dip is reversed. An exposure of rock on the east side of the trail shows a laminated sandstone, generally soft and friable, but in some places very hard. The dip of the first layers is 30°, and this increases as we proceed to 45°, the inclination being here toward the east or northeast. A mile farther on, near the head of Flathead Creek, we notice another fold. The rock is here a soft yellowish sandstone, dipping west at a small angle, 15° to 20°. This contained many oval clayey concretions, and in the seams in the rock there was more or less calcite. Ripple-marks were noticed in one or two places. Still farther on, the opposite side of the fold is seen, and here it appears that the dark-green and gray rocks seen just after leaving the south branch of Deep Creek underlie the soft yellowish sandstone observed near Flathead Creek. For a mile or two more, we pass over the sandstones, chiefly the dark rock, but occasionally noting beds of the lighter-colored. This latter is much cracked and broken, scaling off into platter-like slabs, so that good exposures of it are seldom seen. Another fold is passed over just before reaching the broad valley of Norton's Creek. We have thus the indications of three great folds between South Deep Creek and Norton's Creek, a distance of ten miles in a straight line. The strike varies from north to west, the dip is generally as much as 40°, and sometimes much more. A mile or two before reaching Norton's Creek, we pass to the left of a high butte formed by three narrow dikes of eruptive rock, seemingly conformable to the sandstone.

At Norton's Creek, the country changes a little more, and we come upon a broad fertile synclinal valley. In this neighborhood, igneous rocks, before rare, beome very common, and beds of trachyte and basalt are repeatedly seen interstratified with the sandstones. The most conspicuous example of this is just to the west side of the meadow through which Norton's Fork flows. Here is a bed of trachyte apparently conformable to the sandstone, and evidently having been erupted between two layers of that rock. It has a semi-columnar structure; the heads of the columns pointing toward the east, thus appearing as if it dipped west, though in reality the sedimentary rocks have an inclination in the opposite direction. In the broad meadow of Norton's Fork, a number of isolated buttes of trachyte may be seen; some of these having taken quite peculiar forms. In these folds, it is seldom possible to trace any single layer of rock, because the characters are not distinctive enough; occasionally, however, this may be done, as in the case mentioned above. A careful plotting of the successive exposures would doubtless show the continuity of the strata, and give an exact estimate of the thickness of the rocks involved, together with the width of each of the folds. This we were of course unable to undertake.

On the east side of Norton's Meadow, the dip is westerly, and the strike northwest. Here a brown sandstone is exposed, followed by a gray trachyte in beds, which, at a distance, look like a solid sandstone, and might easily be confounded with sedimentary rocks. Opposite where the South Fork of the Musselshell is joined by Flathead Creek, is the extremity of a little range of hills, trending northwest, and forming a sort of spur of the Elk Range, conforming in direction to the low folds we have been tracing, and seemingly like one of them, a little deeper, and having brought up lower strata. Following the sandstone, which is without fossils, we have, as we cross the east end of this hill, some beds of red clay, making a red soil, but not apparently very thick. Above on the hill is a hard, red quartzite, in massive blocks, which are scattered over the surface of the slope. On the east side of the hill, near the creek, we have several exposures of a gray and yellow sandstone dipping east, strike northwest, followed by a reversal of dip in the same beds. The rocks here observed are a dark ochery-yellow sandstone, firm, and in rather thick layers, and a whitish sandstone, sometimes in very thin, papery layers, sometimes massive, but not often very firm; much the same association as at Hopley's Hole.

The foldings here are not nearly so extensive as those described before; the thickness of rock involved being perhaps not more than 1,000 feet. Near the hill, the dip is steep; but a mile from it the inclination becomes very gradual, and insensibly the strata subside, becoming nearly horizontal. A slight eastward dip in the white sandstone is, however, reversed before reaching the Forks, where there is a broad alluvial country. This seems to be the dying out of the action which was more intense to the westward. Beyond the Forks, on the road to the Judith Gap (before traveled), the same brown sandstone and white sandstone are seen again, with a slight dip, which is

once more reversed, forming apparently a final fold in our series, though the inclination is so slight that the direction remains uncertain.

Our course along Flathead Creek was very nearly at right angles to the prevailing direction of the strike, so that we had a very good opportunity to observe the relations of the successive folds.

FROM ARMELL'S CREEK TO THE MOUTH OF THE JUDITH.

From our camp on Armell's Creek, a short excursion was made to the mouth of the Judith River; the intention being to make such examination of the country at that point as our limited time would admit of.

The beds at the mouth of the Judith have been explored only once before (by Dr. Hayden), and their age has hitherto been in doubt. We were able to remain but two days in this interesting locality, and the results obtained were of course meager. Enough, however, was seen to establish the age of the beds at this point as beyond a doubt Cretaceous; three members of this division of Mesozoic time having been found there and identified by fossils.

The ravines, which occur so constantly along the Missouri, extend back from that stream but a few miles, except where a river enters it. Tributaries, however, carry the ravines and the accompanying Bad Lands back, sometimes to their sources. The country which may properly be considered as Bad Lands near the Judith is quite extensive, and is of the most rugged and barren character. Each little stream that flows into the Missouri is bordered by a strip of country more or less wide, that is gullied and washed out in deep and precipitous ravines, without vegetation, and generally utterly impassable, except for the bighorn or the wolf.

The Bad Lands on the Judith River extend along that stream for about twenty-five miles from its mouth, and run back from the river for about five miles on each side of the stream. Those on Arrow Creek, which flows into the Missouri a few miles west of the Judith, extend along it for ten or twelve miles back from its mouth, and have an average breadth of four miles on each side of the stream. Those on Dog Creek stretch back into the bluffs for about fifteen miles, running over to meet those of the Judith for about six miles of this distance, and reaching eastwardly nearly over to Armell's Creek, which also has an extensive system of Bad Lands.

The rocks are chiefly sandstone, quite pure, often quite hard, but occasionally so soft as not to cohere in blocks when removed from the beds. Occasionally, thin beds of an arenaceous limestone are seen, and from these a few fossils may generally be obtained. Yellowish sandy clays and marls also occur toward the base of the bluffs, but without fossils, as far as could be seen, and lacking any distinctive features. Much of the lower portion of the bluffs is concealed by deposits of the Fort Pierre beds, Cretaceous No. 4, which occurs all along the Judith River bottom and in many of the ravines, sometimes running far back into the bluffs. These beds agree in all respects with the deposits of that age seen near Carroll, Crooked Creek, and Box Elder. They were the same dark shales, containing the limestone concretions, with *Baculites*, &c., and abounding in the glittering selenite crystals that seem to be peculiar to these beds.

From our Camp on Armell's Creek, we followed the Helena road back toward Camp Lewis for five miles or more, and then, leaving it, took a course a little west of north, and, passing about ten miles to the eastward of the Moccasin Mountains, struck the divide between the Judith and Dog River, by which road alone our point of destination could be reached with the wagons. The time occupied in reaching our camp on the Judith was two days; the distance traveled being a little more than forty-five miles.

At a point two miles north of our camp, on Armell's Creek, an exposure of bare bluffs was noticed, which furnished the following section, from below upward:

	Feet.
Dark-gray horizontally-laminated shales	60
Laminated slightly ferruginous sandstone	12
Soft, whitish clays, about	100
Dark-gray clays, interstratified with layers of impure limestone concretions, about	100
Total	272

The laminated sandstone contains numerous irony concretions, from the size of a pea up to two inches in diameter. These are quite soft, and break readily, showing a concentric structure. The sandstone is much weather-worn. The limestone concretions, on exposure to the atmosphere, crack and break up so that the surface of the bluffs is strewn with their angular fragments. They do not particularly resemble the concretions of the Fort Pierre shales seen near Crooked Creek.

Later in the day, to the northeast of the Moccasin Mountains, we passed over a good exposure of the Fort Pierre clays; and about three miles beyond this, but at a much higher level, were seen about 100 feet of white and yellow sandy clays, capped by a thin layer of fine grained calcareous brown sandstone. This latter was found in place only on the tops of the highest hills. A few shells characteristic of No. 4 were found in the Fort Pierre beds, but none of the other exposures examined yielded any fossils. All the beds seen during the day were substantially horizontal.

The divide along which our road took us is for twenty-five miles a gently rolling prairie, covered with a fair growth of bunch-grass. It is a favorite feeding-ground for the buffalo; but, when we passed over it, only a few of these animals were seen, although signs of their recent presence were everywhere apparent. As we approach the Missouri River, the divide becomes less and less wide and the road more winding. Deep ravines and coulées from Dog Creek and the Judith River run back until they almost meet, so that the road becomes narrow and often difficult. About seven miles from the Missouri River there is a narrow pass, the only approach for wagons to the mouth of the Judith. Here the divide is only 10 feet wide, and on both sides steep and precipitous ravines run off to the east and west. This backbone continues for fifty or seventy-five yards, in which distance it turns and twists sharply every few feet. Sometimes the wagon on one side seems to hang over a precipice a hundred feet in height, while on the other it grinds along against the face of a sandstone bluff elevated a few feet above the level of the road, or it has to be lowered carefully down an almost vertical slope of 30 or 40 feet, and to be dragged painfully up another as high and steep. From this point, a march of four miles over a gently rolling plateau brings us to the final descent into the Judith River bottom. The road down into the valley is long and steep; the difference in height between the top of the bluffs and the level of the valley being 1,200 feet.

The upper 400 feet of the bluffs are composed almost wholly of beds of sand, white and yellow, nearly pure, interstratified with occasional fragmentary layers of a fine-grained, clayey, brown or red sandstone. The beds of white sand contains a few poorly-preserved Unios and the remains of Dinosaurs (*Hadrosaurus*) and Turtles (*Trionyx*). The yellow sands contain many concretions of hard, yellow clay, but are without fossils, so far as examined. All the beds are horizontal, and most of them are quite hard. The white sands in some places change into a laminated white sandstone, and seem to be always overlaid by the brown sandstone. At a lower level, these beds seem to pass into a white, firm, clayey sandstone, which is very hard; but we were unable, in the limited time at our command, to fix the point at which the change took place.

The character of the lowest portion of the beds on the Judith is much obscured by the presence of the Fort Pierre clays in the valley, and by the washing out of the base of the bluffs and consequent dropping down of the rocks above them. This has taken place almost everywhere along the Judith and the Missouri Rivers at this point; and, in consequence of this, the rocks dip at every conceivable angle, and in all directions. A careful examination, however, will serve to convince the observer that all the beds are really horizontal, and that the apparent bendings and twistings of the rocks referred to by Dr. Hayden are due simply to the action of running water. This element has here acted on a scale so enormous as to be almost inconceivable to one who is not familiar with the important part that is played by this agent in denudation in the West.

At a time in the past when the Judith carried much more water than it does at present, the undermining of the high bluffs was constantly going on, just as the higher alluvial banks of the Missouri River are being undermined at present; and, as the lowest beds were washed out, the superincumbent rocks slipped down in vast masses. The process, on a small scale, may be seen every day while ascending the Missouri. Besides this, the water, which in spring, from the melting snows and the early rains, is carried by each of the thousand ravines which we find here, not only washes down the sides of the ridges, but works under the bluffs, often boring for itself an underground passage from one *coulée* to another. Such passages increase in size annually, and finally become so large as not to be able to support the weight of the rocks above, which sink down

and fill up the tunnel. It is to these causes, and to these alone, that the apparent irregularity in the strata at this point is owing, and not to any uplifting of the various mountain-ranges which exist in the vicinity. The beds at the mouth of the Judith have been very little, if at all, disturbed by this latter agency.

The Fort Pierre beds form what may be termed the lowest bench of the bluffs along the Judith near its mouth. They have been very much denuded; at one point reaching a height of 560 feet above the river's level, and at other places along the bluffs being apparently wanting. Deposits of this age are found, not only in the main valley of the Judith, but in many little ravines back in the bluffs as well. It is evident that they at some points have been covered by the younger rocks which have dropped down from above. From the facts above mentioned it is very difficult, if not quite impossible, to get at the lowermost strata of the bluffs; and we were unable to accomplish it satisfactorily at any point.

A considerable amount of surface-drift was noticed in the valley of the Judith and in the ravines running into it. This consists almost wholly of water-worn limestone pebbles, similar in appearance to the limestone observed at the western end of the Judith Mountains, in the Snowy Mountains, &c. One of these drift-pebbles contained *Spirifera centronata*, Winch.

About two miles below our camp, and just above the crossing of the Judith, the Fort Pierre beds extend up the foot of the bluffs to a height of about 100 feet. Above these, where the main bluffs become visible, we noted 40 feet of soft, washed, yellowish clays, and over these 18 inches of hard, blue to gray, impure limestone, containing:

1. *Pholadomya subventricosa*, M. & H.
2. *Liopistha* (*Cymella*) *undata*, M. & H.
3. *Thracia Grinnelli*, Whitf. (n. sp.)

This was followed by 15 inches of soft, finely laminated sandstone, in color from white to yellowish-brown; next came 20 feet of soft yellow clays; and finally a layer of sandy limestone from 3 to 6 inches in thickness, and consisting almost wholly of the following shells, crowded closely together:

1. *Tellina scitula*, M. & H.
2. *Sphæriola Morcauensis*, M. & H.
3. (?) *Callista Deweyi*, M. & H.
4. *Lunatia concinna*, H. & M.
5. *Narica crassa*, Whitf. (n. sp.)
6. *Baculites ovatus*, Say.

At a point said to be about one-third of the way up the bluffs on Dog River, the following fossils were collected by two members of the party:

1. *Mactra warreniana*, M. & H.
2. *Cardium speciosum*, M. & H.
3. *Tellina* (*Arcopagia*) *Utahensis*, M. & H.
4. *Tellina* (*Arcopagia*) *subulata*, M. & H.

They are imbedded in a soft yellow sandstone. These fossils, most of which are characteristic, and which have been compared by Mr. Whitfield with typical fossils now in the Smithsonian Museum at Washington, indicate the lower portion at least of these beds to belong to Cretaceous No. 5.

At a point a little south of where the road descends into the valley, and about 300 feet above the level of the river, the following section was taken, from below upward:

	Feet.
Hard, gray, laminated sandstone, passing near the top into a softer, yellowish rock	50
Yellow clayey sands	30
Soft yellow clays	50
Total	130

Where the road comes into the valley, a bed of hard white sandstone, interstratified with

layers of yellowish laminated sandstone, is seen, the whole about 50 feet in thickness. No fossils were found in either of the above.

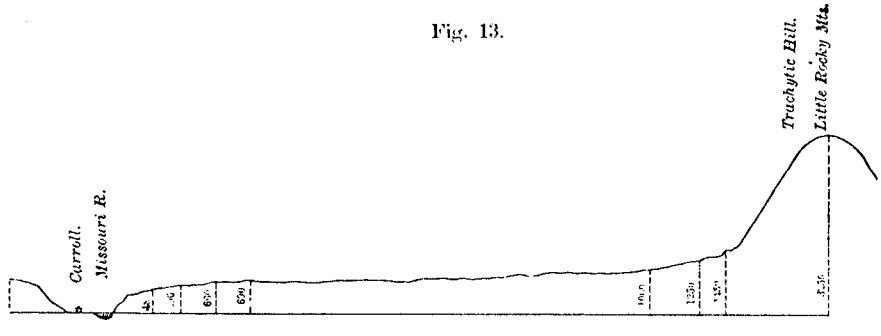
It may be stated in general terms that the lower two-thirds (or 800 feet) of these bluffs consist of yellowish clays, interstratified with thin layers of sandstone and limestone, and that the upper 400 feet is almost wholly sandstone, more or less hard, generally white, but sometimes varying from that to a dark brown. Lignite occurs in the upper sandstone. A few hundred yards from our camp we noticed a bed of sand 15 feet thick, with several layers of impure lignite from 1 to 2 inches in thickness running through it. This bed had slipped down from some point high up on the bluffs, as it had no connection with the neighboring rocks, and had quite a steep dip. From the fossils obtained, it seems that the upper beds of sands and sandstones must be referred to what have been called the Fort Union Beds, or No. 6 of the Cretaceous.

It is a matter of regret to the writers that the observations at this point were so few and so disconnected as to give but little idea of the structure of the bluffs and the relations of the beds. The extent of country to be covered by our observations was very large; and patient study and observation, extended over a considerable time, would have been required to do justice to the locality.

LITTLE ROCKY MOUNTAINS.

A delay of a few days at Carroll on our return journey was in part utilized by a short excursion to the Little Rocky Mountains, which lie about twenty-five miles from the Missouri River, almost due north of that settlement. The starting-point was a short distance below Carroll; and, on reaching the north bank of the stream, we took a trail leading to Milk River, which we were able to follow for some distance. The road rises quite steeply on first leaving the alluvial plain of the river, and attains 400 feet of its final height within a very short distance. From here the rise is more gradual, the road winding to and fro, keeping on the summit of a narrow ridge, whose sides are washed down steeply on either hand. The washing-out of the bluffs was here even more striking than where observed on the south side of the Missouri; and the continually dividing and subdividing *coulées* form a labyrinth of little ridges and valleys, which would present a peculiar appearance could they be viewed from a point a few hundred feet directly above. The course for the road, however, has been so well chosen that the ascent is continuous; no descent into any minor ravines being necessary. The final rise is a matter of time, and the high plateau which forms the true bank of the river is only reached after a ride of several miles. The height at this point, as given by an aneroid, was 680 feet above Carroll, which corresponds closely with the similar measurements taken on the other side. After a little comparatively level prairie, the gradual rise is continued, and at the foot of the hills the height is 1,250 feet above the river. A section from Carroll to the mountains is given in figure 13, which it is interesting to compare with figure 4; the scale is the same.

Fig. 13.



Profile section from Carroll to the Little Rocky Mountains. Course North and South. Distance direct about 25 miles.

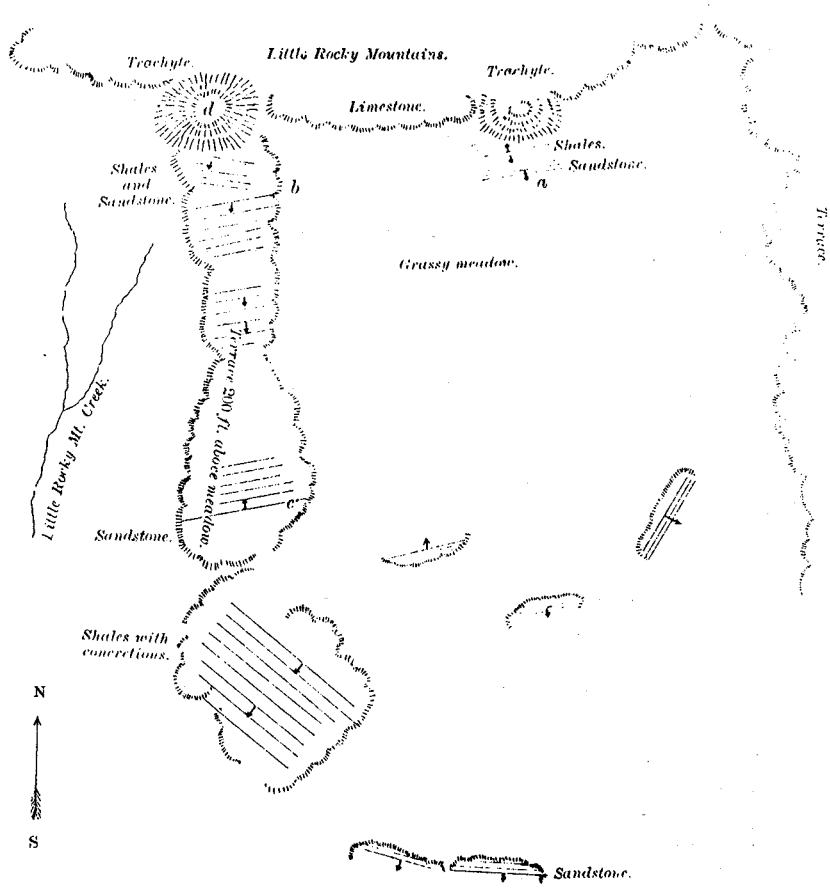
The bluffs on the north bank are made up entirely of Fort Pierre shales, and these were observed from time to time nearly up to the mountains. In general character, they do not differ from those before described. The surface of the prairie as we pass from the river is covered far and wide with drift, very similar to that observed on the south side of the stream; though here the quartzite pebbles are even more numerous, and cover the surface of the ground so thickly as almost to have crowded

out the scanty vegetation. Grass is hardly present at all, and even the few weeds have a hard struggle for existence. This is true for fifteen miles from the river. Approaching the hills, however, the grass is more abundant; and occasionally in the more favored spots it is sufficiently thick to make it worth the while of citizens of Carroll to come here for hay. In addition to the small, smooth pebbles, the same masses of red and gray syenite found on the Crooked Creek road were seen here. The relations of these will be spoken of more particularly hereafter (p. 135). The quartzite pebbles are most numerous within ten miles of the river-bank, and hardly extend much beyond twenty miles. The same is true of the blocks of crystalline rocks to some extent, though they were seen occasionally quite near to the Little Rockies. It is to be remarked that here also there are no deposits of drift, the pebbles being merely sprinkled over the surface. The nearer we approached the mountains, the more numerous became the slightly washed and rounded fragments of trachyte, containing large, clear crystals of orthoclase. Some fragments of the same rock, by the way, had been seen near Carroll, on the south side of the river. The source of these fragments was obviously to be found in the hills we were approaching, and subsequent exploration proved the truth of this conjecture.

The old trail was left after a time, and we continued on our way, striking across the prairie toward the hills. The country was very dry and barren; the only water seen being in some holes, and that was intensely alkaline. In general, it may be stated here that these hills are very dry, and do not give rise to the numerous running streams, which make the region near the Judith Mountains attractive. The level character of the prairie was favorable to the progress of the ambulance, but not at all so for geological investigation; an occasional wash of black shales being the sum-total of all that was observed during a march of twenty-five miles. As we approached the hills, we passed near to the edge of the high bluffs, which pitched steeply down to the valley of Little Rocky Mountain Creek. The view which was opened out to us was extended and striking, looking down on the Bad Lands of the creek at hand, and those which extended on indefinitely westward. The bed of the stream offered attractions for geological work; but the descent promised so badly for the mules and their load that it was decided to turn away, and keep on the high land.

We made our camp in a meadow some two miles south of the mountains at a spot which furnished a little stagnant water. Here we had the hills in front of us, and on either hand a terrace about four miles apart, which stretched southward till they blended with the general level of the prairie. These high terraces two hundred feet above the level of the adjoining plain, are conspicuous features of the landscape, and are important as bearing on the general question of the circumstances under which this country has been denuded. The results of the observations of the following day are contained for the most part in the accompanying sketch. We first examined the strata at the most easterly point (*a*). The intervening prairie was doubtless once covered with the upturned strata, but now only isolated patches are to be seen. At *a*, we found a brown massive sandstone, cellular and remarkably honey combed on the surface as if worn by water washing against it. Its texture was even, with the exception of numerous rusty iron pellets. It dipped strongly (60°) southerly, strike north 80° east; and, standing up as a high wall or rampart, it had survived the denuding influences which had been too severe for the overlying strata. The outer layer of this sandstone was 12 feet in thickness, and more compact than those that followed; the total thickness being 40 feet. The next exposure was in the *coulée* 400 yards behind this wall, where followed a series of blue and yellow shales 500 feet in thickness. These had the same direction of strike as the sandstone, but the dip was steeper, becoming nearly vertical, then changing to north. The observations in this direction were cut off by the high hill of trachyte at *b*. The talus from this hill extends out for some distance from it, covering up all sedimentary strata beneath it. At *c* rises a second complementary hill of trachyte, and lying between these two and limiting the prairie in this direction is an imposing limestone wall. This is worth mentioning, for it is so conspicuous an object as to be distinctly visible in clear weather at a distance of fifty miles to the south. The mountains seem from such a point to have a continuous white girdle running around them. This is due to the limestone and to its continuation east and west in the range; the abrupt wall of trachyte also continues this girdle where the limestone is interrupted. The limestone wall shows no stratification, but its face has a steep dip south 70°, and, in character as well as in result of weathering, resembles the Carboniferous limestone so often described.

Fig. 14.



At the west end of this limestone wall, a little cañon opens out, showing the considerable thickness of the limestone. Lower layers afforded the following fossils, of which a list is here given, with remarks made upon them by Mr. Whitfield:

1. *Glauconome*, sp.?.—"Too indistinct for specific determination."
2. *Productus*, sp. ?.—"This has a feature (elongated depressions) which is seldom seen in rocks above the Chemung of New York or Waverly sandstone of Burlington, Iowa."
3. *Chonetes*, sp.?.—Resembles *C. granulifera*, Owen; also very like *C. subumbona*, M. & W.
4. *Chonetes*, sp.—"This may possibly be only a variety of the preceding, with which it was associated; but had I seen only this fossil, I should have thought it Lower Silurian."
5. *Spirifera centronata*, Winch.

In regard to these fossils, Mr. Whitfield says:

"The general expression of these fossils is that of Lower Carboniferous or perhaps Waverly. The locality and formation is worth further exploration in view of the rocks being Lower Carboniferous, or possibly even lower."

We ascended the hill at *d* with some little labor, owing to the thick growth of scrub-pines, with which it was covered, and from it obtained a fine view of the surrounding prairie and the desert country far to the west. The various ranges of hills were distinctly visible: the Judith Mountains with Cone Butte, to the south fifty miles distant in an air-line; the Moccasin Mountains; Bear's Paw Mountains, and so on. The height of this hill was 3,500 feet above Carroll, or 2,000 feet above the surrounding prairie. Of the general geology of these hills, little can be said from such a survey, except so far as the wide extrusion of the trachyte was noted. The hill in question was made up of the trachyte which had been found in such large quantities over the prairie to the south. This

rock is remarkable for its very porphyritic character; the crystals of orthoclase being very numerous and of considerable size, a quarter to half an inch in length. They are usually more or less altered, and under the microscope prove to be made up of minute crystals apparently of a triclinic feldspar, the base consisting of the same material. The whole rock is very white on the fresh fracture; but the little iron it contains oxidizes on exposure, and the surfacebecomes rusty.

Descending the hill, we pass south over the terrace mentioned before, which would give a good section of the rocks to one who had the time to examine it with care. The lower portion of the southern face of the hill is precipitous; the trachyte showing a bold front. Passing from the talus of the mountain, we came upon a series of variegated shales, mostly bright-red, also greenish and blue, evidently baked by the eruption of igneous rock close by; occasional beds of red sand-rock and mud-shales occur with the others. The general strike is shown on the map. The total thickness of these shales was some 800 feet; no fossils were found, only a few indistinct vegetable remains. Overlying these shales, with a slight change of strike, was a thick-bedded sandstone honeycombed, and in other respects so similar to that described as occurring at *a*, that the identity of the two can hardly be doubted; the underlying shales also correspond. From this point south, the dip became more and more gradual, the terraced hill more grassy, and at *d*, perhaps two miles from the hills, the dip is reversed, and the sandstone of *a* and *c* appears with a slight northerly dip. Still farther south and west, the hills are more broken, and we passed over a series having a somewhat different strike, consisting of a sandstone, then black shales containing large concretions with selenite plates; and, overlying this, other sandstone layers. This shale suggests strongly the Fort Pierre Group, which is seen horizontal only a few miles distant on the prairie. Other exposures of sandstone, yellow and granular, were noted at points to the south (see figure); they had a strike and dip as shown in the sketch. These latter are exceedingly similar to those which yielded No. 5 fossils at Box Elder. No fossils were found, however; though it cannot be doubted that the series of rocks belongs mostly to the Upper Cretaceous. Enough has been said to show, with the help of the sketch, that the relations are by no means simple. In general, it may be said that the hills, at least at this point, give evidence of folding; the axis lying east and west, so that the uplifting force must have been from the south. Our return trip was made by the same trail, and admitted of no further observations.

THE GEYSERS OF THE YELLOWSTONE PARK.

The route followed by the party in going from Fort Ellis to the Yellowstone Lake and Geyser Basins and returning was that generally taken from this point: through the cañon of the East Gallatin River and down the valley of Trail Creek to the Yellowstone River, thence up its valley to the Mammoth Hot Springs, and hence to the falls, the lake, and the geysers. This route has been twice explored by Dr. Hayden and his parties in 1871 and 1872, and the objects of interest in the park have been described in addition in the valuable report of Captain Jones and Prof. Comstock, who visited it in 1873. It was not to be expected, therefore, that our hurried trip of nineteen days from Fort Ellis and return would give us any opportunity to collect any important additional facts.

It therefore does not seem to us desirable to attempt here an account of the somewhat disconnected observations we were able to make on our very rapid journey from Fort Ellis to the Geyser Basins, as they must be, in a great measure, repetitions of what has been already published. We may remark, in passing, upon the very great beauty and interest of the whole region, and the wonderful field that it offers for the study of all kinds of modern volcanic rocks.

It seems, however, that it may be of some little interest to record the action of the more important geysers as observed by us during the day or two which we spent in the basins. We do this, not imagining that the facts in themselves have any especial importance, except so far as this: that the more the facts in regard to the geysers and their operations are accumulated and recorded, the better will ultimately be the understanding of the phenomena involved.

We reached the Lower Geyser Basin the evening of August 20, and, having at that time and during the following morning but a few hours of daylight in all, we saw no display from the more prominent of the geysers of this basin. The only particularly noticeable eruption observed by us

was from the "Architectural" Geyser. The discharge took place in the evening, and was repeated again in the morning, lasting each time about 45 minutes. There was no single stream thrown to a great height; but a continued, confused mass of jets was thrown in all directions, with occasional spirts, to a height of 30 or 40 feet. From its very irregularity, it seemed to us one of the most attractive of the small geysers. The various other interesting points in the basin, the "Mud Puffs," "Paint Pots," etc., were duly examined, but do not need special mention here.

We arrived at the Upper Geyser Basin August 21, and remained there until the morning of August 24, or about 60 hours. Our note-book gives the following facts in regard to the eruptions of the more important geysers:

Old Faithful, the guardian of the valley, showed a very high degree of regularity during the whole period of our stay. The interval between the commencement of the discharges was 65 or 66 minutes; and, as timed by us for nearly 24 successive eruptions, varied very slightly from this interval. The eruptions were of a very uniform character, differing but slightly in manner or duration (about three minutes) or in the amount of water thrown out. During the night, we were roused each hour by the first rush of the water and steam, and certainly nothing could be more beautiful than this grand fountain in action, illuminated by the light of the full moon. The average height of the column of water, as determined by Mr. Wood, was 115 feet.

The solid portion of the geyser, that is, its ornamented crater, has been much injured by the depredations of selfish visitors, who do not realize that the injury to the crater done by them in a few minutes can never be repaired. One of the most interesting features of this geyser, to one who has recently visited the Mammoth Springs, is the great similarity between the step or basin formation here and that of the calcareous springs, the same cause working here, but under quite different conditions.

Bee Hive.—Our camp was situated in a grove of trees on the Fire Hole River, just opposite the Bee Hive Geyser, so that we were able to observe it under very favorable circumstances. During a period of 60 hours, there were three eruptions; the interval between the first and second being 26 hours, and that between the second and third 25 hours. The duration of the action was four or five minutes, and the measured height 200 feet. The amount of water ejected is comparatively very small; the apparent discharge being greater than the real. This discharge consists largely of steam, which is swayed in one direction and another by the wind; the gracefully-waving column of steam and water producing a beautiful effect. Its charms are considerably enhanced when the sun strikes the jet so as to produce a rainbow near the top of the column. This geyser has a crater alone; there being no step formation at its foot in consequence of the small amount of water which it throws out. The force of the escaping steam and water is very great, and seems almost to shake the crust in the vicinity. A little attendant geyser at the foot of the Bee Hive acts as a sort of forerunner to it, giving notice by its little stream when its larger companion is about to move.

Grand Geyser.—We were fortunate enough to see one very fine display of the action of this geyser. It is especially impressive, because of the absence of any elevated crater; the water rising from the very level of the ground. The height of the first discharge did not much exceed 100 feet. It rose to this point in a series of violent pulsations, remained at this altitude for three or four minutes, and then sank back into the pool, which became quite still. A moment later it had commenced again, the water rising certainly 150 feet by estimate. This again sank down and again rose to its maximum height, and this was twice repeated.

Giantess.—The accounts of the eruptions of the Giantess have been so glowing that we were especially anxious to have an opportunity of observing it ourselves. When we arrived, August 21, the crater was quite full and bubbling, seeming to promise a speedy eruption. The following day at 6.30 a. m., it boiled up vigorously, throwing up jets a few feet into the air, exciting hopes that it was about to perform, and bringing those who were in camp somewhat hastily across the stream. At 9 o'clock it boiled up again, at times throwing out considerable water, so that it was nearly empty as far as we could see, looking far down into the crater. It rapidly filled, however, and a second outburst on a small scale took place. Two hours later a more vigorous display commenced, the hot water being thrown to a height of 100 feet, by a series of successive irregular throbs, like the beats of a pump; the heavy thumping going on below in a startling manner. This irregular display, extremely interesting and beautiful, yet nothing compared with what the Giantess

is said to do, lasted for an hour; the entire volume of water thrown out being very great. At length, with a sudden burst, the steam drove up the water to a much greater height than before seen; the noise and concussions accompanying the outburst being very violent. The water was kept at its greatest height for two or three minutes, and for this time we found the Giantess all that had been claimed for it. But the reservoir was almost exhausted, and in a short time the only escape was a mass of steam, which rushed out of the crater with a force which no words could describe.

After we had become somewhat accustomed to the noise of the eruption, and the awe inspired by the vast outburst of steam had in a measure subsided, we experimented upon the violence with which the vapor was ejected by throwing into the crater trunks of trees, logs, and other objects which could be found near at hand, and the height to which these were thrown by the escaping steam was a good indication of the force which was being expended. The heavier of these objects sank nearly to the narrowest part of the crater, and after being held for a moment suspended at this point, rising and falling, according to the violence of the jet which they met, were swiftly shot forth, often rising to a very great height.

This steam escape lasted for an hour without any sensible diminution in violence, and we could not help regretting that all the water had been ejected before the most powerful burst of steam had begun, so that we might have had a full display of the power that was at hand acting on the water. The conception of force given by this great steam escape was perhaps even greater than if it had taken merely the form of a fountain. Six hours later the steam was still escaping, though with somewhat diminished energy, and an occasional liquid jet seemed to show that a little water was draining into the reservoir, only to be immediately ejected.

This great steam escape is important as bearing upon the general subject of geysers, showing the vast amount of steam which must be accumulated before the discharge can take place, and the high tension under which it must be.

The *Castle Geyser* was active most of the time during our stay, though with varying force. The amount of water discharged was never very large, and the highest jets did not exceed 50 feet.

The *Grotto* was also almost continuously active, and after seeing the injury done to its crater by visitors, the large majority of whom are residents of the Territory, we could not help wishing that the discharge of boiling water were absolutely continuous, so that the depredators might be kept at a respectful distance.

The *Saw-mill Geyser* played frequently at short intervals, but quite irregularly.

The *Giant* was quiet, occasional spirts of water to the top of the crater being the only sign of latent energy.

GENERAL CONCLUSIONS.

DISTRIBUTION OF THE FORMATIONS.

Pre-Silurian rocks.—Up to the time when we reached the second Yellowstone Cañon, we had seen absolutely nothing of any rocks older than the Primordial series. This is true, not only with respect to our observations, made in the several minor ranges of mountains, but also includes the inferences to be drawn in regard to the elevated points not reached, from the absence of any crystalline rocks in the local drift. The only exception to this was at Camp Baker, where the drift contained such masses, doubtless from the neighboring Big Belt Range, which we were unable to visit, but in which we should expect to find a considerable development of the Pre-Silurian series.

Granitic rocks have been observed by others on the east side of Gallatin River, but they did not appear within the limits of our observations. The inferred absence of crystalline rocks from the minor ranges of hills, which break through the prairie at different points in this part of Montana, for example, the Judith Mountains, the Snow Mountains, Little Rocky Mountains, etc., if correct, would make it improbable that ore deposits of any economic value should be found in them.

Silurian.—Primordial series.—We observed strata, proved by fossils to belong to the Potsdam, at two localities, and the relations of the rocks at these points as far as made out have been described; they may, however, conveniently be recapitulated here.

At Camp Baker, Primordial fossils were found in a limestone hill to the northwest of the Post; the series and the estimated thickness are as follows: Quartzite, 20 feet; variegated shales, mostly bright-red, also green and blue, 150 feet; limestone, in a double series of ledges, 80 feet; quartzite, reddish, slightly micaceous, then a series of colored slates, mostly green, followed by shales and thin beds of sandstones and limestones, in all probably 1,500 feet; still further conformable shales, 1,000 feet. These extend toward the north farther than we could follow them It is enough to say that the total thickness of the conformable strata underlying the fossil-bearing limestone cannot be less than 3,000 feet, and is probably much more. All the facts point to a *very great* development of Lower Silurian rocks.

The same rocks were identified at Moss Agate Springs at the south extremity of the Elk Range of Mountains; we found here red shales like those at Camp Baker, quartzite and limestone, the latter containing many fragments of *Trilobites*. We were able only to glance at this locality, and consequently the observations stand out isolated. To the Primordial we refer also the rocks underlying (in position overlying, in consequence of an overturn) the Carboniferous limestone of the Musselshell Cañon, of which there must be a thickness exposed of some 1,000 feet. It is also very probable that the limestone and red shales of the east bank of Deep Creek observed in isolated patches belong to the same time. With the exception of the above, no rocks older than the Carboniferous were seen by us anywhere from Carroll to Fort Ellis. It is certainly not to be affirmed positively that they do not exist in the mountains touched at; the contrary is probable, but it is quite certain that, if present, they are in all cases subordinate.

Carboniferous.—Carboniferous rocks are largely and very uniformly developed over this part of the Northwest, as has been remarked by Dr. Hayden. All of the minor ranges of hills, repeatedly referred to, contain Carboniferous limestone to a large extent. In fact, the most striking and characteristic features of all these minor ranges are the walls of white limestone, which stand up conspicuously above the timber, and attract the attention even from a great distance. The very uniform nature of this limestone has been noted, and to its character in weathering out into steep walls and isolated towers is due the conspicuous appearance mentioned. The general facts in regard to this formation, collating those obtained at different places, may be summed up as follows: The upper portion consists of limestone in thin beds, with layers of shale and a little sandy slate. These upper layers contain fossils more abundantly than the following beds. *Productus*, *Chonetes*, *Spirifera*, *Athyris*, *Rhynchonella*, and *Streptorhynchus* are abundant forms. At the Bridger Mountains, some bands of red clay in the upper part of the formation were very conspicuous and persistent, and suggestions of them were seen elsewhere. At Cinnabar Mountain, in the Yellowstone Valley, the intensely red clays and shale, from which the mountain derives its name, immediately overlie Carboniferous limestone, and belong, as elsewhere, to the upper part of the formation. Below these irregular, thin beds, showing a somewhat different character at different localities, comes the mass of the limestone already many times described. It is firm, bluish white, and always cherty. The flint is sometimes in uniformly-distributed particles of small size, sometimes in broad bands. When acted upon by the weather, the rock takes the form of vertical walls and steep towers, showing no trace of stratification. Reference must also be made to the remarks of Mr. Whitfield upon the fossils found by us at the Little Rocky Mountains. He says: "The general expression of these fossils is that of Low Carboniferous, or perhaps Waverley." To this, we can add nothing, except that the fossils came from a limestone underlying the massive blue limestone before spoken of, containing *Zaphrentis* and other corals in considerable abundance. Except at this point, we found nothing to suggest the possible occurrence of any rocks between the Primordial and the usual Carboniferous.

As to the total thickness of the Carboniferous formation as here developed, we can only hazard a conjecture, which cannot be of very great value. The compact limestone spoken of must be at least 500 feet in thickness, and the total may be 600 feet. At any rate, it is certain that the deposits point to a uniform condition of things at the time when the formation was laid down.

Jurassic.—Jurassic fossils were found on the east slope of the Bridger Mountains at both points where the ascent was made. The only rock observed was limestone, and the fossils were quite abundant, in some layers, at least. The thickness seen was small, and on the one side was a Cretaceous fossil-bearing sandstone, and on the other the undoubted Carboniferous limestone. The

interval on both sides was small, and we should regard an estimate of 100 feet for the total thickness as a large one. In regard to this, Dr. Hayden says: "The Jurassic rocks are crushed together in the uplift to such an extent that they are quite obscure, and do not appear to much advantage; but, in Union and Flathead Passes, they are much better exposed." His final estimate of their thickness is not clearly stated; but elsewhere, in the same vicinity, he speaks of them as 1,200 feet thick. Whatever may be the facts at this point, we can safely affirm that the development of Jurassic rocks to the north and east is very limited. We had several opportunities for examining beds possibly Jurassic, in search of fossils; but in no case were we successful in our efforts to find such remains. On the contrary, in two distinct localities we passed from undoubted Cretaceous to undoubted Carboniferous, with a very small interval between of non-fossil-bearing strata. These intervening strata may very possibly belong to Jurassic time, and their apparent absence elsewhere may be due to the disturbing influences of the uplifts; but their relative insignificance seems to us quite certain. Banks of red soil were conspicuous at several points, and in appearance suggested, to a certain extent, the "Red Beds" referred to the Triassic in other localities. In three distinct cases, however, we found such layers immediately underlaid by Cretaceous sandstones; so that we think that the beds in question must belong in all cases to the latter horizon.

Cretaceous.—To the Cretaceous formation belongs the rock underlying the prairie over nearly all of the route traversed by us. We were unable, however, to obtain any satisfactory results as to the succession of the various beds. The sandstones, of which these rocks for the most part consist, are quite different at the various localities at which they were seen. They are generally without fossils, though frequently containing indistinct vegetable remains, and seem to lack any particularly distinctive or characteristic features. They have been so often described in the preceding pages that it is needless here to enlarge upon them. The lower part of the formation must be that visible on the Bridger Mountains, directly overlying the Jurassic. Very little is in sight, however, and the fossils obtained were very poor. When the rocks appear again in the valley, they are mostly the constantly-recurring "somber" sandstones. At the headwaters of Cottonwood Creek (see p. 122), we obtained a few poor fossils in a bed which stratigraphically was the lowest in a series of 5,000 feet involved in a gigantic fold. One of these fossils is credited to Cretaceous No. 2 of Meek and Hayden. From here up, in the order of their time, the rocks have been briefly mentioned. They are mostly dark-colored sandstones, occasionally shales, and all nearly destitute of remains of life. The only suggestions of fossils are the indistinct vegetable remains before mentioned, which were found best preserved in the upper strata. The thickness of this Cretaceous series has been estimated at 5,000 feet. Most of it is referred by Hayden, though without facts, to the doubtful "Coal Group, forming the transition from the Cretaceous to the Tertiary". We regard them all as properly Cretaceous; in fact, in some of the upper strata, fossils belonging to No. 5 were found. As has already been stated, beds of red clay immediately overlie some of the lowest Cretaceous strata; and, though their character is probably local and changeable, they are so noticeable where they occur that they deserve mention here.

Cretaceous No. 4.—The most distinctly-marked and characteristic member of the Cretaceous is No. 4, or the Fort Pierre clays, which have already been fully described. Their thickness was estimated at 700 to 1,000 feet. They extend from Carroll north and south for a distance of twenty-five miles from the Missouri. Further than this, they were observed below on the river one hundred and fifty miles from Carroll, and from here to the Judith River a distance of two hundred miles. Beds referred to these take part in the uplifted strata, both at the Judith Mountains and the Little Rocky Mountains, overlaid by Cretaceous No. 5. The Fort Pierre clays were not observed at any greater distance from the river than the points mentioned; and this is true, although beds both below and above them have shared in the folding near the Bridger Mountains. From this, it is concluded that the Fort Pierre clays are limited to the immediate valley of the Missouri at this point. In other words, while the conditions were such as to cause an immense accumulation of mud in what s now the immediate valley of the Missouri, different conditions prevailed at a greater distance from the river, and deposits of sandstone were going on.

Cretaceous No. 5.—The Fox Hills Group was determined beyond all question at three points: at Box Elder Creek, near the Judith Mountains; at Haymaker's Creek, near the Forks of the Musselshell; and at the mouth of the Judith River. The rock in each case was a sandstone, which is

characteristic of the formation. Upper layers are very yellow and ferruginous, and lower beds white and gray. The local changes are very great. At the Judith Mountains, the thickness of the sandstone, at a point where some estimate of its relation to the underlying clays could be made, was thought to be about 300 feet. North of the Missouri, at the Little Rocky Mountains, sandstones similar to those of No. 5 were seen overlying concretions, and selenite-bearing shales, presumably No. 4; and hence their existence here may be considered probable. If now Cretaceous No. 5 is found at two points, on either side of the river, at a minimum distance of twenty-five miles, while between is No. 4, and no trace of No. 5, what has become of the latter? One fact observed may be mentioned in this connection: the dark clays are carried from Carroll one hundred miles and more down the river; and, at some of the lower points, these clays, which appear alone in the immediate river-bank, have a capping at a little distance of white and yellow sandstone. This observation, made from the deck of the steamboat, is of little value; but it suggests that the No. 5 may be here, where it belongs, directly overlying No. 4, while farther west, in the neighborhood of Carroll, it has been removed by the glacial flood, to be mentioned later.

A more thorough study of the Cretaceous beds at the mouth of the Judith would no doubt have assisted us materially in deciding the point in doubt had we been able to give the requisite time to their examination. As it was, the relations of the beds were, as has been said, somewhat complicated; and we were able to do no more than to identify by fossils the several members of the group exposed at that point. We found here the Fort Pierre clays in close apposition with rocks containing No. 5 fossils.

No. 6. *Fort Union Group.*—Beds of white sandstone, containing occasional layers of a clayey brown sand-rock, were found at the mouth of the Judith River, evidently overlying the beds of No. 5, before referred to. From these deposits of sand, we obtained the vertebræ and long bones of Dinosaurs, identified by Professor Marsh as belonging very near the genus *Hadrosaurus* of Leidy. With these remains were found Unios, and, in some layers, a little lignite; the general association seeming to refer the deposits to the Fort Union beds. Their thickness was estimated at 400 feet, though no sufficient data were collected to warrant any great confidence in this estimate.

Tertiary.—Distinct tertiary strata were observed in the neighborhood of Camp Baker, and their relations have been so fully described that a repetition is unnecessary. It may be mentioned, however, that the occurrence of a Miocene lake at this point, with beds 250 feet thick, is a matter of no little interest, and opens many interesting questions as to the relations of this with the other well-known Miocene lakes, as also to the Pliocene beds of the Upper Missouri and the Yellowstone Valley. The red and yellow slates, which seem to accompany the Miocene beds of Camp Baker, may possibly be Lower Tertiary, although, as has been remarked, they are not conformable with the overlying beds. In the absence of any decisive facts, however, we must leave this point undecided.

Quaternary.—More or less distinct evidence of Quaternary action was obtained at several points. True traveled drift was observed in the Missouri Valley alone. In Upper Yellowstone region, the amount of material transported has been immense; but the action is, comparatively speaking, local. Fine striæ, presumably glacial, were seen in the cañon above the mouth of Work Creek, and also in the granitic rocks near the bridge. At the latter point, the amount of transported blocks was very large. It may be of interest to note that the blocks apparently from this spot were traced south; and some few scattered bowlders were seen within 1,500 feet of the top of Mount Washburne, as if the action had been in that direction. This matter has been discussed for this locality by others, and we refrain from carrying it further.

The drift at the foot of the Bridger Mountains, the Elk Range, Little Belt Mountains, Snow Mountains, and Judith Mountains, in many cases exceedingly abundant, is in all cases purely local; almost exclusively Carboniferous limestone or trachyte. The masses and pebbles were distributed in the time of glacial flood, when the flow of water from these hills was very great. The action of this flow of water, in washing out deep valleys, has already been noticed. The special interest attaching to Quaternary phenomena is connected with the facts observed in the Missouri Valley, which have been alluded to, though not described in detail. North and south of the river from Carroll, the prairie is more or less covered with drift-pebbles and masses, whose source is not to be found in the neighboring ranges of hills. On the contrary, the southern limit of this drift is reached

twenty-five miles from the river and about ten miles from the north limit of the Judith Mountains, where the surface-drift changes its character and commences to be made up entirely of trachyte from Cone Butte and the neighboring hills. To the north, the limit is not so distinctly marked; but it is reached within twenty miles of the river, where the trachyte of the Little Rocky Mountains takes its place. This drift is divided into two classes quite distinct from each other: first, we have the rounded pebbles, very uniformly scattered over the surface of the prairie; and, second, the large, angular blocks distributed here and there at random. The pebbles are generally small, sometimes several inches in diameter, but more frequently much less. They are flattened, quite smooth, and in fact bear much the appearance of common stream-pebbles; they are almost never glaciated. They show, however, the marks of the force of attrition by which they have been smoothed into shape, for the surface-layer of those of uniform texture is curiously marked with semicircular cracks, due to the constant blows which they have received against each other, giving them often quite an ornamented appearance. The material of the pebbles is 90 per cent. quartzite, generally yellow, sometimes dull red (jasper), and also rarely dark-colored. The remaining 10 per cent. is made up of material so heterogeneous that a catalogue of the varieties would be more curious than valuable; pieces of fossil wood, however, must be mentioned. As has been stated, the deposits are superficial in all cases. The material composing the drift of the second class is very generally a bright-red syenite; this forms masses sometimes three or four feet in thickness, but averaging about 18 inches. Next in importance is a similar rock, in which the place of the hornblende is taken mostly by black mica; still again, there are masses of black hornblende rock, a grayish syenite, but very little true granite. All these have a very Archæan look. Masses of semi-crystalline limestone also occur, though not frequently. These blocks, as has been stated, are uniformly angular, showing little trace of wear. They are less uniformly distributed than the pebbles.

The source of these drift masses can hardly be held in doubt. Confined, as they are, to the Missouri Valley, they make it almost certain that they have been brought by running water in the direction of the present stream. In the flood which followed the melting of the ice, which, to a greater or less extent, doubtless covered the higher mountains, and at a time when the land is supposed to have been depressed, the waters may well have spread over a width of forty miles, covering the now so nearly level prairie, and could readily have transported the smaller washed pebbles. The large blocks evidently demand stronger agencies, and it is difficult to make any other supposition than that they have been carried by floating ice brought from the westward, from the high mountains which form the main divide of the Rocky Mountains, in which the red feldspar-syenites and the quartzites must have a large development. This would account for their not being rolled bowlders. To the same time of glacial floods belong the formations of the terraces seen; especially those at the Little Rocky Mountains and Judith Mountains.

Our opportunities for making observations above and below Carroll on the river were exceedingly limited. Masses of a syenitic rock were observed, here and there, down the river, prominent at the mouth of the Musselshell River, and again at Fort Peck. Running notes from the steamboat-deck have little value, and not much can be based upon them. Far down the Missouri, near Bismarck, eight hundred miles from Carroll, the drift bowlders are numerous, and the quaternary sands form deep stratified deposits. These phenomena, however, join on to those which are observed more and more decidedly to the eastward, and the source of which is to be found to the northeast. West of Carroll, near the mouth of the Judith River, the drift just described was not observed. This evidence is negative merely, since, if once deposited as below, it can easily be imagined that subsequent denudation has obscured it.

It is interesting to note, in connection with the facts stated in regard to the drift from the westward, the extended and careful observations of a similar character, made at many different points, by Mr. G. M. Dawson, F. G. S., and described in the "Geology and Resources of the Region in the Vicinity of the Forty-ninth Parallel," Montreal, 1875.

If the report in question be consulted, a full description of these interesting facts will be found. It is sufficient for our purposes to call attention to the great prevalence of the quartzite drift over the prairie far to the north of the Missouri. The general character of this drift was much the same as that found by us, and it was also referred to the Rocky Mountains as its source.

PERIOD OF MOUNTAIN-ELEVATION.

Much of the country covered by our reconnaissance is, in some respects, a unique one, as may be gathered from the remarks previously made. The prairie, deeply gullied, as it is, by the Missouri and other minor streams, is, in general, of a pretty level character. The strata are horizontal, and there is little evidence of any elevation since those Cretaceous beds were laid down. Above the prairie, at a number of points, rise ranges of hills of no very great extent, and with an altitude averaging about 2,000 feet. They are seen far and near; and, rising blue and misty in the distance, from the dry, parched level, they are a most agreeable relief to the otherwise unbroken monotony of the landscape. They are important as serving to redeem the country from utter worthlessness, since they give rise to numbers of clear, flowing streams. The Judith Mountains, Moccasin, Highwood, Snow, Little Belt, and, north of the Missouri, the Little Rocky and Bear's Paw Mountains, are the most prominent of these ranges.

Rising, as described, from the level prairie, it is to be expected that they would give good sections of the rocks which once lay horizontal over the whole of this part of the country. This would doubtless be true, could the relations be studied in detail in each case. In fact, however, the extensive denudation has left only remnants of once extensive formations, so that in a given spot the continuity has been much interrupted. Furthermore, the commonly occurring ejection of masses of igneous rocks has served as a decidedly disturbing element.

As to the time when the elevation of our numerous mountain-ridges took place, the evidence, where decisive, points to the same conclusion reached elsewhere in the West, which indeed was to be expected. The time of elevation followed the close of the Cretaceous era. This is clearly seen at the Judith Mountains, where Cretaceous No. 5 has been involved in the general disturbance. The same cannot be questioned for the Little Rocky Mountains. The elevation of the Snow Mountains and the Little Belt Range embraced Cretaceous deposits; and, though it cannot be positively stated that the upper members of the formation came in at these points, this cannot be doubted, in view of the evidence.

The Bridger Mountains are the most interesting and satisfactory. They include strata from the Primordial to the top of the Cretaceous; all apparently conformable, and all elevated at one time. The junction of the Lower Silurian with the Carboniferous did not appear in that portion of the range examined by us.

At the other points where the Silurian was found, we unfortunately could not observe its relations to the overlying Carboniferous. At the Musselshell Cañon, the evidence is not conclusive; but the relations seem to imply conformability from the Cretaceous down to the Primordial. At Camp Baker, the Primordial stands alone; and we saw no evidence of the Carboniferous following it in the sequence of the strata, as would be expected. This fact strongly suggested to us, while on the ground, an earlier elevation of the Silurian; but this cannot be regarded as of much weight, in view of the fact that the extensive deposits of Miocene Tertiary may well cover up what follows and would otherwise be exposed.