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THE PALEOZOIC SECTION IN THE VICINITY OF THREE FORKS, MONTANA

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No. 110

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UNITED STATES GEOLOGICAL SURVEY

J. W. POWELL, DIRECTOR

THE

PALEOZOIC SECTION

IN THE

VICINITY OF THREE FORKS, MONTANA

BY

ALBERT CHARLES PEALE

WITH

PETROGRAPHIC NOTES

BY

GEORGE PERKINS MERRILL

WASHINGTON
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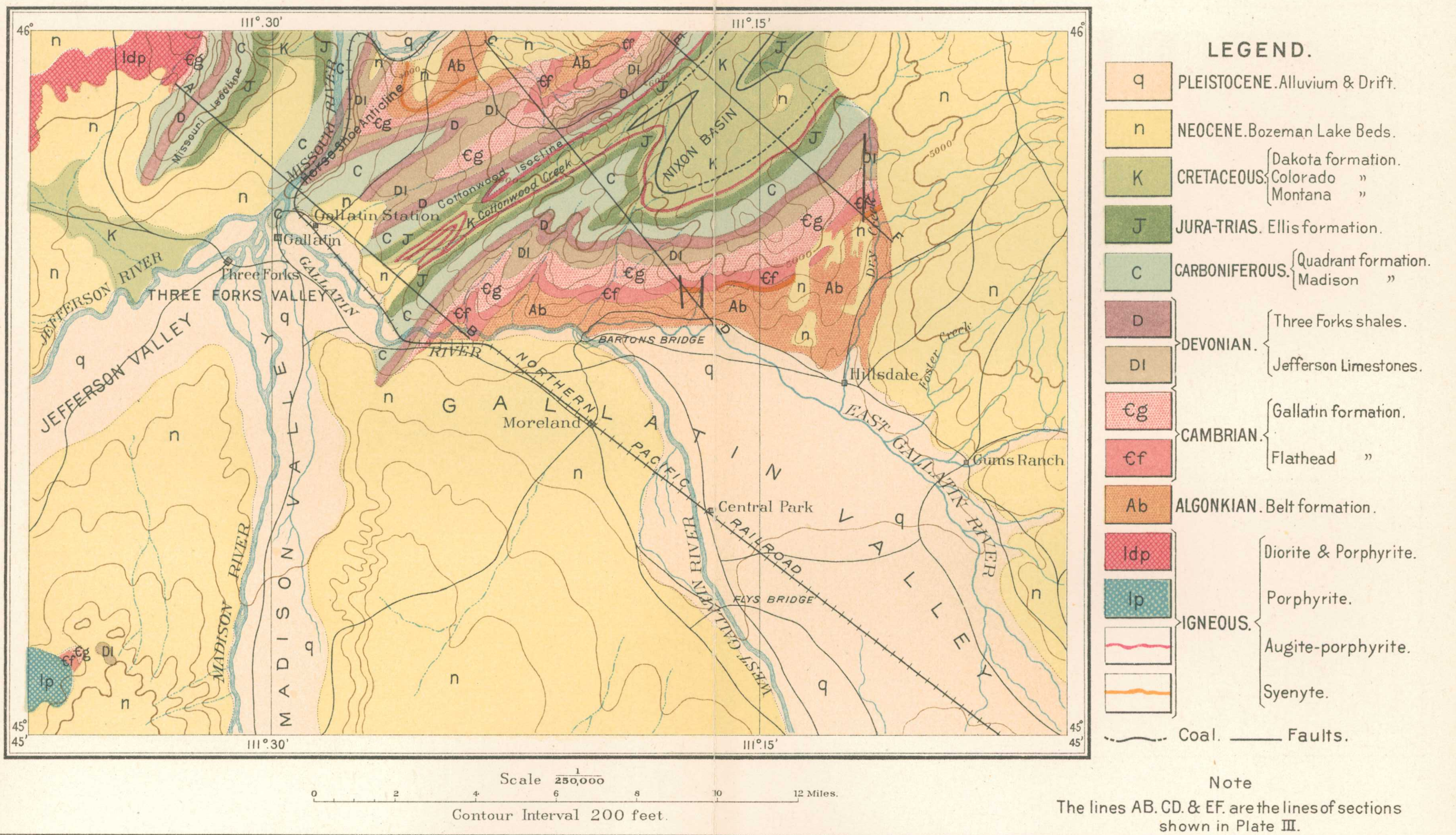

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BY

A. C. PEALE.

THE PALEOZOIC SECTION IN THE VICINITY OF THREE FORKS, MONTANA.

By A. C. Peale.

INTRODUCTION.

The Three Forks sheet of Montana includes the area lying between the parallels of 45° and 46°, and extending from longitude 111° to 112°. The three forks of the Missouri river unite in the north central portion of this area about 5 miles south of the northern line of the map.[1]

The area selected for the initial work in the construction of this section was the area adjacent to the three forks of the Missouri river at the northern end of the Gallatin valley, and is shown on the accompanying map. (Pl. I.) This region was the field of reconnaissance work for very brief periods in 1871 and 1872, when the writer, with Mr. W. H. Holmes, under Dr. Hayden's direction, made a hasty examination of a small part of the area, securing the section published on pages 172 and 173 of the Sixth Annual Report of the U. S. Geological Survey of the Territories. The rather complicated structure of the region was then recognized, but time did not permit any work except that of the most general character, and it was hoped that the future might see the work undertaken with a prospect of completing it in more detail. This opportunity was presented in 1884, and the object of this paper is to describe briefly some of the results of the more detailed reexamination then begun.

The first white men to visit the "Three Forks of the Missouri" were the members of Lewis and Clarke's expedition in July, 1805, by whom the three rivers were given the names of Gallatin, Madison and Jefferson, respectively. No geological work, however, was done until the expedition of Raynolds visited the Three Forks in 1860, when Dr. Hayden made the first geological examination of the area.[2] This work was

[1] This paper was prepared during 1886 and 1887 and completed in the early part of 1888, since which time the geological exploration of the entire sheet has been finished. The paper has been revised only so far as to make the nomenclature consistent with that adopted for use in the publication of the atlas sheet.

[2] Geol. Rept. of Explorations of the Yellowstone and Missouri rivers, Washington, 1867, p. 90.

naturally more general than the later work of 1871 and 1872. The map published by the Northern Transcontinental Survey under Prof. Pumpelly[1] has this area colored geologically, but goes into less detail than does the Hayden map of 1872, and none of the accompanying text refers to it, the explanation of which omission is found in the fact that the object of this survey was mainly the discovery of the various coal horizons, and the determination, exploration, and preliminary development of the coal fields. In the adjacent region beyond the limits of the Three Forks Sheet, on the north and east, considerable detailed geological work was done by W. M. Davis[2] and George H. Eldridge,[3] while the eruptive rocks of the region examined by them have been reported upon by Waldemar Lindgren[4] and J. E. Wolff.[5]

In 1875 Ludlow's expedition passed along the eastern side of the Bridger range just beyond the eastern limits of our sheet on the way from Fort Logan to Fort Ellis, and Messrs. Grinnell and Dana made a hasty examination of the east side and summit of the range. Their observations are published in Capt. Ludlow's report.[6] The region examined by them, however, lies mainly east of the mountains on the Livingston sheet. Prior to 1884 also, Prof. J. S. Newberry crossed the Great Belt mountains from Sulphur springs to Townsend on the Missouri river, about 26 miles north of Three Forks. He also crossed the Gallatin valley from Bozeman to Gallatin city.[7] This completes, so far as I am aware, the list of those who have done any geological work in or near the region of the Three Forks.

STRUCTURE.

It would be manifestly premature to attempt to deduce from the facts observed within the limited area of one topographic sheet of only 3,354 square miles generalizations affecting the entire Rocky mountain system of Montana, and especially so in view of the fact that the observations noted during hurried trips through various parts of the state indicate considerable complication and irregularity in its mountain structure. Still there are a few points to which attention may be called which seem to be characteristic at least of the immediate area under consideration, and may yet possibly be extended to other portions of the state.

The most striking feature to be noted is the rather common occurrence of folds in which the strata on one side are inverted so that the

[1] Report on the Mining Industries of the United States, vol. xv, Tenth Census.

[2] Report of Tenth Census, vol. xv, p. 697.

[3] Op. cit., p. 739.

[4] Op. cit., p. 719.

[5] Neues Jahrb. 1885, I, p. 69, and "Notes on the Petrography of the Crazy Mountains, etc., Heidelberg, 1885."

[6] Rept. of a Reconnaissance from Carroll, Montana Territory, etc., to the Yellowstone National Park and return. Washington, 1876, pp. 93-197.

[7] Notes on the Geology and Botany of the country bordering the Northern Pacific Railroad by Prof. J. S. Newberry. From the Annals of the N. Y. Acad. of Sci., vol. III, No. 8, 1884.

beds are bottom side upward. This isoclinal structure was noted in the Madison range[1] in 1872, when it was illustrated. (This illustration is reproduced in A, Pl. II.) It was also noted in the range west of Radersburg, 18 or 20 miles north of the Three Forks[2] and again in the Bridger range, which lies partly on the northeast corner of our sheet (see B, Pl. II). The latter is in its southern extension an overturned monocline, complicated by faulting on the west side of the range as we trace it to the northward, but as we stand on one of its southern peaks where the beds are inverted and look northward, the beds are seen to return to their normal condition very much in the way noted in the Elk mountains in Colorado by the writer in 1873.[3] Still farther along the beds are again overturned, and at the extreme north end of the range they are once more in their normal position.

The area under consideration in this paper was recognized in 1871 and 1872 as one in which there were several local anticlines and synclines. Our later examinations develop that in the space between the Gallatin river and the hills northwest of the head of the Missouri river we have four synclines, two isoclines, and one well-defined anticline. The latter begins at the head of the Missouri river with a fold which at first has an overturn on the right (i. e., it is an isoclinal fold), but within a few miles develops into a normal anticlinal fold, the northwest side of which has been cut through by the Missouri river, which occupies a monoclinal rift in the Lower Carboniferous and Upper Devonian for about 4 miles from its head, when it cuts across the Carboniferous just before it emerges into the broad valley of the Horseshoe bend on the northern line of our sheet. A similar inversion was noted in 1872[4] in one side of the anticlinal fold across which Spring or Rocky canyon is cut. It begins as an isocline at the north end, and very soon becomes a normal anticline as it is traced southward. Some indications of similar inversions were noted in the uplift west of the Rocky canyon uplift, that is in the one which is on a line with the Bridger uplift.

In all of the folds observed up to the present time, what may be called the plane of the axis dips westward or northwestward; that is, the steep or overthrown portion is on the west or northwest side of the synclinal basin. This is noted even in the beginnings of those folds which at first are isoclines, but are in the main normal anticlines. The trend of the folds near the Three Forks is about N. 60° E.; in the southern portion of Bridger range, where the overturn occurs, the axis is N. 15° to 20° E.; in the Rocky canyon uplift it is N. 25° W.; and in the Madison range it is approximately north and south. In none of the folds which have an east or west direction has any similar inversion

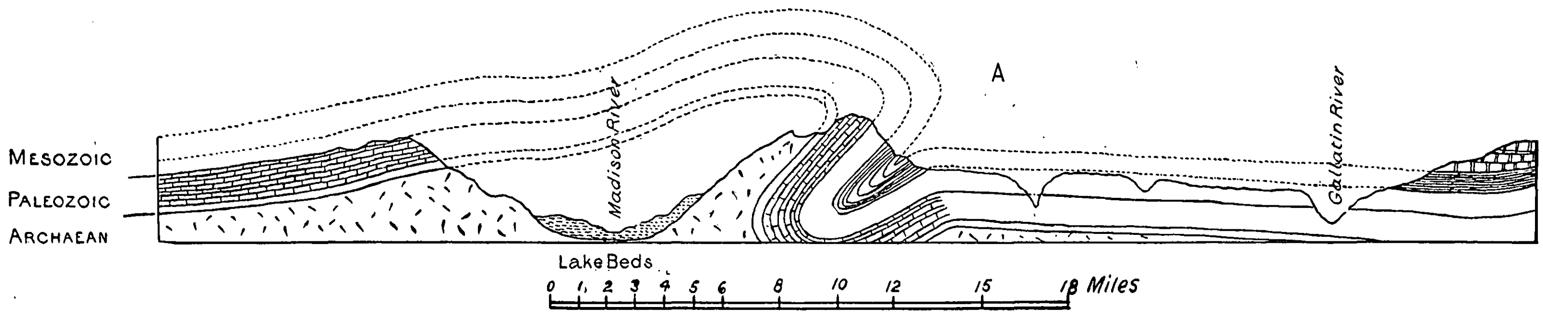
[1] Sixth Ann. Rept. Geol. Survey Territories, p. 164, also p. 84.
[2] Sixth Ann. Rept. Geol. Survey Territories, p. 82.
[3] Seventh Ann. Rept. U. S. Geol. and Geog. Survey of the Territories, p. 256; see also Pl. XVII and Pl. XVIII.
[4] Sixth Ann. Rept. Geol. Survey of the Territories, p. 109.

been seen. Reference to the sections in Pl. III will make clear the structure in the vicinity of the Three Forks. The first section (A) begins on the Gallatin river at a point about 2 miles above the Northern Pacific Railroad bridge, and continues northwest, crossing the Missouri river near its head. This section is the only one that crosses to the west side of the Missouri, and shows therefore the Cottonwood isocline and the Missouri isocline, both of which are well marked, and have been traced in a northeasterly direction to the limits of the sheet.

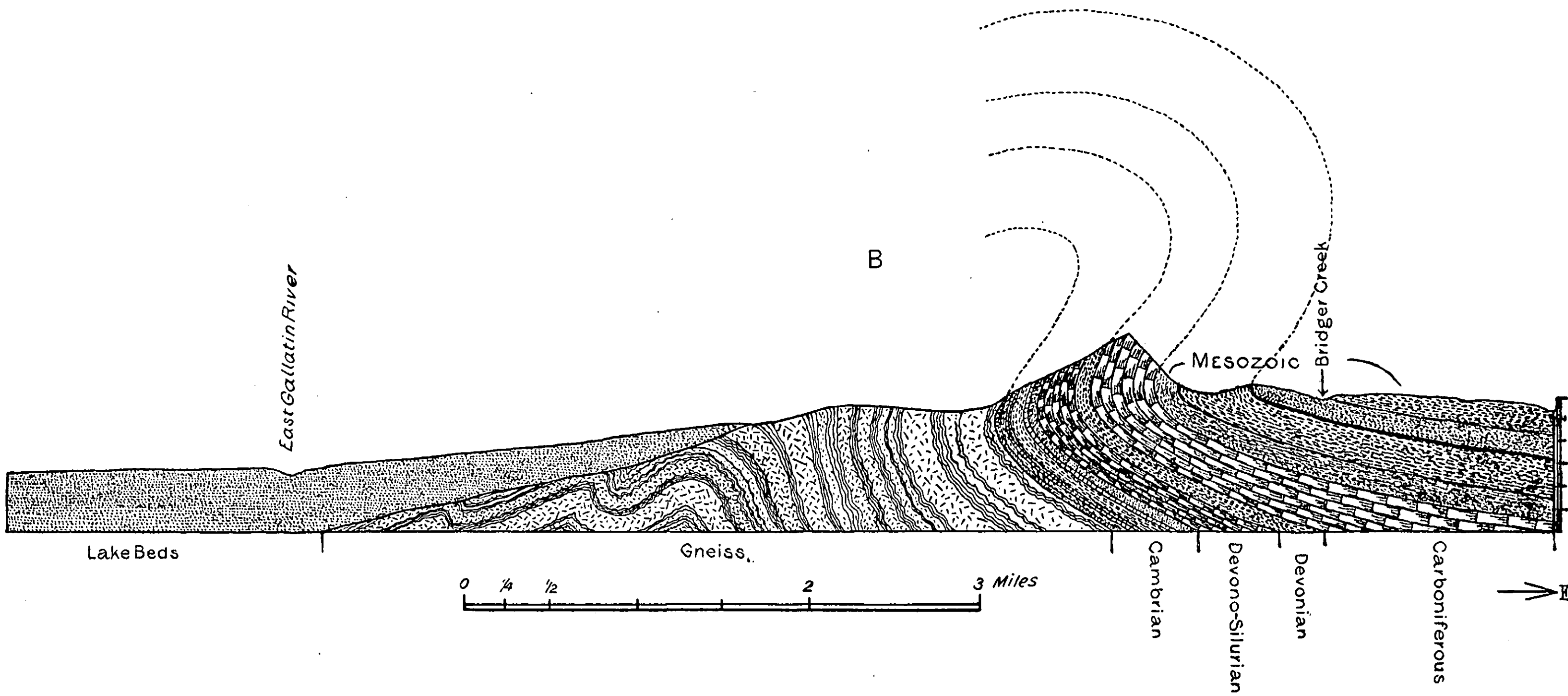
Leaving the Gallatin river on the line of the first section, we cross successively the upturned edges of the Belt beds, the Cambrian, Devonian, Carboniferous, and Mesozoic strata, all dipping conformably to the northwest at angles of from 8° to 10° in the lower beds, and 20° or 25° at the top of the Paleozoic and base of the Mesozoic beds, on the southeast side of Cottonwood valley. This valley is filled with Cretaceous sandstones and shales with two intrusive sheets. Crossing to the northwest side of the valley we find the beds repeated in reverse order, the lower portion of the Jura-Trias dipping to the northwest beneath the Upper Carboniferous at angles of 50° to 60°. These beds show abundantly slickensided surfaces, evidencing the slipping of the beds upon each other during their overturning. Crossing next the edges of the Carboniferous and Upper Devonian strata, we find the latter standing upon end and after crossing an area in which the beds are partially concealed by Pliocene lake beds, we come to the upper portions of the Devonian dipping to the northwest in their normal position. Proceeding northward on the central portion of the Devonian or Devono-Silurian limestones as exposed here between the two upper Devonian outcrops we find very soon that an anticlinal fold develops, in the center of which the Cambrian portion of the section rises to the surface, and still farther along erosion has brought to light the Belt beds occupying the axis of the fold. The right or southeastern side of this fold is very sharp, the beds for the most part being upon end or inverted, as shown in the second section (B, Pl. III).

This second section was made on a line parallel to the first, about 5 or 6 miles farther northeast. It shows the beginning of another synclinal fold—that of Nixon basin—which, as we follow it, merges with that of Cottonwood creek. From the middle of this basin an anticline begins to rise before the line of the third section, (C), 5 miles farther northeast is reached. This last uplift attains a comparatively slight elevation and soon dies out again to the northeast. The Cottonwood isocline, however, it will be observed, continues through all three sections and is equally well marked where the north line of the sheet crosses it, as at the lower end of the Cottonwood valley, 10 miles to the southwest.

Returning to the first section and following it to the head of the Missouri river, we reach the Horseshoe anticline, the axis of which extends from near the mouth of the Gallatin to the Horseshoe bend of the Missouri, its direction being almost parallel to the course of the river.



Section across the Madison Range between the Madison and Gallatin Rivers



Section across the south end of Bridger Range

SECTIONS ACROSS MADISON AND BRIDGER RANGES.

This fold has already been referred to. As we trace it toward the northeast it becomes broader and broader, older and still older beds rising one after the other until the bend is reached, where the Belt beds are exposed in the center, with patches of lake beds resting upon them. The three streams forming the Missouri river unite in the Carboniferous limestones, and the river flows at first into a canyon-like valley in these rocks, which dip from 25° to 30° toward the northwest on both sides of the valley.

Very soon, however, the river cuts across into the soft sandstone and shales of the Upper Devonian, and the valley becomes somewhat wider. Still farther on the channel is cut in a northerly direction diagonally across the Carboniferous limestones and a portion of the overlying Mesozoic beds for a mile or two, when it turns abruptly to the south, forming the western side of the Horseshoe bend. On the west or northwest side of the Missouri we find a synclinal basin filled in part with lake beds, resting on the upturned Mesozoic strata. Crossing to the west side of this basin we come to a repetition of the Cottonwood isocline, the beds here also being inverted, dipping 50° to the northwest, with the older beds on top. On the east side of the synclinal basin the same beds in the regular order of succession dip in the same direction at angles of only 25° or 30°. This Missouri isocline has also been traced to the northern limits of the map.

Attention should be called to another point, viz, the isolated character of the uplifts, that is the existence of folds which are for the most part of limited extent, as traced in the direction of their axes. This is true even within the small area included in the map accompanying this paper, where there are at least four anticlines that die out in both directions within very short distances.

The fact that over a large portion of Montana the crumpling and folding of the strata has resulted in an almost innumerable number of ranges was stated in 1871 by Dr. F. V. Hayden. In the report for 1871, p. 147, he says:

> We might say that from longitude 110° to 118°, a distance of over 500 miles, there is a range of mountains on an average every 10 to 20 miles. Sometimes the distance across the range in a straight line is not more than 5 to 8 miles, while it is seldom more than 20 miles. From these statements which we believe to be correct, the reader may form some conception of the vast amount of labor yet to be performed to explore, analyze, and locate on a suitable scale, these hundreds of ranges of mountains, each one of which is worthy of a name.

He recognized that although due partly to erosion, they were the result in the first place of folding or crumpling of the strata, the valleys in most cases being synclinal folds, and the mountains anticlinal. The truth of Hayden's observation becomes more and more apparent as the country is more and more carefully studied and mapped.

Many of the ridges do not attain the dignity of ranges, and we find that inversion of the strata is a more common occurrence than we supposed in 1871, being found in many of the ridges of very low elevation.

This orographic structure has given rise to the numerous lake basins which, with their peculiar deposits, have been noted by all workers in the region as characteristic of the territory. Above these basins, when occupied by the old lakes, the higher ridges undoubtedly projected as islands. Beyond the limits of the immediate area under consideration here, the members of the Northern Transcontinental Survey have recognized and described the various ranges examined by them as being similarly isolated or separated from each other. In addition to what may be called the normal type, that is where the ranges show the older rocks and are due to folding, Messrs. Davis and Lindgren, in the region outlying the main ranges, describe a second type of mountains, where the rocks are mainly of Cretaceous age, with little if any disturbance, and the mountain structure is due to the fact that the intrusion of dikes and the consequent induration and metamorphism of the surrounding beds has preserved them from the destructive erosive forces which have worn away the softer beds beyond the eruptive areas.[1] This type we have not yet found in the mountains and it is probably confined to the plains lying immediately eastward of them.

Still another point to which attention should be called is one which was but vaguely apprehended in 1871 and 1872, and to which reference was not made in the reports of those years, viz, the existence of an ancient pre-Cambrian shore line, which extends in a general westerly direction from the Bridger range across the northern part of our area. It crosses the Madison and Jefferson rivers probably from 10 to 12 miles above their mouths. Its eastward and northeastward extension beyond the mountains will probably be difficult to trace, but future investigation ought to determine approximately its direction to the west. All that we can say at present is that all of the area included within the limits of the Three Forks sheet south of this line was in pre-Cambrian time a part of a continental land mass, the outlines of which, with the data now at hand, can be defined only in the most general way.

Against this Archean land mass the sedimentary beds were pushed in the process of folding or crumpling, and the result was the series of folds already described.

THE THREE FORKS SECTION.

The following system of nomenclature for the Paleozoic section was determined upon for the contiguous sheets in Montana, after consultation with the members of Mr. Arnold Hague's division. The names given below replace those published on page 131 of the 10th Ann. Rept. of the Geological Survey.

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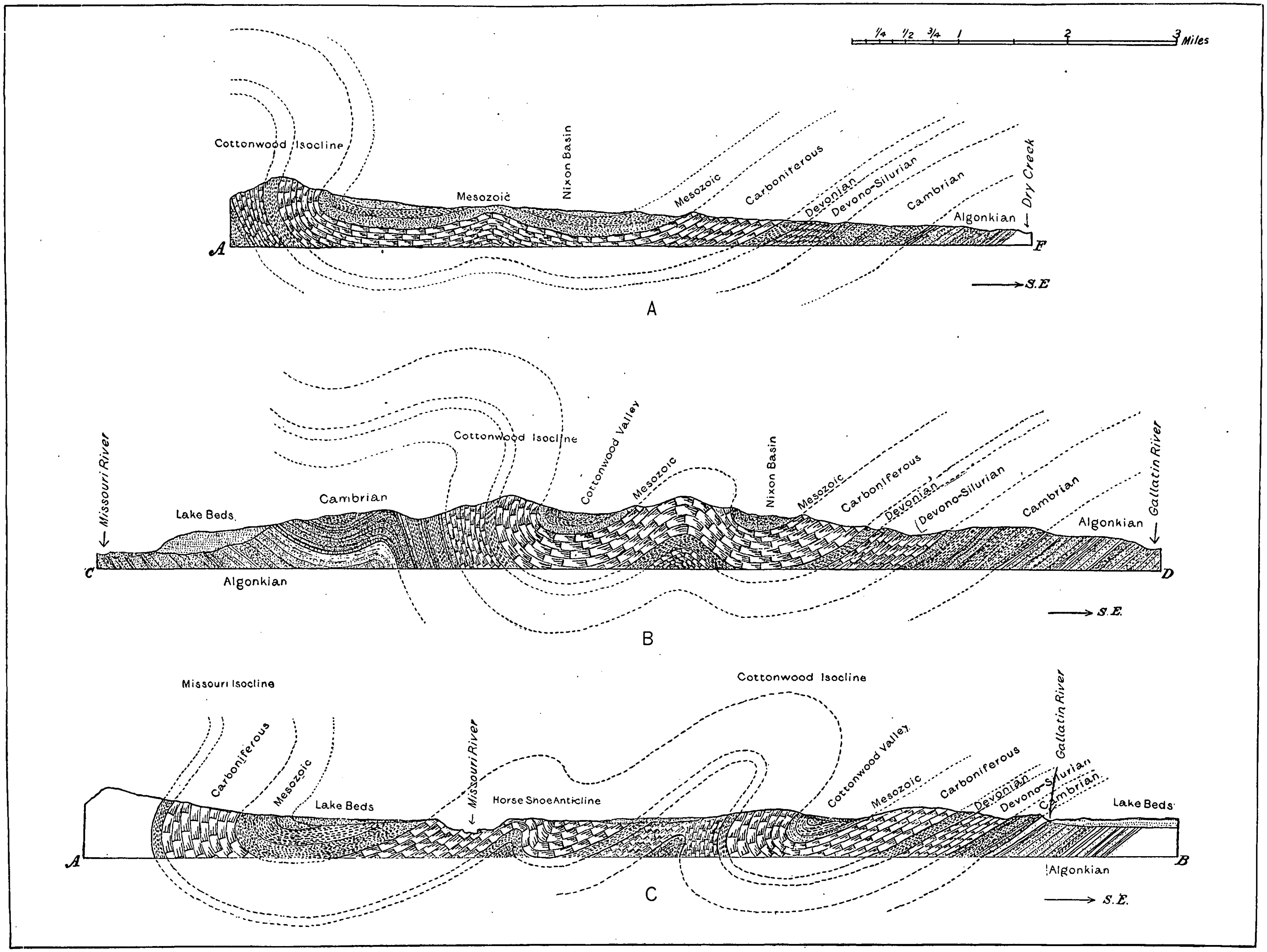
[1] Rept. of 10th Census, Vol. xv, pp. 703–705, and 724, 737.



SECTIONS BETWEEN THE EAST GALLATIN AND MISSOURI RIVERS.

Periods.	Formations.
Carboniferous	Quadrant formation. Madison formation.
Devonian	Three Forks shales. Jefferson formation.
Devono-Silurian	
Cambrian	Gallatin formation. Flathead formation.
Algonkian?	Belt formation.

The Paleozoic section of the Three Forks region, including the beds provisionally assigned to the Algonkian, consists of a series of sedimentary deposits of nearly 10,000 feet thickness, resting upon Archean gneiss. Over 8,000 feet are shown in the Gallatin section (Pl. IV), which does not, however, reach down to the Archean. A few miles south of the region shown on the map (Pl. I) this thickness is reduced to a little over 3,600 feet by the absence of the Belt formation, as the Flathead formation whenever seen there rests unconformably upon the Archean gneisses without the interposition of the Belt formation. The section of the region to the north, as given by Mr. W. M. Davis, is from 15,000 to 20,000 feet, the increased thickness being due mainly to the greater development of the Belt formation (called by him Lower Cambrian barren slates).[1]

The gneisses of our region can not at present be correlated, even provisionally, with the Archean rocks of the east. They are certainly pre-Cambrian, if the Flathead formation is of Lower Cambrian age, for included in the lower strata of the latter at several localities are fragments of gray and red gneiss evidently derived from the underlying Archean, and that they are pre-Algonkian is proved by similar occurrences in the Belt formation in the northern portion of our sheet.

Mr. Merrill's notes, appended to this paper, show that the materials forming these were without doubt derived from beds similar to those now forming the gneissic foothills of the Bridger range. The evidence for the reference of the Belt formation to the Algonkian is of a somewhat negative character, and will be noted more particularly when the included beds are described on a subsequent page. The entire section so far as observed is conformable from the base to the top. There is difficulty in attempting to define exactly the lines between the formations, even so far as the greater divisions are concerned, and the correlation necessarily has not been carried any farther, local names being applied to the minor divisions. It is a question whether the divisions of the geological scale as made in the eastern United States can ever be recognized in the strata of the Rocky mountain region.

The characters and stratigraphical position of the Flathead quartzite and shales indicate the general subsidence of the country just prior to their deposition, a subsidence which in all probability continued pro-

[1] Tenth Census, vol. XV, p. 697.

gressively throughout all Paleozoic time, with numerous oscillations of comparatively slight importance.

Between the upper part of the Cambrian limestones and the Devonian horizon above the Jefferson limestones, which we have described as the Three Forks shales, there is a thickness of over 700 feet of beds, of which the lower 350 feet have so far yielded no fossils. In the upper part meager remains have been found which have a Devonian rather than a Silurian facies, while a few indistinct remains occur a little above the middle portion. The lithological characters are the same from the bottom to the top, showing that the conditions were essentially the same throughout, and that the stratigraphic record was probably continuous, and until the paleontological record has been completed for this barren interval there remains a doubt as to the age of the lowest of these beds. The probabilities are, however, in the opinion of the writer, rather in favor of their Devonian age, and they are so described under the heading, Jefferson limestones.

ALGONKIAN.

BELT FORMATION.

The section in the vicinity of the Three Forks begins with a series of beds of littoral formation which was in 1884[1] provisionally called the East Gallatin group, so named from the well exposed outcrops occurring along the north side of the East Gallatin river near its junction with the West Gallatin, where a detailed section of 2,300 feet has been carefully measured. It consists of an alternation of coarse micaceous sandstones and conglomerates, with beds of hard argillaceous slates, and bands of thin bedded dark-blue silicious limestones. The latter are very hard and some are slightly magnesian.

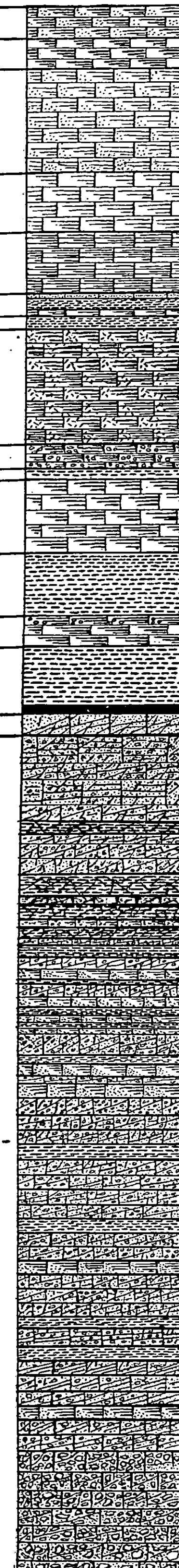
The following analyses by Mr. Charles Catlett in the laboratory of the Survey are of the two typical specimens from the lower portion of the measured section.

	I.	II.
Calcium carbonate [Ca CO_3]	67·85	59·11
Magnesium carbonate [Mg. CO_3]	6·18	1·96
Iron oxide [Fe_2 O_3] } Aluminium oxide [Al_2 O_3] }	2·50	1·92
Insoluble [silica]	23·50	35·26
Total	100·03	98·25

The limestones are developed mainly toward the base of the measured section and occur in bands from 5 to 20 feet in thickness but sometimes reaching nearly 50 feet. Many of the beds are very finely laminated, of a dark blue almost black color in fresh fractures, and show-

[1] Sixth Ann. Rept. U. S. Geol. Survey, p. 50.

CARBONIFEROUS.	1600 FT	QUADRANT. FORMATION.	350 FT	b. Cherty Limestones. 150 ft.	FOSSILS.
				a. Red Limestones. 200 ft.	
		MADISON. LIMESTONES.	1250 FT	c. Jaspery Limestones. 575 ft.	
				b. Massive Limestones. 350 ft.	
				a. Laminated Limestones. 325 ft.	
DEVONIAN.	775 FT	THREE FORKS SHALES	135 FT	Upper Shales. 70 ft.	
				Lower Shales. 65 ft.	
		JEFFERSON LIMESTONES	640 FT	Black Limestones. 640 ft.	
SILURIAN?	1250 FT	GALLATIN FORMATION.	835 FT	e. Pebbly Limestones. 145 ft.	
				d. Dry Creek shales. 30 ft.	
				c. Mottled Limestones. 260 ft.	
CAMBRIAN.				b. Obelella Shales. 280 ft.	
				a. Trilobite Limestones. 120 ft.	
		FLATHEAD FORMATION.	415 FT	Flathead Shales. 290 ft.	INTRUSIVE SHEET.
				Flathead Quartzite. 125 ft.	
ALGONKIAN.	5000 FT	BELT MOUNTAIN FORMATION.	5000 FT	Conglomeritic micaceous Sandstones with bands of siliceous Limestones and clay shales.	



TOTAL THICKNESS, 8625 FT

THE THREE FORKS SECTION.

ing light yellowish brown on weathered surfaces. About half way up in the section the limestones change in their appearance. They are more compact, not so dark in color, but are still highly silicious and layers with peculiar flat round concretions are seen. These concretions have been mistaken for fossil turtles by the people living in this part of of the Gallatin valley. Some of the concretions are very large, often measuring several feet in diameter and from 6 to 12 inches in thickness, but they average about 6 inches to a foot in diameter with a thickness of only 3 to 4 inches. Sections of them show no peculiarities.

The indurated clay-slates are also most abundant towards the middle and base of the measured section, and present a variety of colors—yellowish-brown, olive-green, and bluish-black predominating. The beds are very fissile, frequently breaking down into fine splintery débris, generally of a light color, and with frequent local bands of a bright red tint, as though the beds had been subjected to heat. These appear to be scattered over the country irregularly, and their weathering gives a very bright red débris. The slates are particularly well exposed in the bluffs along the west side of Dry creek below its first canyon.

The sandstones are prominent in the upper and lower parts of the section, and occur in heavy beds of 5 to 10 and sometimes 20 or 30 feet in thickness. They frequently break into cubical blocks with sharp edges, which increases their resemblance to eruptive rocks, for which they have sometimes been mistaken. As seen in hand specimens, their arkose character is evident, and often water-rolled pebbles of considerable size are seen, especially in the coarser beds near the base of the section.

The name "bastard granite" has locally been applied to them. Some of the layers are slightly calcareous, especially near the base, where they are intercalated with numerous thin bands of limestone, and some of the lowest sandstones are cut by seams of pure dolomite. The beds are generally very coarse and in places strongly conglomeritic. That Archean land masses, when they were deposited, existed not far to the south is very evident from the general character of the beds, and is also proved conclusively when they are compared microscopically with the Archean rocks of the adjacent region.

In the Bridger range, where the section is carried lower than on the East Gallatin, they contain many pebbles of Archean rocks, and in the lowest outcrops there are included angular masses of gneiss, showing the immediate proximity of the ancient shore line. There is considerable difference between the various beds so far as structure is concerned, but all are more or less micaceous and occur in massive layers. They are very similar in color, dark greenish gray, steel-gray, and rusty brown tints prevailing. Seen from a distance, these sandstones resemble outcrops of eruptive rocks, owing partly to their somber appearance and partly to their mode of weathering; in fact, when first seen in 1860, they were so mistaken in the following description:

Beneath are a series of thin strata of dark steel-gray micaceous sandstone, sometimes becoming a fine aggregation of water-worn pebbles, and dark brown clay-slate, gradually passing down into what appears to be a true eruptive rock with vertical seams of white quartz running through it.[1]

The formation occurs in bluffs along the Gallatin for a distance of 5 miles, and also makes up the mass of the foothills on the western side of the Bridger range from Spring hill northward, reaching in the latter place a thickness of at least 6,000 feet. It is also characteristically exposed in the canyon of the Jefferson river, 14 or 15 miles above its mouth, where the upper sandstones and conglomerates are seen in massive beds of dark green color.

In the Big Belt range, north of the limits of the Three Forks sheet, Mr. W. M. Davis, in two sections, found a series of from 10,000 to 12,000 feet of beds, which from his description undoubtedly belong to this group.[2] He refers to them as "a vast series of Lower Cambrian barren slates.[3]

The same beds are described by Prof. Newberry,[4] who says: "There is little doubt that this is the same formation as that seen beneath the Potsdam in Little Cottonwood canyon near Salt Lake city, and in the canyon of the Colorado, a formation considered Cambrian by King, Powell, and Walcott, and which has yielded the latter a few fossils, but is universally barren and disappointing." He also refers to their absence in the Belt mountains, farther to the east, and says they are absent "for the same reason that the 'Georgia slates' do not underlie the Potsdam in the Adirondacks, viz, because the Potsdam is a sheet of sea-beach, produced by a widespread, almost continental, depression of the land, or general elevation of the sea level, which carried the shore line inland beyond the areas where the Cambrian rocks had accumulated."

Nowhere in the Gallatin valley have we as yet seen this group in immediate superposition upon the Archean, although we have reason to think that the line of junction is nearly reached at the base of the section, as seen in the Bridger range. A great fault in the canyon of the Jefferson, by which the Paleozoic limestones and the overlying Mesozoic beds are thrown down against this formation, prevents our seeing the junction at that locality, while the overlapping lake beds and alluvial deposits of the Gallatin valley conceal the line of junction within the limits included in the accompanying map (Pl. I).

As to the age of this formation we have no paleontological evidence to offer, as careful search in the beds for fossils during several seasons has been unsuccessful. Hayden, in 1860, in 1871, and in 1872, was in-

[1] Exploration of the Yellowstone and Missouri rivers, p. 91.
[2] Report on the Mining Industries of the United States, vol. xv, Tenth Census, pp. 701, 702.
[3] Ibid., p. 697.
[4] Op. cit., pp. 249, 250.

clined to regard them as representing a portion of the Potsdam sandstone.[1]

In 1885 they were doubtfully referred to the Middle Cambrian;[2] in 1872 the writer suggested the possibility of their Huronian age,[3], and as already noted, Davis and Newberry both refer to them as Lower Cambrian.

All that can be said with certainty is that they are post-Archean and probably pre-Cambrian, as they are made up largely of Archean débris and lie below beds containing Cambrian fossils. So far as observed, no well-defined unconformity between them and the overlying Flathead quartzite has been seen; but there is certainly an unconformity by subsidence, which is not always well shown and might easily be overlooked. There is no doubt that after the Belt formation was deposited there was an orographic movement by which the Archean area of nearly the entire region represented on our map south of the Gallatin and Three Forks was submerged just prior to the beginning of the Cambrian before the Flathead quartzite was deposited. Whether this movement occurred immediately after the laying down of the Belt beds or after an interval is of course the question to be decided, and the decision can not be positively reached with the meager data now at hand. I am inclined to think that the subsidence of the Archean continent (or possibly islands) began with the first accumulation of the sediments that formed the lower portion of these beds and was coincident with their deposition throughout the entire period. It may have been succeeded by an emergence of the land area for a brief period, but the probability is that the interruption to the downward movement, if it occurred, was slight. Next the widespread pre-Cambrian subsidence preceding the formation of the Flathead quartzite took place, and the Cambrian sea covered large areas that had thitherto been above the sea level. There is a marked difference in the character of the beds of the two groups. Little, if any, induration is seen in the Flathead formation, while the Belt beds are so altered in most cases as to resemble closely the metamorphic crystalline rocks which underlie them, and from the breaking down of which they were derived.[4] Notwithstanding the metamorphism there is no mistaking their sedimentary character.

We have, therefore, a nonfossiliferous group of clastic beds, sometimes slightly metamorphosed, which lie between the Archean gneisses and a belt of quartzite, above which are beds with Middle Cambrian fossils. From its stratigraphical position this group could be only of Lower Cambrian or of Algonkian age.

The possibility that Lower Cambrian fossils may yet be found in the quartzite at the base of the Flathead formation; the absence of organic

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[1] Exploration of the Yellowstone and Missouri rivers, p. 91, Preliminary Report of the U. S. Geological Survey of Montana, p. 140; 6th Annual Report of the U. S. Geological Survey of the Territory, p. 72.

[2] Seventh Ann. Rept. U. S. Geological Survey, p. 86.

[3] Sixth Annual Report of the U. S, Geological Survey of the Territories, p. 174.

[4] See Mr. Merrill's notes appended to this paper.

remains in the Belt formation; the metamorphosed condition of the latter, and the existence of the unconformity between the quartzite and the beds below lead us to refer the latter, for the present at least, to the Algonkian.

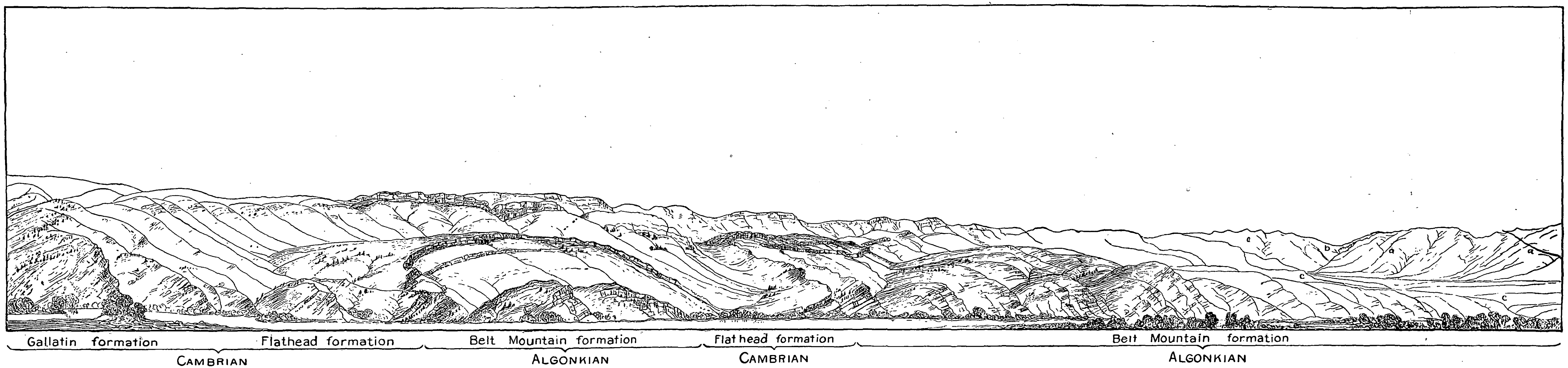
CAMBRIAN.

The Cambrian rocks of our section are divisible into two portions, differentiated from each other by their lithological characters, the lower being mainly arenaceous and the upper calcareous. They will be described under the names of the Flathead formation and the Gallatin formation. The former may be subdivided into the Flathead quartzite and the Flathead shales, while the Gallatin formation will be described under the following subdivisions: The trilobite limestones, the obolella shales, the mottled limestones, the Dry creek shales, and the pebbly limestones.

As the collections of fossils have been only partially examined, no attempt will be made to draw with precision the lines separating the Lower Cambrian from the Middle Cambrian, nor the latter from the Upper Cambrian. The Flathead quartzite in the main probably represents the Lower Cambrian or its upper portion, and the trilobite limestones are very likely of Middle Cambrian age, while the mottled limestones with the overlying beds should doubtless be referred to the Upper Cambrian. It is altogether possible, however, that the pebbly limestones, or a portion of them, may eventually have to be taken from the Cambrian and considered as belonging to the Silurian.

FLATHEAD FORMATION.

Flathead quartzite.—Resting upon the Belt formation in the Three Forks area is the remarkably persistent quartzite or sandstone, which has long been recognized in the Rocky mountain region as lying in most cases at the base of the Paleozoic section, and which has been almost universally referred to as the equivalent of the Potsdam sandstone. It is usually quartzitic, and in the Gallatin valley is composed of siliceous grains of considerable uniformity in size, cemented by a siliceous matrix. In some localities there are interlaminated beds of reddish or reddish-brown sandstones in which the cementing material is partly an iron oxide. These sandstone sometimes have sufficient development to furnish a good building stone, and they have been utilized and quarries have been opened at several places in the valley, the one at the south end near Salesville, on the West Gallatin river, being the oldest. Owing to the hardness of the beds as exposed in most localities this quartzite is conspicuous topographically, and serves admirably as a reference horizon in making detailed sections in this region. In the illustration in Pl. V it is well shown, outlining the double fold in the beds that outcrop on the north side of the Gallatin and East Gallatin rivers.



SECTION ALONG THE NORTH SIDE OF THE GALLATIN RIVER.

a, a, a. Bridger Range. *b.* Flathead Pass. *c, c.* Dry Creek Valley.

From the comparatively small thickness of the basal quartzite, it being only about 125 feet, and the fact that it is usually inclined at a considerable angle, the area occupied by it is relatively small, and if separately colored upon the map it would be represented by little more than a line of color.

Although the Flathead quartzite in the southern portion of the Bridger range and south of the Jefferson Valley rests immediately upon Archean schists or gneisses without the interposition of the Belt beds, it presents exactly the same lithological characters as in the region of the Three Forks, where the latter are well developed. Its thickness, however, is somewhat less. An interesting fact in connection with its outcrops seen north of the East Gallatin is the occurrence of several dip faults in it where the quartzite is apparently thrown down in blocks, and wherever these blocks occur there is found an intrusive sheet lying immediately above the quartzite or separated from it in a few cases by a narrow belt of shales. These sheets are apparently absent at every place where the beds are in their normal position. The faults will be referred to again under the head of "Eruptive rocks," where this intrusive sheet is described in detail.

In view of the fact that no fossils have been found in the quartzite, and that those from the beds above have been only cursorily examined, it is impossible to designate with exactness its position in the geological scale. From the preliminary examination of the fossils of the Cambrian and Devonian portions of the section Mr. Walcott has no doubt that this region belongs to the same geologic province as do the Paleozoic rocks of the "Eureka district," and if we attempt to correlate the two sections this quartzite should be at least provisionally correlated with the Prospect mountain quartzite, which he considers to be of Lower Cambrian age.

Flathead shales.—Above the quartzite, separated from it in several places, as already indicated, by a layer of eruptive rock, follows a series of rather shaly beds, which, owing to their generally soft character, form one of the deepest of the ravines met with in crossing the country at right angles to the strike of the beds. These shaly beds attain a thickness of about 290 feet, and seem to be transitional in their lithological characters. The detailed sections show them to be made up of beds in which the arenaceous element largely predominates in the lower portion near the quartzite, but gradually becoming more and more calcareous as we ascend towards the base of the massive limestones that lie next above. There are thin beds of glauconitic limestone interlaminated with the shales, and several of these bands have been found to be fossiliferous. They are frequently micaceous on the surfaces and contain green grains of what is apparently glauconite. The general color of the beds is green, due in all probability to the occurrence of this mineral. Towards the base there are beds of very dark reddish brown and green sandstone that are slightly calcareous and highly fossiliferous in the bottom layer. The shales seen at the top, immediately below the limestones, are greenish and purplish, with very thin bands of sandstone and glauconitic limestone in equally thin layers. They are sandy, and separate into laminæ of only an inch or two in thickness, with green micaceous surfaces. The area occupied by the shales is coincident with that of the underlying quartzite.

The weathering of the beds results in their concealment in most places, but they form characteristic ravines which can be traced without difficulty above the quartzite from the beginning of the fold at the Gallatin to the crossing of Dry creek, the zone or belt occupied by them widening or narrowing, as shown upon the map, according to the effect of the erosive forces upon the overlying limestones.

The Flathead shales are fossiliferous at about three horizons, the first near the base, the second a little below the middle part, and the third near the top. The collections have not been specifically determined, but there is apparently no difference in the specimens from the different horizons. The following genera were identified:

Lingulella.
Hyolithes.
Ptychoparia.

An exact reference of these shales can not, therefore, be made at present. So far as lithological characters go, they seem to be transitional between the Flathead quartzite and the trilobite limestone, but where the line between the Lower and Middle Cambrian should be drawn if they are in part of Lower Cambrian age it is at present impossible to say.

GALLATIN FORMATION.

The lower limit of the Gallatin formation has been drawn at the base of the first well defined limestone (trilobite limestone). The shales that immediately follow the latter attain a greater thickness than do the limestones or their underlying shales, but they are more calcareous than arenaceous, while in the Flathead shales the latter character is predominant. There are three belts of limestone and two of shaly beds, the upper one of the latter being comparatively thin.

Trilobite limestones.—Immediately following the fine green sandy shales that lie at the top of the beds described as the Flathead shales are thin bedded limestones dark gray in color, breaking into laminæ of an inch or two in thickness. These laminæ are highly fossiliferous wherever they have been examined, and at several localities have at the bottom a few thin bands of greenish shales containing concretions which are full of trilobite remains. The very lowest limestone is about 3 feet in thickness, followed by 6 inches of shale and then 7 feet more of limestone, above which are found dark blue laminated limestones breaking into laminæ 2 or 3 inches thick. The total thickness of the trilobite limestones is about 120 feet. The central portions are massively bedded, while the upper part becomes more and more laminated, pebbly layers also being found at the top. In the latter a few indistinct remains of trilobites were found.

These limestones are very persistent and form a low bluff back of the sharp ridge formed by the Flathead quartzite, from which they are separated by the shaly interval already described. They are characteristically fossiliferous, especially at the base, as already indicated.

The list of fossils identified by Prof. F. B. Meek from the collections of 1871 (made mostly by the writer) has been revised by Mr. Walcott after comparison with the collections made in 1884, and the following list is the result:

Lingulella sp.?	Agnostus bidens.
Kutorgina sculptilis.	Ptychoparia gallatinensis.
Acrotreta gemma.	Olenoides serratus.
Hyolithes gregaria.	Bathyuriscus? haydeni.

Of this Mr. Walcott says: "The facies of the above group of species correlates the horizon at which they occur with that of the Middle Cambrian zone of the Nevada and British Columbia sections. There is not, to my knowledge," he says, "such a grouping of genera and species at any known Upper Cambrian horizon."

The collections examined by Prof. Meek and revised by Mr. Walcott came from only three or four localities in all, while the collections made since then are much larger, and represent the same horizons from at least a dozen localities. The later collections have not yet been thoroughly examined, but when they are the list of species will undoubtedly be greatly enlarged.

Obolella shales.—For a space of 280 feet above the trilobite limestones the outcrops are very obscure in most places, owing to the soft character of the shales, whose erosion has caused the formation of deep ravines parallel to the strike of the beds. Such exposures as have been seen, however, leave no doubt that the entire space is occupied by shaly beds, which are mostly calcareous. There are a few thin bands of limestone and several calcareous sandy beds with micaceous surfaces in the central portion of the outcrops. The lower beds are covered from the breaking down of the shales above, and the upper beds are concealed by the yellowish débris washed down from the overlying limestones. Very fine, rather dark greenish shales prevail in the lower part, while the upper beds are very much lighter in color. The only organic remains found were from the middle of the series, and they consist solely of undetermined species of Obolella, from which the shales have been provisionally named the Obolella shales.

Mottled limestones.—The trilobite limestones and overlying Obolella shales are followed by massive-bedded limestones that form one of the characteristic topographical features of the area under consideration. They weather into the first high and prominent bluff face that is met with after leaving the Flathead quartzite. These beds are well shown in Pl. V where the mottled limestones come to the river's edge in the extreme left of the illustration, and can thence be readily traced, forming the line of bluffs back of the ridge of Gallatin quartzite which is seen in the central portion of the picture. The name mottled has been applied to these limestones from the mottling of yellowish and dark spots observed in the central portion of the beds. This mottling, however, is not peculiar to them. It occurs also in a slight degree in the trilobite limestones and in some of the Jefferson limestones. The total thickness is about 260 feet. The lower 20 or 25 feet consists of laminated beds, generally of a light gray or brownish color; some of the layers are glauconitic and oolitic and contain remains of trilobites (*Ptychoparia?*) and *hyolithes*.

The mottled portions are light bluish gray and massively bedded, gradually becoming more and more laminated as we approach the top, where they are again glauconitic and pebbly, with numerous fragments of fossils, mostly trilobites. None of the collections from these beds have been studied by the paleontologist, but the facies is apparently not very different from that of the trilobite limestones. Until more specific determinations are made it can not be stated whether these beds are referable to the Upper Cambrian or to the Middle Cambrian.

Dry creek shales.—An interval of shales or shaly calcareous sandstones follows the glaucónitic and pebbly layers that cap the mottled limestones. The outcrops are naturally obscure in most localities, and the best exposure noted was found on Dry creek, where the total thickness is about 30 feet. Here they consist of brownish yellow, red, and pink sandstones, saccharoidal in structure, breaking into thin laminæ, with streaks and seams of calcite. So far as examined they are nonfossiliferous.

Pebbly limestones.—Passing up from the narrow belt of the shales just described we find a series of light colored laminated limestones, which reach a thickness of 145 feet. They are in bands of 4, 6, or 8 inches to a foot, and are pebbly from top to bottom, although the lower bands are the coarsest, and contain glauconite abundantly. The pebbles are of limestone, and reach a diameter of an inch or two. At the base the beds are yellowish brown in color and are somewhat thicker, and generally crowded with the remains of trilobites and small shells. As we ascend in the beds they become more and more compact, and are mainly dove-colored limestones, with many trilobite fragments in the central portion, although the latter are not so numerous or so distinct as at the base. These upper beds are not glauconitic. The upper 25 feet are much darker in color, more crystalline in structure, probably somewhat siliceous, and gradually approach so closely the general characters of the overlying black limestones that it is difficult to draw a definite line of separation between them. Dark bluish layers began to alternate with the lighter-colored ones as we ascend, and the line for the top of the Cambrian has been arbitrarily drawn at the base of the lowest crystalline black limestone, 20 feet above the last fossiliferous horizon of the pebbly limestones. The remains collected here are very fragmentary, and, although they are referred to the Cambrian, they are undoubtedly on or near the border line between the Cambrian and the Silurian.

As just noted, three horizons are fossiliferous in these limestones: the base, the middle part, and the top.

The lowest fossiliferous band contains innumerable fragments of trilobites crowded in the rock, with shells and pebbles.

The middle beds have two fossiliferous lines separated by only a few feet, and from both collections were obtained. They contain apparently the same forms as those identified from the lowest layer.

In the latter Mr. Walcott has recognized:

Leptæna melita.	Triplesia calcifera.
Ophilita sp?	Ptychoparia sp?

Of the forms specifically indentified he says: "In the Eureka district section they occur in the Cambrian and pass into the base of the Ordovician." It is possible, therefore, that these beds may eventually have to be taken from the Cambrian and referred to the Silurian (Ordovician).

DEVONO-SILURIAN.

The pebbly limestones just described, and referred to the top of the Cambrian, pass gradually and almost imperceptibly into a series of black crystalline limestones, which for about 700 feet have as yet yielded no paleontological evidence that is conclusive as to their age. The lower 350 feet of the beds are barren of all remains so far as we have examined them, but careful search in other localities may be rewarded by the finding of fossils which are as likely to prove the Silurian age of the lowest beds as to determine their reference to the Devonian. The pebbly limestones have every indication of being on or near the border line between the Cambrian and the Silurian, and there is a possibility of a part of the beds being Silurian. A part of the beds above may also have to be so referred eventually. They will all, however, be described under the head of Devonian, inasmuch as the very meager remains found in the middle portion have more the aspect of the Devonian than of the Silurian.

The evidence for the presence of Silurian beds in the Rocky mountains is still very meager, and may be briefly detailed as follows:

In 1871 Dr. Hayden obtained from limestones above the Potsdam in Box Elder canyon, Utah, a specimen of *Halysites catenularia* (*catenulatus?*).[1]

From the finding of this fossil in Utah and the occurrence of Upper Silurian fossils in the Nevada section the 100 to 200 feet of the Ute limestone in the Wasatch section is referred by King to the Upper Silurian.[2]

[1] See pp. 15 and 373, Hayden Report for 1871. (In vol. 1, Systematic Geology, U. S. Geol. Exploration of the 40th Parallel, p. 178, the finding of this fossil is credited to Prof. F. W. Bradley, who was not with the Hayden Expedition of 1871.)

[2] Vol. 1, U. S. Geol. Exploration 40th Parallel, pp. 180, 181.

In 1872 Prof. Theo. B. Comstock[1] referred the beds immediately overlying the Potsdam sandstone in the Wind river mountains to the Niagara group from the presence of *Halysites catenulatus* and other corals of the genera *Cyathophyllum* and *Zaphrentis*, with a specimen of an *Orthoceras* and a poorly preserved brachiopod resembling *Pentamerus* (*galeatus?*).

A series of limestones in Colorado, occupying the same stratigraphical position in relation to the Potsdam, has also been referred to the Silurian.[2]

In Mr. Hague's Eureka section of Nevada[3] there is a considerable development of Silurian with a characteristic fauna in the lower portion and some imperfect corals of the genus Halysites in the upper part. Mr. Walcott also refers to the occurrence of *Halysites catenulatus* at the same horizon in the White Pine district. (See p. 4 of Paleontology of the Eureka district.) Although these latter are not in the Rocky mountain region, they are mentioned here because a large number of the species in the collections from the upper part of the Devonian of our section are identical with species occurring in the Upper Devonian of the Eureka section, and the Cambrian of the Gallatin section also bears a general resemblance to that of the Eureka section.

Mr. R. G. McConnell,[4] of the Canadian Geological Survey, in his general section of the formations examined by him in the vicinity of the 51st parallel recognizes the Silurian horizon in a series of beds 1,300 feet thick, which he calls the "halysites beds."[5]

Neither Dana and Grinnell,[6] nor the members of the Northern Transcontinental[7] Survey obtained any fossils from these beds in the region north and northeast of our area.

In view of the fact that there is no apparent break in the continuity of the beds from the top of the Cambrian to the top of the crystalline limestones, just above which the Devonian fossils occur in great abundance, I have given them throughout the name "Jefferson limestones," simply referring to the fact that the lower portion may be of Silurian age, drawing at present only an arbitrary line, dividing them below from the pebbly limestones in the hope that future careful search may reveal evidence that will establish their age positively.

It is probable that the more we know of the organic remains of these beds the more difficult will it be to draw the lines of separation between them, for the lithological characters are the same throughout and there is little doubt that the sedimentation was continuous, and if there were any changes in the character of the fauna they probably occurred

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[1] Reconnaissance of N. W. Wyoming, Jones, 1873, p. 112.

[2] Geology and Mining Industry of the Leadville Region, 1886, p. 60.

[3] Third An. Rep. of the U. S. Geological Survey, pp. 253, 260, et seq.

[4] Report on the Geol. Structure of a portion of the Rocky Mountains, etc., 1887, p. 15 D.

[5] Report on the Geol. Structure of a portion of the Rocky Mountains, etc., 1887, p. 21 D.

[6] Report of a reconnaissance from Carroll, Montana, to Yellowstone Park and return, Ludlow, 1876, p. 122.

[7] Davis's report on Mining Industries of U. S., vol. xv, 10th Census, p. 697.

gradually, so we need not be surprised if we find a mingling of Silurian and Devonian forms of life on the border line.[1]

DEVONIAN.

JEFFERSON FORMATION.

As just intimated, it is impossible to define exactly the base of the Devonian, but provisionally the entire thickness of the Jefferson limestones is so referred. It includes three fossiliferous horizons, although the fragments from the lower two are so poor that practically only the upper one is worthy of mention.

Above the Jefferson limestones are two belts of shales, mostly argillaceous and calcareous, separated from each other by a band of limestone. The upper belt of shales is highly fossiliferous, and from its organic remains the first identification of the Devonian in this region was made. The divisions of the Devonian will, therefore, be described below, under two heads, viz: *a*. The Jefferson limestone, and *b*, the Three Forks shales.

Although the collections of the Hayden survey from this region in 1871 and 1872 contained genera common to both the Carboniferous and Devonian, as determined by Prof. F. B. Meek,[2] the specimens were all from the limestones that overlie the Upper Devonian shales, and, as will be shown subsequently, were of Lower Carboniferous age.

From the upper shales that lie above the Jefferson limestones the writer obtained in 1884[3] a collection of fossils which were identified by Mr. Walcott as proving a well-marked Devonian fauna horizon. This was the first positive identification of that horizon in Montana, and in 1885 another fossiliferous horizon, 40 to 75 feet lower down, afforded a meager collection of Devonian forms.

Jefferson limestones.—Above the pebbly limestones which were referred provisionally to the upper part of the Cambrian we have beds resembling at first the pebbly limestones, but gradually becoming more crystalline and darker, so dark indeed, as a whole, that in our field notes they are usually designated as the "black limestones."

They are well developed in the hills a mile or two north of the East Gallatin river and on the main Gallatin above the Gallatin bridge of the Northern Pacific railroad, as shown to the right in the illustration, (Pl. VI). Here the river cuts across the ends of the beds almost at right angles to the strike. They are also well exposed in the hills on both sides of the Missouri just below the junction of the Three Forks

[1]Since writing above I am informed by Mr. Walcott that he has received a collection of Lower Silurian (Ordovician) fossils from the Black hills. He has also identified the Trenton fauna among some of the collections of Mr. Emmons from Colorado, and has recognized in collections made in the mountains eastward forms which indicate the probable equivalent of the Pogonip limestones of the Eureka and Nevada section.

[2]Hayden's 6th Ann. Rept. U. S. Geol. Survey, p. 432. (A part of these collections were made by the writer, who unpacked all of them, and is certain that none of them came from the Devonian horizons since found and collected from.)

[3]Science, vol. V, March 27, 1885, p. 249.

and on both sides of the Jefferson a few miles above its mouth. They have been designated the Three Forks limestones because they are so well shown at many localities near the Three Forks.

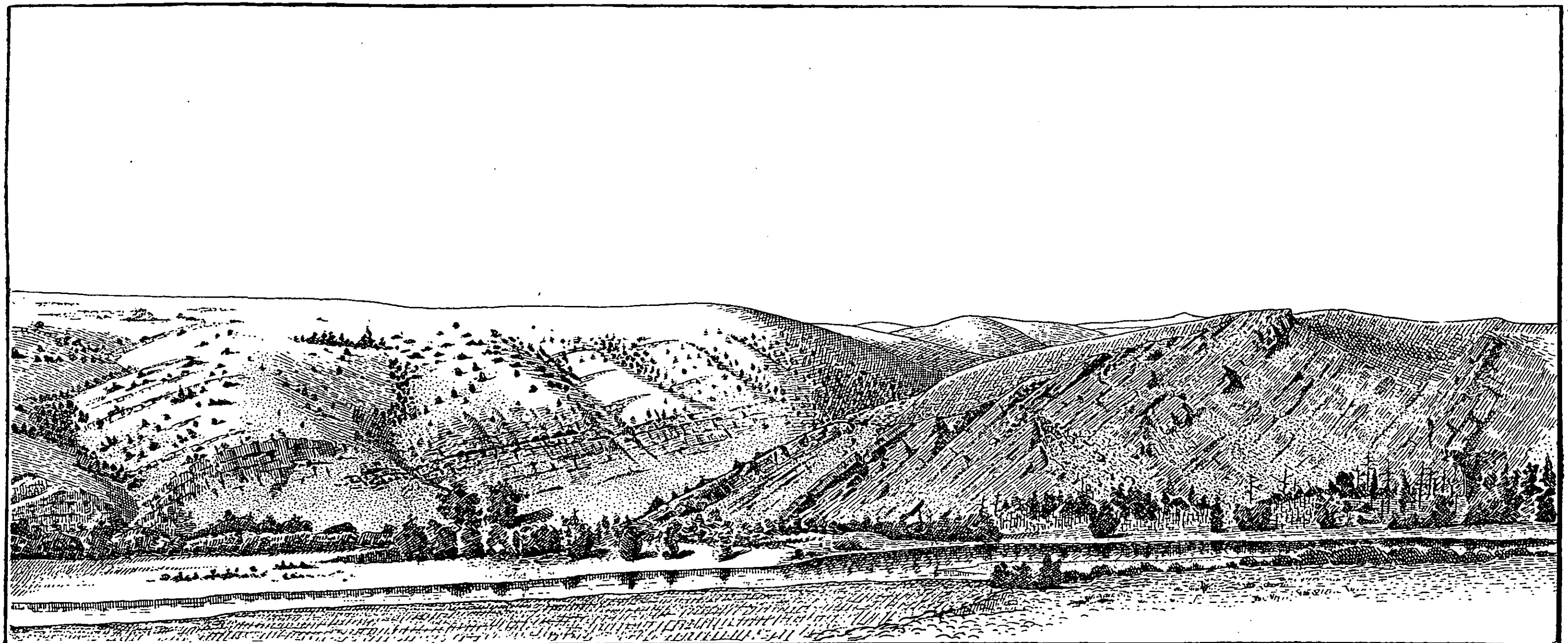
Although there is considerable difference in detail between the limestones as noted at different localities, still there is a general resemblance between them and they are not easily mistaken. In the Bridger range they consist of an alternation of dark, almost black, beds, and lighter, mud-colored beds at the top, with a brecciated limestome at the very summit of the series. On the Gallatin the beds are generally darker than in the Bridger range, but otherwise the general appearance is the same. They are brown and blackish in color, and microgranular in structure, due to their being very crystalline, and occur in alternations of rather massive beds of the very dark limestones, from 10 to 15 feet in thickness, with lighter colored, more laminated limestones in layers of 2 feet to 5 or 6 feet each. At some of the localities there are indications of light colored sandy beds near the top, but the dark limestones generally prevail to the very top. On the south side of the Jefferson the upper and lower portions of the series are considerably lighter in color, the very black limestones being restricted to a central zone of several hundred feet. The lower portions here are drab-colored crystalline limestones with considerable yellow jasper distributed through them, while the upper part of the section, although generally much obscured, consists of light colored limestones of rather irregular structure.

On the North Boulder, still farther west, the black limestones are more intense in color, but so far as the structure and general appearance is concerned they are identical with those on the Gallatin. The brecciated beds of the Bridger range have as yet not been seen at any of these more western localities.

The following analyses were made in the laboratory of the Survey by Mr. Charles Catlett. I is a brownish-black limestone from north of the East Gallatin, and II is a very black limestone from the west side of the North Boulder valley.

	I.	II.
Carbonate of lime ($CaO\ CO_3$)	54·54	54·54
Carbonate of magnesium ($Mg\ CO_3$)	43·63	42·62
Iron oxide (Fe_2O_3) / Aluminium oxide (Al_2O_3)	·22	·40
Insoluble (silica)	·34	1·78
Organic matter (includes water)	Undetermined.	Undetermined.
Total	98·73	99·34

The specimens analyzed are from localities more than 30 miles apart, and it will be seen that the limestones are remarkably alike, their composition being that of normal dolomite.



Bridger Limestones

Three Forks Shales
(In Devonian Ravine)

Three Forks Limestones

SECTION NORTH OF GALLATIN RIVER.

East of Gallatin Bridge of N. P. R. R.

As previously indicated, only the upper portion of the limestones have yielded any recognizable fossils. From one locality about 30 feet below the top of the limestones a few fossils were obtained, and among them Mr. Walcott has identified the following:

Spirifera disjuncta.	Smithia ? sp. undetermined.
Chonetes macrostriata.	Orthis, sp. undetermined.

Three Forks shales.—Back of the Jefferson limestones, which generally dip at angles of 20° to 30° there is usually found a deep ravine beyond which the Carboniferous limestones rise with steep bluff faces. This ravine is due to the interval of shaly beds which lie between the two belts of limestone. For purposes of description the shales may be divided into the Lower and Upper Shales. They are separated by a band of limestone 15 to 20 feet thick which is grayish brown in color, generally very compact and close grained, sometimes micro-granular with streaks of calcite, and upon weathering gives a yellow débris. The structure appears to be irregular. A qualitative analysis by Mr. E. L. Howard in the Survey laboratory proves that it is argillaceous and contains strontia in appreciable quantity.

The Lower shales.—No good continuous exposure has been seen of the entire 50 feet of shales below the limestone just described, as they occur so low down in the ravines that they are generally covered with the material from above, or if not so concealed, the breaking down of their own beds and the intermediate limestone has obscured them with an orange-colored débris which is quite brilliant at a number of localities, and generally serves to indicate their position. The beds are, so far as known, reddish and brownish yellow calcareous and argillaceous shales. No fossils have been obtained from them or from the overlying limestones.

The Upper shales.—Immediately above the thin band of limestone occur the shales referred to several times as containing a fauna characteristically Devonian. They begin at the bottom with about 30 feet of fine green argillaceous shales which are generally so soft as to be broken down and largely concealed under their own débris. In some places these shales are purplish and at others black. In their upper part are bands of black or purplish calcareous and argillaceous limestones which are also very soft and shaly, and these beds pass gradually up into dark bluish drab, almost black, limestones, which are highly argillaceous and are succeeded by limestones with greenish surfaces on their thin bands. They are very irregular in structure, greenish gray in color, and contain numerous nodules or concretions which are generally filled with fossils. They break into small angular pieces for the most part, and the fossils are finely preserved. These greenish gray argillaceous limestones become somewhat arenaceous at the top, and contain strontia in small quantity. They have a total thickness of about 45 feet, and contain fossils at five or six different levels, but as there is no apparent difference in the fossils from them, they are not separated in the lists. The shales are capped by a yellow, laminated sandstone which is usually about 25 feet thick. This sandstone gives frequently an orange-yellow colored débris which indicates the position of the beds when they are covered, which is often the case. The lower part of this sandstone is slightly magnesian and the cementing material is calcareous. A qualitative examination shows the presence of strontia as in the beds just below. Near the Horseshoe bend of the Missouri a detailed section shows just below the sandstone a band of coal black slate about 5 feet thick, which has misled prospectors, who at one locality have sunk a shaft in it for 60 feet in hopes of finding coal.[1] It is followed by 10 feet of gray limestone crowded with fossils. Below are the green shales with bands of limestones fossiliferous in many layers. The very lowest beds are also highly argillaceous and full of fossils.[2]

The base of the Upper yellow sandstone at nearly all the localities examined contains a few fossils, among which *Rhynchonella tethys*, Billings [?], occurs most frequently.

The total thickness of the section is about 135 feet. The description just given has reference to the region north of the Gallatin and East Gallatin rivers. When followed eastward into the Bridger range, the beds appear to be somewhat more arenaceous, while to the west on the north side of the Jefferson, they are more calcareous, especially in the layers that are fossiliferous. South of the Jefferson on Antelope creek at the same horizon, below the yellow sandstones, are very hard black shales, almost slates, in which a shaft has been sunk to the depth of some 20 feet, and a coal claim has been located, although no coal has been found. The slate is coal black in color and has evidently misled the prospectors, as in the locality already noted between Gallatin station and the Horseshoe bend of the Missouri. At the latter place, however, the beds are not so hard. As they are inclined wherever they have been examined, their soft character is the cause of their erosion into one of the most conspicuous ravines of the area under consideration. This persistent topographic feature indicates their position wherever the section is crossed, even when the outcrops are concealed by the débris of the beds overlying them. In Pl. VI this ravine occupies the center of the illustration, and at this locality has been named Devonian ravine. The beds here are highly fossiliferous, and the first fossils found were obtained from the eastward or northeastward continuation of this ravine, 2 or 3 miles from the river. Although so characteristic a feature on the north side of the Gallatin and along the Jefferson river, in the region a few miles farther north, it appears to have

[1] In the Jefferson Valley, just below the cañon above the station of Sappington, coal is found at this horizon with nodules of limestone in it containing Devonian fossils, some of the species being identical with those found on the Gallatin and at Horseshoe bend of the Missouri.

[2] The fossils from Horseshoe bend have not been studied as yet and therefore they are not included in the lists that follow, although there is not the least doubt that many of the same forms occur in these collections that were found in the others.

escaped the notice of the geologists connected with the Northern Transcontinental Survey, who have included the entire series of limestones between the Cambrian and the Mesozoic under the head of the great series of mountain limestones[1]. In 1871 and 1872 the Hayden survey also included the Devonian as now outlined, and the overlying Carboniferous, all under the head of the Carboniferous. The beds just described were not recognized, mainly on account of the rapidity with which the work had to be carried on, and partly from their obscure outcrops, and if any stray fossils from this horizon were obtained (which is extremely doubtful), they were referred to in the descriptions as coming from the lower Carboniferous limestones, which lie immediately above.

The collections of 1884 were obtained at a point about 4 miles northwest of the mouth of the East Gallatin river, and about the same distance northeast of the Northern Pacific Railroad bridge crossing the main Gallatin. Among them, the following were identified by Mr. C. D. Walcott:

Discina lodensis, Hall [?]
Streptorhynchus chemungensis, Conrad.
Orthis vanuxemi [?] Hall [?]
Chonetes mucronata, Hall.
Productus lachrymosus var. limus, Conrad.
Productus speciosus.
Spirifera disjuncta, Sowerby.
Spirifera engelmanni, Meek.
Rhynchonella pugna, Martin.
Rhynchonella sinuata, Hall.
Rhynchonella tethys, Billings.
Atrypa reticularis, Linnarson.
Ambocœlia umbonata, Conrad.
Athyris hirsuta, Hall.
Athyris sp. [?]
Aviculopecten.
Grammysia, three sp.
Modiomorpha.
Nucula.
Schizodus.

Of the twenty-two species enumerated in the list, Mr. Walcott says "twelve are identical with species occurring in the Upper Devonian of the Eureka district, Nevada; of the others, two are Upper Devonian species in New York State."[2] The remaining forms are lamellibranchs belonging to five genera, and the species closely resemble those of the Lower Carboniferous of the Eureka district. The collections made from the same horizon in 1885, 1886, and 1887, have added to the number, and the list now includes thirty-nine species, as follows:

Fenestella, sp. undet.
Discina lodensis.
Orthis vanuxemi.
Streptorhynchus chemungensis.
Strophomena rhomboidalis.
Strophodonta, sp. ?
Chonetes filistriata.
Chonetes mucronata.
Productus speciosus.
Productus lachrymosa var. lima.
Productus lachrymosa var? stigmatus.
Spirifera disjuncta.
Spirifera engelmanni.
Syringothyris cuspidata.
Atrypa reticularis.
Ambocoelia umbonata.
Athyris sublamellosa.
Athyris, sp. ?
Athyris hirsuta.
Rhynchonella [Stenochisma] tethys.

[1] Report on the mining industries of the U. S., vol. xv, 10th census, pp. 679, 701, etc.
[2] Science, vol. v, 1285, p. 249.

Rhynchonella [L] sinuata.
Rhynchonella pugna.
Rhynchonella metallica.
Rhynchonella horsfordi.
Rhynchonella [Leiorynchus] laura.
Rhynchonella, sp. ?
Aviculopecten.
Aviculopecten, sp. undet.
Modiomorpha.
Nucula.
Grammysia, three species.
Schizodus.
Orthoceras [annulated species].
Orthoceras, sp. undet.
Goniatites, sp. ?
Schizodus orbicularis.
Conularia.

Of the twenty-three forms specifically determined, thirteen occur in the Upper Devonian of the Eureka section, and seven in the Lower Devonian of the same, while two are common to both. Four are found in the Lower Carboniferous of the Eureka district. Of the remainder, at present only generically determined, as Mr. Walcott says, "Five have a close resemblance to species of the Eureka Carboniferous," and all the genera are found in the Devonian.

There is a faint possibility that when the localities are added to and larger collections are made, these beds may be relegated to the lower part of the Carboniferous, but at present the preponderance of evidence seems to be in favor of the Devonian. They are certainly near the border line and there is no reason why a mingling of forms from the two horizons should not be a common occurrence throughout our region, not only at this line, but at all the others which lie so close to the division lines between the formations.

CARBONIFEROUS.

The carboniferous rocks, although considerably reduced in this section from the thickness originally given them in the Montana Rocky Mountains by Hayden and others, are still conspicuous and uniformly well developed on the borders of the Gallatin valley, and especially so in the northern portion, in the vicinity of Three Forks, where there are above the Three Forks shales about 1,600 feet of beds (mainly limestone) which probably are all referable to this period. It is impossible to divide the beds into Lower, Middle, and Upper Carboniferous, as the fossils collected up to the present time do not present sufficient evidence to warrant such a subdivision, although two divisions can be made, based partly on the paleontological evidence, but mainly upon lithological and stratigraphical grounds.

The Carboniferous, therefore, is described in this paper under two heads, viz, the Madison formation and the Quadrant formation. The former are well exposed in the central portions of the Bridger range on the east, and in the area adjacent to the Three Forks on the west, as well as at the head of the Missouri river at Gallatin city, and wherever examined has been found highly fossiliferous. The canyon of the Jefferson river presents one of the best and most fossiliferous sections of the upper beds.

In the region immediately adjacent to the Three Forks, both the

Madison and Quadrant formations are equally characteristic, not only in the exposures, but also in the contained fauna, and from top to bottom the sections present the same general characters as are seen elsewhere. The beds consist of bluish gray or drab limestones compact or fine grained and even bedded, sometimes in massive beds and often laminated, partly pure limestones, partly cherty, and in the upper part passing into quartzitic beds that can scarcely be distinguished from the quartzites that we have taken as the base of the Mesozoic (Jura-Trias).

For purposes of description the following subdivisions may be made. Beginning at the base the Madison formation is divided into Laminated limestones, Massive limestones, Jaspery limestones; and the Quadrant formation is divided into Red limestones and Cherty limestones.

Paleontologically, the Madison formation appears to be of Lower Carboniferous age, and some of the fossils from the lower portion have naturally a Devonian facies. The lowest beds of the Red limestones have so far yielded a comparatively meager fauna which does not positively determine its horizon, but which might be Middle or even Upper Carboniferous, while the upper portion of the Cherty limestones up to this time have given only a linguloid shell and an undetermined species of Athyris. However, the collections from the lower horizons indicate the Upper Carboniferous age of the greater part at least of the Cherty limestones, and possibly also of the Red limestones, and renders doubtful, therefore, the separation of any portion to which the name of Middle Carboniferous can be applied.

MADISON FORMATION.

The Laminated limestones.—Immediately overlying the yellow sandy beds of the Upper Devonian, dark colored, compact, and fine-grained limestones are found occurring in laminated beds. Indistinct fossils are seen on the weathered surfaces of some of these lower layers, and among them an undetermined species of Fenestella is always found. The rather even bedded limestones continue with little or no change in appearance for about 170 feet in vertical distance, when they pass gradually into bluish gray Laminated limestones, some bands of which weather yellowish on the surfaces. These are about 85 feet in thickness, then follow about 70 feet of Laminated limestones very much the same as those just below, except that they are rather lighter in color, especially on the weathered surfaces. An analysis of a specimen from the base, collected in the Bridger range was made by Mr. Catlett with the following result:

Carbonate of lime ($CaCO_3$)	88·50
Carbonate of magnesium ($MgCO_3$)	·95
Iron oxide (Fe_2O_3) } Aluminium oxide (Al_2O_3) }	·38
Insoluble (Silica)	9·98
Alkalies, undetermined	
Total	99·81

The lowest fossils from the laminated limestones were obtained south of the Jefferson river, between Willow and Antelope creeks. There have been identified among them the following:

Productus elegans.	Lophophyllum, sp. undet.
Productus, sp.?	Strophomena rhomboidalis.
Chonetes, ?	Spirifera centronata.
Aviculopecten, sp. undet.	Retzia radialis.
Rhynchonella, sp. undet.	

Mr. Walcott, who examined them, says "the facies is more Devonian than Carboniferous." In the upper portions of the laminated limestones the following fossils were obtained from the beds east of the Gallatin bridge, where the best section was made.

Lophophyllum? sp.	Spirifera centronata.
Productus longispinus.	Spirifera rockymontana.
Productus semireticulatus.	Chonetes granulifera.
Productus nebrascensis.	Rhynchonella, sp. undet.
Productus cora.	Terebratula, sp. undet.
Streptorynchus crenistria.	Platyceras, sp. undet.

In the upper part of the beds south of the Jefferson, 10 or 12 miles west of Three Forks, the following were collected:

Zaphrentis, sp. undet.	Spirifera crenistria.
Fenestella, sp. undet.	Spirifera, sp. undet.
Streptorynchus crenistria.	Retzia radialis.
Strophomena rhomboidalis.	Athyris, sp. undet.

The Massive limestones.—Light bluish gray limestones in rather massive layers come next above, and in the upper layers which are still more massively bedded, a series of fossils is found, among which the following have been identified by Mr. Walcott:

Zaphrentis, sp undet.	Terebratula bovidens.
Productus cora.	Bellerophon, sp. undet.
Streptorynchus crenistria.	Retzia radialis.
Chonetes granulifera.	Euomphalus, sp. undet.
Spirifera centronata.	Murchisonia, sp?.
Spirifera rockymontana.	Phillipsia, sp.?
Spirifera (Martinia) setigera.	Athyris, sp?

At about this same horizon, farther east, or about halfway between the Gallatin river and Dry creek, the following forms were obtained:

Orthis resupinata.	Rhynchonella, sp. undet.
Strophomena rhomboidalis.	Lithostrotian, sp?.
Spirifera centronata.	

In the bluffs on the east side of the Missouri river at the mouth of the Gallatin the following were collected:

Productus semireticulatus.	Spirifera centronata.
Productus, sp?	Spirifera (Martinia) lineata.
Streptorynchus crenistria.	Retzia radialis.
Chonetes granulifera.	Rhynchonella, sp?
Syringothyris cuspidata.	Phillipsia peroccidens.

A locality 8 miles west of the Three Forks, about 2 miles north of the Jefferson river, yielded the following:

Productus speciosus.
Productus lachrymosa var.
Productus cora?
Chonetes granulifera.
Streptorynchus crenistria.
Spirifera centronata.
Orthis impressa?
Orthis, sp. undet.
Euomphalus, sp. undet.
Murchisonia, sp. undet.
Retzia radialis?

The following occur south of the Jefferson river about 10 miles southwest of the last locality, and represent about the same horizon, coming from three localities:

Productus cora.
Productus nebrascensis.
Productus semireticulatus.
Productus, sp. undet.
Chonetes granulifera.
Rhynchinella, sp. undet.
Spirifera centronata.
Spirifera striata.
Athyris lamellosa.
Athyris sublamellosa.
Athyris, sp. undet.
Streptorynchus crenistria.
Terebratula hastata.
Terebratula, sp. undet.
Strophodonta, sp. undet.
Orthis resupinata.
Orthis, sp. undet.
Fenestella, sp. undet.

From four localities on the Bridger range the following forms were obtained:

Zaphrentis, sp. undet.
Syringopora, sp. undet.
Cyathophyllum, sp. undet.
Streptorynchus crenistria.
Strophodonta, sp. undet.
Spirifera centronata.
Spirifera (Martinia) lineata.
Rhynchonella metallica.
Rhynchonella, sp. undet.
Terebratula, sp. undet.
Euomphalus, sp. undet.
Fenestella, sp. undet.
Productus cora.
Productus, sp. undet.
Chonetes granulifera.
Athyris sublamellosa.
Retzia radialis.
Platyceras, sp. undet.
Lophophyllum, sp. undet.
Michelina, sp. undet.
Phillipsia, sp. undet.

In Cherry creek canyon southwest of the Gallatin valley, about 25 miles south of the Gallatin bridge locality, the same horizon has yielded the following:

Orthis, sp. undet.
Productus cora.
Productus semireticulatus.
Productus longispinus.
Productus, sp. undet.
Streptorynchus crenistria.
Chonetes granulifera.
Spirifera rockymontana.
Spirifera centronata.
Retzia radialis.
Rhynchonella. sp. ?
Rhynchonella (compare R. metallica).
Euomphalus, sp. undet.
Phillipsia, sp. undet.
Athyris, sp. undet.
Terebratula, sp. undet.
Platyceras, sp. undet.

The last two lists may represent also a part of the laminated limestones, as the section could not be very accurately measured at these localities. About 20 miles east of the last locality, and 12 to 15 miles south of the Bridger range, at two localities on Middle creek and Cottonwood creek, the following forms occur:

Zaphrentis, sp. undet.	Productus cora.
Spirifera centronata.	Productus, sp. undet.
Spirifera, sp. undet.	Lophophyllum?
Athyris, sp. undet.	Streptorynchus crenistria.
Fenestella, sp. undet.	Chonetes granulifera.
Productus nebarscensis.	

These come from near the line between the massive beds and the Jaspery limestones that lie above and may belong in part to both, as it is difficult to draw a very sharp line between them, that will be the same at all localities. At one place the Massive limestones may be much thinner and the Laminated limestones thicker, and at still another locality the conditions may be reversed. Usually they are pretty nearly evenly divided as to thickness, the laminated portion being above 325 feet and the more massive portion 350 feet.

An analysis of one of the limestones from these beds shows them to be rather pure limestones. The following is the analysis by Mr. Catlett:

Carbonate of lime, ($CaCO_3$)	91·96
Carbonate of magnesia, ($MgCO_3$)	1·35
Iron oxide (Fe_2O_3) Aluminium oxide (Al_2O_3)	·58
Insoluble (silica)	5·99
Alkalis	undet.
Total	99·88

The Jaspery limestones.—Returning to the section near the Gallatin we find that the upper portion of the massive bedded limestones to which we have applied the name Jaspery limestones, shows a thickness of between 500 and 600 feet. These limestones become more and more massive as we ascend in them, and are somewhat magnesian and also highly siliceous, as the following analysis by Mr. Catlett shows:

Carbonate of lime ($CaCO_3$)	32·28
Carbonate of magnesium ($MgCO_3$)	13·91
Iron oxide (Fe_2O_3) Aluminium oxide Al_2O_3)	·30
Insoluble (silica)	50·74
Alkalis	undet.
Total	97·23

Seams of jasper intersect the beds irregularly. Usually this jasper is yellow, but some of the beds contain black, olive-gray, and red varieties. In one place near the west end of the Gallatin bridge the yellow jasper occurs in masses of 6, 8, or even 10 feet thickness. It is so abundantly distributed in them that jaspery débris is scattered over the surface wherever the limestones are exposed.

The upper 300 or 400 feet of the Madison formation consists of somewhat lighter colored limestones (generally yellowish white and light drab) but still massively bedded. They are all somewhat cherty and jaspery, and chert nodules are frequently found arranged in lines parallel to the bedding. Many of the beds have geodic cavities, lined with chalcedony and drusy quartz. Near the base of the series in the Gallatin section the following fossils were collected from a flinty limestone in which the specimens were very poorly preserved:

Spirifera centronata.	Rhynchonella, sp. undet.
Spirifera, sp. undet.	Athyris hirsuta.
Rhynchonella horsfordi.	Streptorynchus crenistria.

A little higher in the series at another locality the following forms occur in two layers, separated by a distance of about 30 feet, in a fine grained, bluish limestone, which passes down into flinty and jaspery layers. The fossils in the lower layer are very indistinctly preserved.

Orthis, sp.	Spirifera centronata.
Productus cora.	Athyris, sp.?
Streptorynchus crenistria.	

The highest fossiliferous horizon that we noted in the Madison limestones was in a small gully on the south side of the Jefferson valley, below the mouth of Antelope creek, where the stratigraphic relations are somewhat obscure. The limestones from which they were collected were, however, estimated to be about 100 feet below the red limestones, and yielded the following forms:

Productus cora.	Chonetes granulifera.
Productus semireticulatus, var.	Pleurotomaria.
Myalina.	Retzia radialis.
Euomphalus.	Undetermined species of Lamellibranchs.

Combining the collections of the upper part of the limestones from all the other localities bordering the Gallatin valley we get the following list, which represents five localities, and may include a few specimens from the purer limestones that lie just below:

Zaphrentis, sp.? undet.	Spirifera striata.
Terebratula, sp. undet.	Spirifera (Martinia) pinguis.?
Strophomena rhomboidalis.	Discina, sp. undet.
Streptorynchus crenistria.	Orthis resupinata.
Productus speciosus.	Orthis sp. undet.
Productus semireticulatus.	Athyris rossyi.
Productus sp. undet.	Athyris sublamellosa.
Chonetes granulifera.	Athyris lamellosa.?
Spirifera centronata.	Athyris, sp. undet.
Spirifera disjuncta.?	Fenestella, sp. undet.

In comparing the collections from the three portions of the limestones, viz, the base, the middle, and the upper part, we find that about twenty-one species occur in the lower portion, and of these there are only two that have not been collected from the middle and upper portion, viz: *Productus elegans* and an undetermined species of Aviculopecten. Five species are common to all the horizons, among them *Chonetes granulitera*, *Spirifera centronata*, and *Streptorynchus crenistria*.

From the upper portion the list includes twenty-five species, only five of which were not obtained from the middle part. Of these two, viz, *Spirifera disjuncta ?* and *Rhynchonella horsfordi*, occur in the Devonian of the Eureka section, and two, *Athyris hirsuta* and *Terebratula hastata*, are found in the lower Carboniferous of the same section. It will be seen, therefore, that with the material in our collections at present it is impossible to draw any decisive lines of separation in these limestones, based upon paleontological grounds. The following is the full list of forms as identified by Mr. Walcott, from a preliminary examination of the collections:

Zaphrentis, sp. undet.
Syringopora, sp. undet.
Cyathophyllum, sp undet.
Lophophyllum, sp. undet.
Lithostrotion, sp. undet.
Michelina, sp. undet.
Fenestella, sp. undet.
Discina, sp. undet.
Chonetes granulifera.
Chonetes, sp. ?
Productus cora.
Productus elegans.
Productus lachrymosa, var.
Productus longispinus.
Productus nebrascensis.
Productus semireticulatus.
Productus speciosus.
Productus sp. ?
Productus sp. undet.
Productus sp. undet.
Strophomena rhomboidalis.
Strophodonta, sp. undet.
Streptorynchus crenistria
Orthis resupinata.
Orthis impressa.
Orthis sp. undet.
Spirifera rockymontana.
Spirifera centronata.
Spirifera striata.
Spirifera disjuncta. ?
Spirifera (Martinia) pinguis.
Spirifera, ps. undet.
Spirifera (Martinia) setigera.
Spirifera (Martinia) lineata.
Syringothyris cuspidata.
Retzia radialis.
Athyris rossyi.
Athyris hirsuta.
Athyris lamellosa.
Athyris sublamellosa.
Athyris sp. ?
Athyris sp. undet.
Rhynchonella horsfordi.
Rhynchonella metallica.
Rhynchonella sp. undet.
Rhynchonella sp. ?
Rhynchonella sp. ?
Terebratula hastata.
Terebratula bovidens.
Terebratula sp. undet.
Aviculopecten, sp. undet.
Myalina, sp. undet.
Platyceras, sp. undet.
Euomphalus, sp. undet.
Pleurotomaria, sp. undet.
Bellerophon, sp. undet.
Murchisonia, sp. ?
Phillipsia peroccidens. ?
Phillipsia, sp. ?
Phillipsia, sp. undet.

Of *Streptorynchus crenistria*, which ranges from the base to the top of the Madison formation, Mr. Walcott says, "it is essentially the form usually identified as *S. chemungensis* in the Devonian." Including this form we have the following list common to both the Three Forks shales and the Madison formation:

Streptorynchus crenistria (or chemungensis).
Productus lachrymosa var.
Productus speciosus.
Strophomena rhomboidalis.
Syringothyris cuspidata.
Spirifera disjuncta.
Athyris sublamellosa.
Athyris hirsuta.
Rhynchonella metallica.
Rhynchonella horsfordi.

Of these *Productus speciosus*, *Spirifera disjuncta*, and *Athyris sub-*

lamellosa are also found in the middle or upper part of the limestones. Comparing the list with that of the Eureka section, we find twelve are identical with species in the Devonian of that section, seventeen occur in the Lower Carboniferous, and seven in the Upper Carboniferous. The latter are as follows:

Productus cora or pratteniauus.	Spirifera rockymontana.
Productus longispinus.	Retzia radialis.
Productus nebrascensis.	Terebratula bovidens.
Productus semireticulatus.	

Of these, all but the last one are common to both the Upper and Lower Carboniferous in the Eureka district.

As a whole, therefore, the Madison limestones have the aspect of the Lower Carboniferous, to which they must be, at least provisionally, referred.

QUADRANT FORMATION.

After the deposition of the Madison formation there was a marked change in the character of the sediments, due mainly to the prevalence of shallower seas. At one locality north of the Gallatin we find at the base of the formation, below the red limestones, a conglomerate limestone, and the lower beds are everywhere quite arenaceous. They are also magnesian, although no true dolomites are found. These conditions, as already seen, were foreshadowed in the upper part of the Madison limestones. Some of the beds are also somewhat argillaceous, but the arenaceous character prevails at the base, with limestones developing more and more towards the middle, the beds then becoming gradually more siliceous until the section ends with quartzites predominating Qualitative analyses show that the lower beds contain strontia in quite appreciable quantities. There is more lithological variation in this portion of the section when different localities are compared than in any other. The remarks already made apply particularly to the Gallatin, or Three Forks, section. In the Bridger range not only is there a difference in the character of the beds, but the section is also much thinner, while on the Jefferson the upper beds are less siliceous and the fossils more abundant. The Quadrant formation has been divided into the Red limestones and the Cherty limestones. The line of separation is a shifting one when different localities are compared with each other.

The Red limestones.—Conformably overlying the Madison formation is a series of beds which, although presenting considerable variation in detail, are still easily recognized from their bright, red color at the base, their shaly structure and their softness, which causes them to yield readily to denuding influences. Their red color, which is particularly brilliant in their debris, renders them conspicuous in most localities. Their general character is that of limestones, although it is frequently difficult to determine from hand specimens whether they should be called arenaceous limestones or calcareous sandstones. In the Three Forks the base of the section shows red and greenish mottled magnesian limestones, with irregular structured gray or grayish blue limestones immediately beneath them. Occupying as they do in every case the bottom of a ravine of greater or less depth, they are generally concealed and in many places can be traced only by the red debris. A brecciated limestone appears to lie sometimes at the base and at one locality a limestone conglomerate was found. This occurs in irregular layers, the whole thickness being only about 1 foot. The pebbles are small, mostly of light gray or yellowish color. There are a few rounded siliceous grains as seen under the microscope, and cherty pebbles are evident to the unaided vision. The small grains are found mainly in the cementing material, which is calcareous, and red in color. This conglomerate passes into rather coarse arenaceous beds, which are followed by the limestones which here are dark purplish red, the greenish mottled limestones not showing at this locality. The latter are best seen in the hills near the Gallatin bridge, where they occur with fine grained red limestones, and they may be entirely wanting at the other locality. A few of the pebbles in the conglomerate look as though they might have been derived from the bright red limestones. A specimen of the limestone from the latter horizon has been analyzed by Mr. Charles Catlett in the laboratory of the Survey, with the following result:

Insoluble (silica)	25·24
Calcium carbonate ($CaCo_3$)	40·21
Magnesium carbonate ($MgCo_3$)	25·25
Alumina and iron ($Al_2O_3Fe_2O_3$)	5·30
Alkalies	undet.
Total	96·00

The total thickness of these beds is about 50 feet. In the Bridger range they occur as two red streaks, largely argillaceous, separated from each other by a band of reddish gray compact limestone. They are only a few feet each in thickness and have compact limestones both above and below. Near the mouth of the Jefferson canyon the lower red limestones are very much the same as on the Gallatin. Yellow limestones occur at the top and the debris resembles yellow ochre. Qualitative analyses show them to be argillaceous, and as at many other localities they contain strontia.

Near the Gallatin bridge the bright red limestones are followed by about 120 feet of purplish gray and bluish limestones with narrow bands of red. There is considerable chert irreguarly scattered throughout them, and the upper part of the beds are very compact. Many are blue and grayish in color, but frequently purplish bands come in between the others. These upper beds are fossiliferous at two horizons, one at the top and the other with very indistinct fragments a little above the middle portion.

From the former the following were collected:

Productus longispinus.	Productus semireticulatus.
Productus nebrascensis.	Productus sp.?
Productus cora.	Discina, sp.?

The fossils already referred to as coming from the red limestones at the base are as follows:

Streptorynchus crenistria.	Chonetes granulifera.
Productus cora.	

In the Bridger range the following were identified from the red streaks:

Streptorynchus crenistria.	Chonetes granulifera.
Productus cora.	

Near the mouth of the Jefferson canyon the red limestones at the base are probably somewhat less than 100 feet in thickness, and are separated from the limestone above by about 20 feet of quartzite. These upper limestones are not purplish or reddish, as it is in the Gallatin section, but begin with a yellowish limestone which is finely conglomeritic, and contains numerous fragments of fossils at the base. Among them Mr. Walcott recognizes the following, viz:

Chonetes granulifera.	Spirifera camerata.
Streptorynchus crenistria.	Orthis sp.?

This conglomerate bears a close resemblance to the conglomerates already described as occurring in the red limestones north of the Gallatin river. These beds become more crystalline as we pass upwards, and 30 feet above the fossils we find 5 feet of limestones that are crystalline at the base and argillaceous at the top. They are somewhat laminated and have fossils at the base. Among them the following have been identified:

Zaphrentis sp.?	Orthis pecosi.
Chonetes granulifera.	Orthis resupinata.
Productus longispinus?	Spiriferina cristata.
Productus sp.?	Phillipsia sp.?

Five feet above these the following were found:

Productus semireticulatus var.	Spirifera camerata.
Orthis pecosi.	Athyris subtilita.

Then follow 50 feet more of limestones, which are generally light gray and quite compact, especially at the top, where they are also fossiliferous. They contain *Productus cora* in great abundance, and associated with it *Streptorynchus crenistria*, and an undetermined species of Phillipsia. Qualitative analyses prove these to be rather pure limestones.

The Cherty limestones.—In the Three Forks section we have separated from the red limestones about 150 feet of beds in which thin bedded cherty limestones alternate with quartzite layers, the former being most numerous in the lower part and the latter predominating at the top of the series, which is capped by the prominent bed of quartzite which has been provisionally taken as the base of the Mesozoic. The lower portion of the series consists mainly of gray laminated limestones with a pinkish tinge on weathered surfaces. After 25 or 30 feet of these beds a layer of about 2 feet of hard gray limestones is seen, above which we find a light colored pink or white magnesian limestone, very fine grained and compact, with fossils, among which the following are are most numerous, *Productus cora* especially being very abundant:

Streptorynchus crenistria.	Euomphalus (S.) subrugosus?
Productus cora.	Euomphalus (small species).

Above this belt the limestones for about 30 feet are very much the same as below, compact gray limestones alternating with purplish mottled limestones, and in most localities a few quartzitic bands come in. The limestones are all more or less siliceous. About 12 to 15 feet above the fossils last enumerated the following occur:

Chonetes granulifera.	Productus cora.
Productus longispinus.	Orthis pecosi.
Athyris, sp.?	

From the same horizon near the South Boulder, south of the Jefferson river, the following were obtained:

Chonetes granulifera.	Productus (like young shells of P. giganteus).
Productus cora.	Athyris, sp.?

At the locality where the limestone conglomerate was seen the following were collected in the limestones from 75 to 100 feet above the conglomerate. They came from three layers separated from each other about 5 feet, respectively, but showing no specific differences:

Chonetes granulifera.	Orthis resupinata?
Productus cora.	Spirifera camerata.
Productus semireticulatus.	Spiriferina cristata.
Streptorynchus crenistria.	Athyris, sp.?

These are probably from the base of the Cherty limestones or possibly from the upper part of the Red limestones. I am inclined to correlate them with the former.

The upper 100 or 120 feet of the Cherty limestones so far have yielded no fossils beyond an indistinct linguloid shell and an indeterminable species of athyris, which were found near the lower part. The line at the top has been arbitrarily drawn at the base of the Mesozoic quartzite, which forms everywhere throughout the region a characteristic topographic feature very useful as a reference line when the beds have to be mapped.

Beginning at the top of the section, below this quartzite, a series of thin bedded quartzites and cherty beds with flinty limestones continue downward for more than 100 feet, with the quartzite layers largely predominating. These beds in places show cherty masses or rolls of about an inch in diameter which penetrate the beds at right angles to the plane of deposition. Below these beds limestones, which are sometimes crystalline and generally very cherty, make up the most of the section. Chalcedonic geodic cavities are numerous, as are also cherty nodules.

In several layers the latter are several inches in diameter and frequently oval in shape, and are arranged in layers parallel with the bedding. Many of the beds are also conglomeritic. They are altogether most unpromising beds for the finding of fossils, and up to the present, as already noted, they have yielded nothing to determine their exact place in the scale.

Combining all the fossils that have been identified from the Quadrant formation we get the following list. It must be remembered that their examination by Mr. Walcott has been only preliminary, and that when the collections are more carefully studied the list will undoubtedly be considerably enlarged:

Zaphrentis, sp.?	Orthis resupinata.
Discina, sp.?	Orthis, sp.?
Chonetes granulifera.	Spirifera camerata.
Productus longispinus.	Spiriferina cristata.
Productus nebrascensis.	Athyris subtilita.
Productus cora.	Athyris, sp.?
Productus semireticulatus.	(Undetermined species of lamellibranchiata.)
Productus, sp.?	Euomphalus (S.) subrugosus?
Streptorynchus crenistria.	Euomphalus, sp?
Orthis pecosi.	Phillipsia, sp?

Of the twelve forms specifically determined seven were also identified in the collections from the Madison formation, and only one, *Streptorynchus crenistria* (*chemungensis?*), passes down into the Three Forks shales (Upper Devonian).

Comparing with the Eureka section we find that one (Orthis pecosi) is found only in the Upper Carboniferous of that section, and seven are common to both the Upper and Lower Carboniferous, and two run down into the Devonian.

There is an absence of most of the forms so conspicuous in the Madison formation, and there is little doubt but that careful study in the future will confirm the reference of these beds to the Upper Carboniferous, a reference now made largely upon stratigraphical evidence.

ERUPTIVE ROCKS.

The only eruptive rocks noted in the section described in this paper are found in the Flathead shales, and they may be divided into two groups, according to locality: First, the two rocks described by Mr. Merrill as a trachytic or syenitic rock overlain by a dark aphanitic rock from the hills north of the East Gallatin river, and, secondly, the intrusive sheet near the Horseshoe bend of the Missouri.

The former locality was noted first in 1884 and revisited in 1886. The rocks outcrop in the ravines resulting from the weathering of the soft sandy shales which lie immediately above the hard sandstones and quartzites lying at the base of the Gallatin sandstones. The rock itself has presented no more resistance to the erosive forces than have the overlying shales. In most cases it presumably rests immediately upon the quartzite, a few bands of shales only occasionally coming in below it. It therefore occupies the bottom of the ravine and consequently the lower contact is obscured; in fact, throughout the entire 6 miles of observed outcrop careful search has not revealed the actual contact between it and the underlying quartzite.

The total thickness of the rock in the best exposure examined is about 45 feet. Beginning at the top we find in contact with the overlying indurated sandy shales a very compact black rock, tough and hard to break. It is usually about 6 inches in thickness but increases to 12 inches and frequently thins out to only 3 or 4 inches. It is described by Mr. Merrill as aphanitic, but even the freshest specimens obtained after considerable labor show a great deal of alteration, and the relations to the underlying rocks are still obscure. Below it for about 10 feet is a layer of decomposed rock weathering into a greenish débris with seams of a pink rock of about an inch in thickness, which resembles in general appearance the syenitic (?) rock forming the main portion of the outcrop. The harder portions of this pink rock also occur somewhat like seams or very irregular veins of from 1 foot to 3 or 4 feet in thickness, the decomposed material surrounding them having apparently the same composition as the harder portion. At the bottom of the outcrop, however, the rock again resembles that underlying the aphanitic rock at the top. It is a very soft, badly decomposed rock, with a dark greenish débris. Neither this nor the upper belt yielded anything hard enough to make sections for microscopic study.

As noted on a previous page, these intrusive rocks are found in connection with several dip-faults. Three were observed, and the one in which the relations are best shown is at a locality north of the East Gallatin river, a few miles above its mouth, where the basal quartzites of the Flathead formation are found in characteristic outcrops on the right of a ravine in a prominent ridge, the end of which abuts against the shales and upper part of the intrusive sheet, which is exposed on the left side of the ravine in the lower part of a bluff. Opposite this, and below the ridge just referred to, the eruptive rock abuts against the micaceous sandstones of the Belt formation, which lie below the first-mentioned outcrop of the basal quartzites. The fault, therefore, is practically at right angles to the strike of the beds, and lies in the ravine formed by a small stream flowing along its line, the downthrow being on the left or west side. The horizontal displacement was estimated at about 300 feet, the throw being from 100 to 150 feet. The dip of the beds on the side of the downthrow is 20° and on the opposite side it is from 25° to 30°.

The ends of the beds in the narrow belt of shales lying below the erupted mass curve to the south close to the line of faulting, while on the opposite or east side of the fault a very slight turning to the north was observed in the ends of the Belt formation. In the overlying limestones no trace of the fault could be found. In the fault on

Dry creek, which was the most eastern one noted, the line of disturbance cuts across all of the beds from the Cambrian to the upper part of the Carboniferous limestones, where the latter pass out of sight beneath the overlying lake beds, which also conceal the fault line.

Following the Flathead shales to the most western fault, we find the exposures so obscured that the relations could not be definitely determined, but so far as we could see no faulting occurs in the overlying limestones.

From the stratigraphic position of these rocks we can infer only that they are of post-Cambrian age, for they have not as yet been found in rocks of later age in our district. A few miles farther to the northwest, in the Cretaceous section, certain peculiar eruptive rocks occur, in one of which the preliminary examination suggests that eventually some relationship between the two occurrences may be determined. There is a possibility that the faulting may have occurred subsequent to the uplifting and folding of the beds, and also after a certain amount of erosion had been effected. If so, it would indicate a post-Cretaceous or perhaps even a late Tertiary age for this intrusion. Whether there was one intrusion or whether the two rocks were erupted at different times will probably be determined only when the decomposed material underlying the upper aphanitic rock can be traced into a more solid mass that has not undergone such complete alteration. The two, although always occurring together, are, as already stated, entirely distinct in their structure, and Mr. Merrill is unable to trace any connection between them.

The intrusive sheet in the Flathead shales near Horseshoe bend of the Missouri, according to Mr. Merrill, has no connection with this rock, although it suggests certain relations with another intruded rock found in the Cretaceous rocks of Nixon basin of Cottonwood valley, which may possibly be a connecting link between the two. These suggestions at present, however, are too vague for further remarks here.

NOTES ON THE PETROGRAPHY OF THE PALEOZOIC SECTION IN THE VICINITY OF THREE FORKS, MONTANA.

By Geo. P. Merrill.

The rocks described in the following notes comprise (1) specimens collected by Dr. Peale from the Archean outcrops exposed along the western face of the Bridger mountains between Bridger creek and Spring hill; (2) for comparison with the former, from which they were evidently derived, specimens of fragmental rocks from the Belt group, as shown along the north side of the East Gallatin river and in the foot-hills of the Bridger range between Spring hill and Flathead pass; (3) specimens from an intrusive sheet in the lower part of the Flathead shales about a mile north of the East Gallatin river, and equidistant from Hillsdale and the mouth of the river. In the summer of 1886 the writer visited this locality, and thus had an opportunity to observe the field relations of these rocks. (4) Three specimens of an intrusive sheet from the base of an exposure of the Flathead shales near the Horse Shoe bend of the Missouri river.

GNEISSIC ROCKS FROM THE WEST SIDE OF BRIDGER RANGE, MONTANA.

No. 232. Mouth of Bostwick canyon.—The rock is a highly quartzose-gneiss, or possibly a quartzite, but with so pronounced a cataclase structure that there was felt at first some doubt regarding its true nature. In most cases the individual quartz granules are separated from one another by a comparatively wide zone of triturated material almost as fine as dust and stained reddish by infiltrated iron oxides. The only original constituents now recognizable are these shattered quartzes, feldspars, if such existed, having been completely crushed and kaolinized. The abundant segregations of hematite along the lines of crushing give the rock a reddish hue.

No. 233. Bostwick canyon.—This rock consists essentially of a bright green dichroic hornblende, occurring in broad plates quite devoid of crystal outlines, but with deep rounded embayments, which, together with the interspaces, are occupied by badly kaolinized feldspars. The kaolinization has in most cases gone so far that the true nature of the feldspars is almost unrecognizable. In a few instances traces of twin striæ indicate a triclinic variety. The only other constituent worthy of note occurs, but rarely, and in the form of pale greenish, almost colorless, rounded crystals with faint pleochroism, and which show on basal sections nearly rectangular cleavages and on longitudinal sections give extinction angles as high as 40°. It is presumably a monoclinic pyroxene.

No. 234. Between Bridger and Lyman creeks.—This rock differs radically from either of the above. It is evidently a gneiss very poor in iron-magnesian silicates, but consisting essentially of quartz and potash feldspars with an abundant besprinkling of a plagioclastic variety. Here, as in No. 232, a cataclase structure has been developed, though in a less pronounced degree. A portion of the feldspar is evidently orthoclase, but a much larger portion shows the beautiful basket-work structure of microcline. The plagioclases are repeatedly twinned in very thin bands, some of the sections showing not less than 40 striæ on face not over 1 mm. in diameter. The most striking feature of the rock is the amount of distortion through mechanical agencies exhibited by some of the feldspars. In many instances twinning bands show a wavy structure throughout their entire length. In others the crystals, besides having suffered faulting and slight displacement (as shown by the twinning bands), are often distorted and crimped in a very interesting manner.

No. 235. Bostwick canyon.—This is also a gneiss, but has suffered less from mechanical agencies than has the last. As seen under the microscope it consists of abundant plates of clear, fresh plagioclase nonstriated feldspars, which may be orthoclase, clear colorless quartzes, and occasional shreds of brown mica.

No. 236. Limestone canyon, near Spring hill.—This is a highly micaceous gneiss. The thin section shows very abundant small and irregular scales of deep brownish red strongly dichroic mica, comparatively large plates of a plagioclase feldspar, orthoclase, finely granular quartz, and occasional small and very irregular garnets. In a few instances were noticed foliæ of a colorless biaxial mica with the brilliant iridescent polarization colors of muscovite. The feldspars are, as a rule, badly kaolinized.

No. 237. Locality as above.—This is also a highly micaceous gneiss, showing under the microscope the same very irregular foliæ of deep reddish brown strongly dichroic mica and occasional garnets and iron ores interspersed with quartz granules and badly kaolinized feldspars as does No. 236. The garnets are, in the section, of a pale wine color and devoid of crystal outlines; the iron ores are apparently magnetite. The quartzes contain but few fluid inclusions, and these are of small size. The feldspar is in part at least a triclinic variety, but in most cases is so badly kaolinized that the twinning bands are quite obscured.

FRAGMENTAL ROCKS FROM THE BELT FORMATION.

No. 224. Clastic rock, from section north of East Gallatin.—This consists of abundant clear, fresh, and sharply angular fragments of quartz and feldspar, interspersed with calcite shreds of mica and a plentiful besprinkling of iron oxides. The feldspars, which are very clear and fresh appearing, are in part orthoclase (or microcline) and in part a plagioclase variety. The cementing constituent is by ordinary light very light greenish, chloritic in appearance, and, between crossed nicols, it remains almost wholly dark during an entire revolution of the stage. Both as regards the mineral character and their relative conditions of purity and freshness, this rock resembles very closely No. 234 of the gneiss series, from which it was evidently derived.

Nos. 226 and 227. Locality same as above.—These are both similar to 224. No essential differences.

No. 228. Canyon in Bridger range, south of Flathead pass.—This rock is evidently of the same origin as the above (Nos. 224, 226, and 227), but has undergone a certain amount of metamorphism, and may be said to stand intermediate between a truly fragmental and a crystalline rock. The mineral fragments, and especially the quartzes, have undergone a process of secondary enlargement, and are surrounded by a narrow and very irregular zone of the same substance, which merges gradually into the material of the cement. The interstitial or cementing constituent itself is largely chloritic, and remains perfectly dark, or polarizes in bluish colors between crossed nicols. In places the section shows a crystalline granular structure such as is characteristic of the gneisses and schists; other portions show a fragmental structure. As a whole the section resembles that of a clastic rock which has undergone a certain amount of metamorphism more than a crystalline rock that has suffered through mechanical agencies. The rock has the same mineral composition as Nos. 224, 226, and 227. The grains, however, too closely interlock and by too irregular borders to permit one to consider it a product of sedimentation only.

No. 229 from the same locality as 228, and No. 230 from the limestone canyon just north of Spring Hill, are similar.

INTRUSIVE ROCKS IN THE LOWER PART OF THE FLATHEAD SHALES.

NORTH OF THE EAST GALLATIN RIVER.

The rocks described below outcrop at the base of the sandy shales that lie just above the basal quartzite of the Flathead formation as exposed in the hills about 1 mile north of the East Gallatin river. They have been traced eastward about 3 miles from the most western exposure when they pass beneath the lake beds, but show again where the Flathead shales cross Dry creek 3 miles farther to the northwest. In all these outcrops they hold the same relation to each other. The upper rock is usually from 6 inches to a foot in thickness, but sometimes thins out to even less than 6 inches. It lies in close contact with the shales, is dark gray, nearly black, in color, tough, fine grained, and compact, and shows to the unaided eye only occasional small black crystals evidently belonging to a mineral of the pyroxene group, and numerous small reddish amygdules. This is succeeded by and seems to pass gradually into a zone of decomposed material which carries numerous scales of black mica and which is traversed in a direction parallel with the sheets by several veins from 1 to 2 inches in width of a light pinkish feldspar. The lower or underlying rock, which also seems to pass into this zone of decomposed material, appears to the unaided eye as a holocrystalline mass composed essentially of elongated light pink feldspars and abundant small, often radiating, foliæ of black mica. The microscopic and chemical properties of this rock are given below. Although the upper and lower rocks belong apparently to two quite distinct types their constant association, even when in sheets but a few inches thick, is somewhat confusing. Geologically they appear as one and the same body; from a petrographic standpoint they differ radically. It is useless to speculate on their possible relationships until further outcrops are found, or until, by digging or blasting, the nature of the intermediate zone of decomposed material is made apparent. The total thickness of the eruptive sheet or sheets is about 45 feet.

The Upper Rock.—Macroscopically this is a very tough aphanitic rock, hard, dark gray, and nearly black, bearing abundant small pseudo-amygdules of a dull red or yellowish green color and with rarely a black porphyritic mineral sufficiently developed to suggest a member of the pyroxene or amphibole group. In the thin section the rock was found so completely altered that it was only after repeated sections had been cut from samples from various portions of the outcrops that anything like a satisfactory idea of its original nature could be learned. Sections of the freshest samples obtainable show under the microscope a nearly colorless devitrified base impregnated with innumerable small, sometimes mere dust-like particles of opacite and elongated yellowish mica-like needles, in places so abundant as to form a truly felt-like groundmass. Scattered thickly throughout this groundmass are numerous pseudo-amygdules of calcite, chloritic and ferruginous substances, and occasional badly shattered, imperfect, and greatly decomposed augites.

The amygdules are due wholly to the decomposition of porphyritic augites and olivines, as can be determined by occasional still quite perfect crystal outlines in the least decomposed portions of the rock, and are in no case true gas cavities filled with secondary minerals. In a few instances the outlines of these cavities were such as to suggest that the decomposed mineral may have been a feldspar, but this can not be determined for a certainty. Sections from the more highly altered portions of the rock exhibit interesting changes. The groundmass here, as above, consists of the colorless base so filled with mica (?) needles as to be almost felsitic, but the porphyritic augites are replaced wholly by light greenish blue, faintly dichroic, somewhat fibrous hornblendes. Although optically these secondary forms are undoubted hornblendes, giving maximum extinctions on clinopinacoidal section of 15°, their outlines, when sufficiently perfect for measurement, are still in part at least those of augite. In a number of cases the prism outlines on cross sections were measured with results varying from 87° to 90°. The cleavage in such cases was somewhat imperfectly developed, but I was able to obtain measurements of the obtuse angle varying from 123° to 125·5°, which is perhaps as close as can be expected in sections

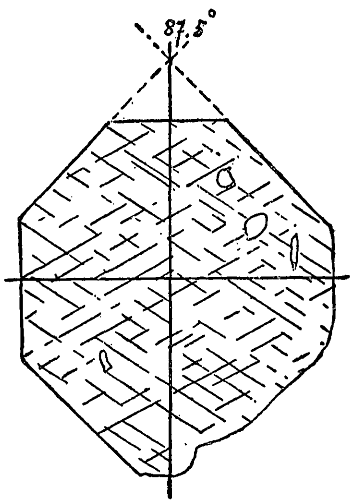


FIG. 1. Paramorphic hornblende.

cut at haphazard. The above features I have endeavored to bring out in the accompanying figure.

Although the hornblendes are so plainly paramorphic, I have found in no case traces of an augitic nucleus, the change being in all cases complete. (Fig. 1.)

Chemical analysis of a rock so highly altered can be regarded as merely suggestive. The following results were obtained by Mr. Eakins on a sample in which the augitic alteration just described was complete:

SiO_2	49·47
TiO_2	·21
Al_2O_3	12·15
Cr_2O_3	Trace.
Fe_2O_3	1·93
FeO	4·07
MnO	0·10
BaO	0·03
CaO	9·30
MgO	10·86
K_2O	2·42
Na_2O	2·08
H_2O	4·14
P_2O_5	0·37
CO_2	3·31

The association of this rock with that next to be described is peculiar and needs further investigation.

The Lower Rock.—In the hand specimen this rock appears to the unaided eye as a holocrystalline mass of pink lath-shaped feldspars interspersed with very numerous, long, slender, and at times radiating, needle-like folia of black mica. As seen under the microscope the structure is quite simple, consisting of a holocrystalline aggregate of badly kaolinized sanidins, lath-shaped plagioclases, scales of mica, scattering granules of iron oxide, apatite needles, and in the interspaces, secondary calcite, plagioclase and rarely quartz. The most interesting feature of the rock is the almost constant intergrowth of the sanidins with plagioclase, the effect being in the section as if each crystal of plagioclase was set in a frame of orthoclase. Unfortunately in the samples at hand both feldspars are so badly decomposed that their optical properties are greatly obscured. The plagioclase alteration gives rise to innumerable minute flecks of a silvery white mica, and in many cases the twin structures have become entirely obscured; the potash feldspar has become brown, muddy, and opaque, resembling the orthoclase of many granite rocks, and at times acts scarcely at all upon polarized light. The effect of this is that when the section is examined by a low power and between crossed nicols the plagioclases appear surrounded by a dark irregular border of varying width. (See Fig. 2.)

That this border is not an individualized base, which it at times closely resembles, is shown by still evident cleavage lines and its indistinct optical properties. Such sections as show two sets of cleavage lines cutting one another at right angles give their maximum extinctions parallel with these lines and show the optic axes lying in a plane parallel with the cleavage most pronounced. Other sections traversed by but a single series of parallel lines give extinctions varying from 0 to 9. All the characteristics seem to indicate that the mineral is a normal monoclinic potash feldspar. A similar parallel intergrowth is mentioned by "Rosenbusch"* as occurring in the trachyte of Mount

* "Mik. Physiographie" (1885), p. 513.

Dore, Auvergne. The mica of the rock occurs only in very irregular shreds and is apparently normal biotite. The small plagioclase in the interspaces are judged to be secondary both by the position relative to the other constituents and by their perfectly fresh and unaltered appear-

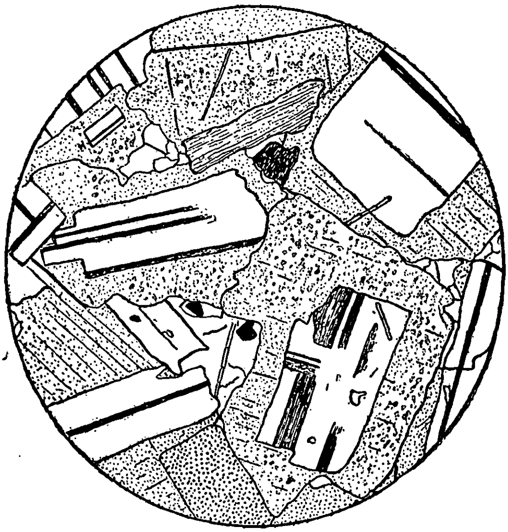


FIG. 2. Microstructure of syenitic rock.

ance. No truly amorphous ground mass was anywhere observed. A partial analysis of as fresh a sample of the rock as could be obtained yielded Mr. Chatard results as follows: Silica, 58·88; potash, 518; soda, 3·46. The rock is therefore of a trachytic or perhaps a syenitic type.

The intermediate zone of decomposed material mentioned above was observed traversed at intervals of a couple of feet by veins from one to two inches in width, composed of a light pinkish feldspathic material. Examined under the microscope these veins were found to consist of a portion not over a centimeter in width, made up largely of clear pinkish nonstriated feldspars. This was bounded on either side by a zone consisting of feldspars and brown mica as in the underlying rock, though here the feldspars in no case showed the plagioclase intergrowths, and they were, moreover, much less decomposed. These veins would seem to have been injected along lines of rift at the time the lower rock was erupted. The microstructure of the rock as described above I have endeavored to bring out in Fig. 2, in which the clear portions with twinning bands represent the plagioclase and the dotted portions sanidin.[1]

[1] Since the above was written these same rocks have been found near Antelope creek in a much better state of development and presentation.

INTRUSIVE ROCKS FROM NEAR THE HORSESHOE BEND OF THE MISSOURI RIVER.

These are massive holocrystalline rocks, consisting of a feldspathic groundmass, through which are strewn abundant small shreds of brown mica and scattering granular aggregates of a nearly colorless (in the section) monoclinic pyroxene. The feldspars are in lath-shaped forms, and in large part a plagioclase variety, though sundry unstriated forms may prove to be sanidins. All are greatly muddied through decomposition. Augitic and micaceous alteration has given rise to abundant flecks of a greenish and yellowish chlorite.

There is no evident connection between this rock and either of those described above.

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