VIII. SOME NOTES ON THE GEOLOGY OF SOUTHWESTERN MONTANA.

By Earl Douglass.

While exploring the Tertiary deposits of southwestern Montana, I have become interested in some of the older formations, and have made collections from those which contain fossils. Several of these collections have been submitted to specialists, who have sent me lists of the fossils, and have given their opinions concerning the ages of the beds containing them. I am especially indebted to F. H. Knowlton, Geo. H. Girty, and T. W. Stanton, of the United States Geological Survey, and to Percy E. Raymond of the Carnegie Museum, for determining fossils and furnishing the lists, which have been of so much interest to me in my geological work.

ARCHÆAN.

Under this head I include only the gneisses and schists which are Pre-Cambrian and generally recognized as Archæan. Concerning the more massive granites, regarding the age of which there is doubt, and which are probably in part of later age, I have little to say.

I have observed the Archæan rocks in the following localities:

1. In the region between the lower and upper Madison Valleys, where the Madison River has made a long cañon through these rocks;

2. In the western portion of the Madison Range, and in the eastern portion of the Jefferson Range, which includes the Tobacco Root and the South Boulder Mountains, where they have been mapped by the United States Geological Survey;[1]

3. On the western slopes of the Jefferson Range;

4. Along the lower cañon of the Ruby (Passamari) River nearly west of Old Baldy Mountain;

5. In the Ruby Mountains;

6. In the vicinity of Rochester. This region is between Table Mountain on the north and McCarty's Mountain on the south, and

[1] Atlas Folio No. 24.

between the Jefferson Valley on the east and the Big Hole Valley on the west.

The relief of these areas varies from hills projecting above the Tertiary deposits, through low, variously-shaped foot hills and ridges, higher hills, and low mountains, to peaks, which, like Gallatin Peak, attain an altitude of ten thousand feet or more.

The rocks of this formation are, as a rule, fairly well covered with vegetation, sometimes with heavy forests. In some places the dip is quite regular and the stratification plain. This is especially the case along Alder Creek on the western slope of the Tobacco Root Range. In other places there is much contortion and the stratification is not so evident.

As determined in the field, without careful classification, the rocks would be denominated as quartzyte schists, metamorphic quartzytes, mica schists, hornblende schists, chlorite schists, micaceous gneiss, granitoid gneiss, garnetiferous gneiss, etc.

The rocks contain many veins of nearly pure quartz and some valuable metalliferous deposits. In the early days of mining in Montana the quartz mines were principally in Archæan rock. At present nearly all the evidence indicates that the vast amount of placer gold which has been taken from Alder Gulch came from near the contact between the Archæan and Cambrian, probably from the upper part of the Archæan, at the foot of Old Baldy Mountain at the head of Alder Creek.

On Camp Creek east of Melrose there is an excellent section of the Palæozoic rocks overlying the Archæan gneiss. Their relations are shown in the sketch of the section of this region, made in traveling up Camp Creek in going from Melrose to Rochester. Though, as stated in my notes which I quote later, I did not carefully examine the exact line of contact between the Archæan and Palæozoic, I did ascertain that rock which is apparently Cambrian quartzite is very close to if not in actual contact with the gneiss.

THE ALGONKIAN?

In several localities in the Cordilleran region of Montana there are beds different from the gneisses described above, and lying beneath rocks which contain undoubted Cambrian fossils. They present a problem which will require much work for its solution, and which in the present state of our knowledge is quite puzzling. I have ascertained

that some of these beds, the ones containing the crystalline limestone, overlie the Archæan gneiss in the Ruby Mountains. In some places they are entirely absent and the Cambrian rests on the gneiss.

The relations of the Archæan, doubtfully Algonkian, undoubted Algonkian, and Cambrian I will discuss more fully later.

THE CHERRY CREEK FORMATION.

Some beds of metamorphic rock near the eastern base of the Tobacco Root Range in the Upper Madison Valley southeast of Old Baldy Mountain, and on the opposite side of the Madison River at the western base of the Madison Mountains were named by A. C. Peale "The Cherry Creek Beds," and were assigned to the Algonkian. They were described as, "a series of marbles or crystalline limestones, and interlaminated mica-schists, quartzytes, and gneisses." They were undoubtedly named from Cherry Creek which flows through the exposure.

Only eight or ten miles distant from the typical locality at the foot of Old Baldy Mountain, what are undoubtedly Cambrian (Flathead) quartzytes rest directly on Archæan gneiss. Below this Alder Creek cuts through a thick series of gneisses and schists. In this series I have never seen the thick beds of crystalline limestones, though I have many times observed the outcrops along the whole length of Alder Creek; nor does Peale designate them on the map of this region. But they may have been weathered more than the gneisses and become covered with soil and vegetation, thus escaping notice. They appear again, however, in the Ruby Cañon west of Old Baldy. I observed several years ago what I took to be a limestone vein in the gneiss in the hills south of Alder Creek.

Westward and northwestward of the exposure of the limestones in the Ruby Cañon they occur on the eastern slope of the Ruby Mountains. Here in beds lower in altitude, in a sandy stratum, I found a trilobite, which was determined by S. A. Miller as *Asaphiscus wheeleri*. This sandstone contained green grains, which appear to be glauconite. Geologically the beds are undoubtedly higher than the crystalline limestones, but time was not taken here to settle the stratigraphical relations.

But farther to the north in the highest portion of the Ruby Mountains I found along the highest ridges a section, showing the relation of the crystalline limestones to the gneiss, and of this to the Cambrian.

On June 25, 1902, I ascended one of the cañons (Taylor) that have their beginnings near the crest of the Ruby Mountains and extend eastward as deep valleys or ravines in the Palæozoic rocks to the Ruby valley. I copy from my notes:

"After passing some limestone pillars, showing peculiar weathering, I came to the thin-bedded Subcarboniferous limestone [Madison Laminated Limestones] with fossils. In the upper part of the cañon the Subcarboniferous is near to the gneiss. On the top the rock is gneiss dipping northeast or between east and north. I turned toward the north, ascending a higher ridge, and finally came to crystalline limestone. I was anxious to find the relation of this to the gneiss, and so went back perhaps 20 or 30 rods in the gneiss and saved samples[2] of the different kinds of rock from the gneiss, and then went a long distance up into the crystalline limestone. The limestone is nearly uniform, but with some layers that are different from the main mass. . . . This limestone makes a very high sharp ridge. . . . Above this I found another band of gneiss. I then began down in the limestone and saved samples through the band of gneiss, the shales that lie above it, and the Cambrian limestones which were identified by the fossil trilobites which it contained."

So here we have the following:

5. Cambrian limestone with trilobites;
4. Shales (undoubtedly Flathead shales);
3. Gneiss;
2. Crystalline limestone;
1. Archæan gneiss.

I made no measurements, but the narrowest of the divisions is probably not less than 150 to 200 feet in thickness.

It is probable that the crystalline limestones and a portion of the gneiss here represent the Cherry Creek formation. If it be thought that the upper band of gneiss might be metamorphosed Cambrian rock we would have a sudden change from the highly altered to the unaltered Cambrian which is evidently not due to local Post-Cambrian metamorphism.

The western portion of the Ruby Mountains in the vicinity of Dillon is gneiss, but I have not examined all the area that intervenes between this and the eastern crest just alluded to.

[2] In the collection of the University of Montana.

ALGONKIAN.

Not greatly Metamorphosed.

In portions of middle western Montana there are thick and extensive exposures of sandstones, slates, and shales or argillites, with some conglomerate and limestone, which in some places, at least, are known to lie beneath Cambrian rocks.

A portion of the beds in the vicinity of their eastern outcrops have been mapped and described in the atlas sheets and other publications of the U. S. Geological Survey, which give the results of research here. They have been observed in the Big Belt Mountains, Bridger Mountains, the Horseshoe Hills (west of the northern portion of the Bridger Mountains between this range and the Missouri River), and in the mountains northeast of Helena.

In the region west of the Rocky Mountains similar rocks cover a large area. Between the meridian of 113° and the Bitter Root Mountains, and between the parallels or 46° and 47° they are more common than any other rocks. In the region around Missoula there is little other rock older than the Tertiary. The Hell Gate Cañon from Missoula to Beramouth and the lower portion of the Big Blackfoot Valley are in quartzytes and slates that are probably Algonkian. In the western exposures they appear to be on the whole more arenaceous.

All of these beds are distinctly stratified, sometimes very thinly laminated and beautifully banded. The prevailing color is reddish, or brown, of the color of iron rust, with bands and series of layers which are green. In the Smith River Valley there are cream-colored shales or slates which break into thin flakes. At a distance the color and the general relief make them appear like the Miocene deposits which occur in the same locality.

These beds do not, as a rule, have a very ancient appearance. They are not highly metamorphosed. The sandstones have been changed to quartzytes, but of course that is common in deposits of all ages. They are seldom greatly disturbed. They usually dip at gentle angles and there is not that almost inextricable confusion in which the Palæozoics, especially the Devonian and Carboniferous, have become entangled, in so many localities. In places where the Palæozoic limestones are near or in contact with the Algonkian, the former is often greatly distorted and disarranged, sometimes forming rugged,

almost perpendicular masses, while the latter forms comparatively smooth slopes, whether gentle or steep, and the rock has a much more regular dip. These rocks, too, usually form graceful hills and mountains with regular slopes and wide V-shaped valleys with forested ravines and wooded and grassy inclines fashioned into pleasant upland copses, woodlands, and parks, even to the tops of the highest mountains, in great contrast with mountains where the Palæozoic limestones predominate. Of course in the Algonkian, where series of hard quartzytes prevail, the scenery is sometimes more rugged.

West of the Rocky Mountain divide the formation is, for the most part, carved into mountains, low, of medium height, and extensively covered with evergreen timber.

With the exception of the eastern portion, where a few fragmentary fossils have been found and described by Dr. C. D. Walcott, the rocks appear to be almost destitute of fossils. I have searched many times for any vestige of plant or animal life, but have found nothing, with the possible exception of tracks in the vicinity of Missoula.

The deposits were made, at least to a great extent, in comparatively shallow water. The slates and quartzytes are commonly ripple-marked and in some places these markings are the finest I have seen.

I do not remember noticing any place where these Algonkian beds, which have just been described, are resting on Archæan gneiss.

The Bitter Root Mountains west of the Bitter Root Valley are composed to a great extent of granite and granitoid gneiss. I once examined the rocks in Bear Creek Cañon. They are different from the so-called Archæan gneiss east of the main divide but I noticed that part of the rock in the cañon was gneiss and schist, and that it had the appearance of stratification and dipped to the east. It has been considered of late origin, but some of it may be metamorphic.

RELATIONS OF PRE-CAMBRIAN ROCKS.

The older Pre-Cambrian rocks have not been studied sufficiently here to warrant any decided opinion concerning the problems involved. I wish, however, to present one or two questions of general geological importance. First I wish to avoid confusion with regard to names and will define the terms as I shall use them.

1. Archæan gneisses. The various gneisses and schists usually having the appearance of stratification known to underlie rocks of Cambrian age and often in direct contact with them.

2. The Cherry Creek Formation. (*a*) "A series of marbles, or crystalline limestones and interlaminated mica-schists, quartzytes and gneisses,"[3] in the foothills in the region of Cherry Creek in the Upper Madison Valley.

Cherry Creek Formation? (*b*) A thick body of massive crystalline limestone and a body of a similar thickness of stratified gneiss which lies between Archæan gneiss and the Cambrian shales. This probably is the equivalent of the Cherry Creek formation, but to avoid possible confusion, I will call these for the present the Ruby crystalline limestone and gneiss.

3. The Belt Formation. (*a*) Coarse and fine-grained sandstones, quartzytes, red and green slates and shales, and in the Horsehoe Hills north of the Gallatin valley, containing conglomerates near the base, and higher in the series silicious limestone and argillites. This formation occurs in the Horseshoe Hills, in the Belt Mountains, in Smith River Valley and in other places.

(*b*) Reddish quartzytes and slates and green slates and argillites principally in the region of Missoula, Montana. Again to avoid confusion I will call these the Missoula quartzytes and slates.

By referring to the Three Forks Atlas Sheet it will be seen that the Belt beds are in all the localities of their exposures overlain by Cambrian strata, and in the region north of the Gallatin there is no doubt as to the Cambrian age of these latter rocks. In the Bridger range the relations are the same — that is in the portion represented on this sheet. But on the Livingston sheet it is seen that in the southern part of the Bridger range the Cambrian is in contact with the Archæan. South of this the Belt beds are not seen.

If we now refer to the Little Belt Atlas Folio we seem to find what we wish, viz.: the relation of the Algonkian to the Archæan. Here on three sides of the town of Neihert the Belt beds are represented as lying between Archæan gneisses and schists below and Cambrian rocks with Middle Cambrian fossils above. But on page 1 of this folio Mr. Weed says: "The older rocks of the region are the gneisses and schists found in the Little Belt Range in the northwestern part of the quadrangle. They are in part at least of igneous origin. Being a complex of rocks whose relations and origin are uncertain, and forming a group whose characters are alike throughout and differ from all other formations, they are considered to be of Archæan age."

[3] Three Forks Atlas Folio, No. 23.

So they differ in some respects from the gneisses in the region of Virginia City and other places to the southward in not showing traces of stratification.

The Belt Terrane is here divided into the Neihert quartzyte and the Belt formation. Their total thickness is 5,000 feet.

Only two or three miles southwest of this area and in part contiguous to it the Cambrian is represented as being in contact with the Archæan.

If we now turn to the Cherry Creek formation and the Ruby crystalline limestone and gneiss we meet the same difficulties. In the typical locality for the Cherry Creek formation we find by referring to the Three Forks Folio, that, south of Ruby Creek, the Cambrian is in contact with the Archæan, while to the north of the creek it is in contact with the Cherry Creek beds. I have not personally noted the contact here. At the foot of Old Baldy Mountain not far distant I have done so, and there is no trace of the limestones of the Cherry Creek beds. A few miles farther to the west, as stated before, the Ruby crystalline limestones are in contact with the gneiss.

Why do beds thousands of feet thick thin out so suddenly? On page 2 of the Three Forks Folio the following statement is made: "To the northward beyond the limits of the district, these beds [Belt] attain a thickness of 10,000 or 12,000 feet. In the northern quarter of the area the Belt formation immediately underlies the Flathead quartzyte but to the southward it is absent and does not intervene between the Archæan and the undoubted Cambrian, and the formation certainly was not laid down on the Archæan except within a comparatively narrow strip of the northern edge of the area shown on the map, and even here the actual contact has not been seen."

It seems to me that there are other possible alternatives than the theory that Algonkian rocks were not deposited where they are not now found. It seems incredible that 6,000 or 7,000 feet of sandstone slates and arenaceous limestones should be laid down in one locality and nothing be deposited ten miles or less away. Evidently shores of seas must advance or recede unless the agents which tend to build out the shore lines are exactly balanced by the invasion of the waves and tides. But it hardly seems possible that this could be continued for an inconceivably long age so that fine sediments a mile or two in thickness should suddenly decrease to zero.

The theory that the Cherry Creek beds and the similar ones of the

Ruby Mountains were formed by metamorphism of the Belt beds is naturally suggested, but this would not get rid of all the difficulty, for both are apparently absent from a great part of the area in the regions in which they occur. Gneisses probably underlie all the sedimentary rocks, but the ones containing the crystalline limestones appear at present to be confined to a restricted portion of the Tobacco Root and Ruby Mountain Ranges. Perhaps more careful observation may extend this area.

Above the old gneisses the first beds that are fairly constant, so far as my observation goes, are quartzytes that are apparently Flathead quartzytes. In some places they surely are. I will not say that these are not sometimes wanting, but they, at least, are widely distributed, as are the shales and limestones above. These latter are said to contain Middle Cambrian fossils.

The idea that after the deposition of Algonkian strata there were continental conditions, with upheavals, faulting, and a vastly long period of erosion, presents itself, but this theory like all others has apparent difficulties as a sufficient explanation of all the data. The truth is in all geological inquiry imagination is apt to run far ahead of observation and it often hinders the accumulation of facts which would help toward the settlement of the problem.[4]

PALÆOZOIC.

Dr. A. C. Peale, in his "Palæozoic Section in the Vicinity of Three Forks, Montana," (Bull. 110, U. S. Geol. Surv.), has described the excellent Palæozoic section here. The studies of the various areas mapped by W. H. Weed, of the United States Geological Survey, and my own observations, show that the upper portion of the Palæozoic, especially, possesses much local variation in lithological and other characters, and its more thorough study will undoubtedly be interesting.

I give a sketch section made on Camp Creek east of Melrose. With the Three Forks Section there is a general similarity, and though I found fossils only in the Devonian shales, yet the different members of the series can be assigned to their position in the scale with a fair degree of probability. This section is interesting, as only

[4] For an interesting discussion of the relations of these different formations see "Pre-Cambrian Fossiliferous Formations." C. D. Walcott. *Bull. Geol. Soc. Amer.*, Vol. 10, pp. 210–215.

about fifteen miles south of here, at Zeigler's Cañon of the Bighole River, a most beautiful section supplements that on Camp Creek. The first-named one begins with the Archæan and ends with the massive Carboniferous limestone, while the section at Zeigler's Cañon begins with the upper Carboniferous quartzytes and goes through Permian?, and a thick series of Mesozoic rocks, probably to the Tertiary.

CAMBRIAN AND DEVONIAN.

Regarding these formations I cannot add much to what has already been published. The Cambrian, though it varies locally, appears to be more nearly uniform lithologically than the formations extending upward from the Carboniferous. In an outcrop on the crest of the Ruby Mountains it contains many *Trilobite* heads, as it does on the Gallatin near Logan. At the foot of these mountains farther to the south, in a glauconitic sandstone, I found some *Trilobite* remains which S. A. Miller identified as *Asaphiscus wheeleri*. What has the appearance of Cambrian limestone occupies a small exposure in the Algonkian area south of Missoula, on the Bitter Root River, opposite Lo Lo Creek.

The Devonian shales, about three or four miles northwest of Three Forks, are fossiliferous and contain finely preserved Brachiopods and Cephalopods. Mr. George H. Girty identified a small collection sent to him. The following is the list:

Spirifer disjunctus.
Cleiothyris n. sp.
Camarotœchia Tethys.
Pugnax pugnus.
Goniatites (2 sp.).

The shales on Camp Creek contain a few fossils.

CARBONIFEROUS.

The Carboniferous here is well worthy of a careful study. The lithological characters, especially in the upper portion, are not so uniform as we might expect in marine formations.

Bridger Mountains. — The rocks of the Bridger Mountains have been mapped in the Three Forks Folio. On Bridger Peak, in the Madison limestone, I found the following new species which were named and described by S. A. Miller:[5]

[5] Bulletins 10 and 12 of the Illinois State Museum.

Poteriocrinus bozemanensis Miller.
Poteriocrinus douglassi Miller.[6]
Platycrinus bozemanensis Miller.
Platycrinus bridgerensis Miller.
Platycrinus douglassi Miller.
Rhodocrinus bozemanensis Miller.
Rhodocrinus bridgerensis Miller.
Rhodocrinus douglassi Miller.
Rusophycus montanensis Miller.

Miller assigns the strata containing these fossils to the Burlington, or Keokuk. The strata here are nearly vertical and are extremely fossiliferous. Some slabs are covered with Brachiopods and Bryozoa. Three of the new species of crinoids, *Rhodocrinus douglassi*, *R. bozemanensis* and *R. bridgerensis*, were found on one small slab.

Old Baldy Mountain. — In the 6th Annual Report of the United States Geological Survey of the Territories on pages 468–470 a list of Carboniferous fossils from Old Baldy Mountain is given, but there is no distinction of horizons. Last summer I made collections from the Madison laminated limestones on the north escarpment of the, and in the more thickly bedded limestones much higher on the southern or southeast slope of the mountain. The collections were kept separate. They were submitted to Mr. Percy E. Raymond of the Carnegie Museum who furnished lists which I give below. As stated before, the Cambrian, the lowest member of which is a quartzyte, rests here on the north escarpment of the mountain, directly upon the Archæan gneiss. Above this are Cambrian shales. Above these there are limestones which are mapped on the Three Forks Folio as Cambrian and Devonian. I do not know that fossils have been found in the Devonian, but Mr. DeMors, a geologist and mining man, told me he had found Cambrian fossils here. Above these beds are the thin-bedded limestones of the Madison division of the Carboniferous. Field No. 133 came from here. I did not have time to make a large collection, and the higher beds seemed of more importance. Field Nos. 134, 136, 137 and 138 came from these upper beds. In the latter besides a considerable invertebrate fauna there are fragmentary vertebrate remains (principally fish teeth, etc.), which have not been studied. I copy below Mr. Raymond's lists with his opinions as to horizons.

[6] I am not certain, but think the locality of one of these species of *Poteriocrinus* has been wrongly assigned and was found at Logan.

"Old Baldy, head of Alder Gulch, Montana, Field No. 133.

Favosites sp. ind.
Platycrinus sp. ind.
Fenestella sp.
Ptilopora sp.
Productus gallatinensis Girty.
Productus lævicosta White.
Athyris lamellosa L'Eveillé.
Proëtus peroccidens Hall and Whitfield.
Spirifer centronatus Winchell.

"Three of these species: *Productus gallatinensis*, *P. lævicosta* and *Proëtus peroccidens* are among the commonest species of the Madison limestone of the Yellowstone National Park, and may be considered as characteristic of the Mississippian, though *Productus gallatinensis* has been found in the Hermosa formation (Pennsylvanian) of Colorado. *Athyris lamellosa*, though rare in the Madison limestone, seems to be confined to the Mississippian. *Spirifer centronatus* is a characteristic Lower Carboniferous form.

"Baldy Mountain, Montana, Field No. 134.

Productus cora d'Orbigny.
Productus sp.
Spiriferina spinosa Norwood and Pratten.
Hustedia mormoni Marcou.
Myalina cuneiformis Gurley.
Cleiothyrus sp.
Athyris sp.
Proëtus cf. *P. peroccidens.*

"Judging from the presence of *Hustedia mormoni*, *Productus cora* and a *Spiriferina* of the *spinosa* type, this faunule belongs to the Upper Carboniferous, though the last two species on the list are Madison forms."

Though the Nos. 134, 136, 137 and 138, were all collected in the same locality and strata it is barely possible that some might have come from a stratum a trifle lower which might make a considerable difference in age. But I think it will be found that they are all of the same horizon.

"Old Baldy. Field Nos. 136, 137, 138.

Cœlenterata.

Zaphrentis sp.

Favosites sp.
F. divergens White & Whitfield.
Syringopora sp.
Chætetes milleporaceus Troost.

Echinodermata.

Archæocidaris sp.
Platycrinus sp.
Crinoid stems.

Bryozoa.

Prismopora sp.
Paleschara sp.

Brachiopoda.

Orthothetes sp.
Derbya crassus Meek & Hayden.
Chonetes loganensis (?) Hall & Whitfie d.
C. flemingi Norwood & Pratten.
Productus inflatus McChesney.
P. cora d'Orbigny.
P. nebraskaënsis Owen.
P. semireticulatus Martin.
Productus sp. ind.
Marginifera muricata Norwood & Pratten.
M. haydenensis Girty.
Spirifer rockymontanus Marcou.
S. striatus (?) Martin.
Spiriferina spinosa Norwood & Pratten.
Martinia sp.
Reticularia sp.
Sqamularia perplexa McChesney.
Seminula subtilita Hall.
Cleiothyris orbicularis McChesney.
Hustedia mormoni Marcou.
Pugnax rockymontana Marcou.
Dielasma bovidens Morton.

Pelecypoda.

Pleurophorus sp.
Myalina sp.
M. wyomingensis Lee.
Edmondia sp.

Nucula sp.

Gastropoda.

Platyceras sp.

Strophostylus remex White.

"This fauna is plainly Upper Carboniferous (Pennsylvanian) in character, and seems to be somewhat closely related to the Hermosa formation of the San Juan region, Colorado, as described by Girty."

Sheep Mountain. — This mountain lies to the south and west of Old Baldy Mountain. Here several years ago I found a few crinoids which were determined by Girty as *Platycrinus bozemanensis*, *Rhodocrinus douglassi* and *Actinocrinus?* sp. This is Lower Carboniferous. Above these beds there is a considerable thickness of crystalline limestone full of links of crinoid stems and fragments of Brachiopods. I found no good fossils here. This perhaps is Upper Carboniferous.

Tobacco Root Mountains. — In the summer of 1900 Prof. E. H. Murray and myself, while collecting for the University of Montana, ascended the Tobacco Root Range and traversed about 25 miles of its crest. The rocks examined here were chiefly Carboniferous and Jurassic. Here we get the upper members of the former, which are just beneath the latter. Here the upper part of the Carboniferous is a peculiar formation principally limestone with red stains. In it there were many fossils. In one cliff near a little red lake I made a considerable collection which is now in the University of Montana. I think this is upper Carboniferous but the fossils have not been determined. It will be interesting to know what relation this fauna bears to that from the upper Carboniferous quartzytes at Ziegler's Cañon, a list of which I give later. In the bedded sandstones which I found overlying the Carboniferous here there were Jurassic invertebrates and in a layer of clay were many bones of large Dinosaurs. There certainly is not any great thickness of Carboniferous quartzyte here.

Snow Crest Range. — This is a high mountain ridge which has a rather unusual trend for a mountain range of this region. Its direction is north of northeast and south of southwest. Its height and sharpness and the extending of the Tertiary beds high on its western flank gives one the impression that it is a comparatively new uplift. What surprises the geologists who have examined the Palæozoic rocks of the surrounding region is the entirely different character and appearance of the rocks here. Instead of the gray, more or less brown-

stained, rather thinly stratified limestones of the Lower Carboniferous of the Bridger, Ruby, Madison, and the Tobacco Root Ranges, which are usually overlaid by gray massive or more thickly bedded limestones, we have not less than 1,500 feet of a uniformly colored black limestone with alternations of thinner and thicker strata. This is in turn overlaid by heavy quartzytes. In the rock beneath this I found no fossils, but it is almost identical in appearance with the Cambrian elsewhere. There are fossiliferous strata through the entire thickness of the formation. The lists are given in Mr. Girty's communication, which is quoted farther on.

Sage Creek. — In one locality on a branch of Sage Creek which flows into Red Rock Creek below Lima a collection was made. This is where the stream has cut a ravine through a portion of the Carboniferous series. It is about twenty miles farther west than the place where the fossils were collected on the Snow Crest Range.

Rocky Mountains. — Main Divide south of Red Rock Lake. Here the Palæozoic rocks are more nearly horizontal than is usual. The mountains here stand up like a great wall or tableland. The northern part is made up of timbered slopes, slides of broken limestone, and perpendicular cliffs. The rock is in thin and thicker layers. The fossils that were found there were poor.

I now give the lists of fossils sent me by Mr. Girty with the portion of the letter which gives his views as to the horizons represented.

The following species have been identified.

1. Spring Cañon, Ruby Mountains, about fourteen miles west of Virginia City, near Laurin, Montana.

Cyathocrinus sp.
Taxocrinus sp.
Actinocrinus sp.
Platycrinus bozemanensis.
Platycrinus n. sp.
Rhodocrinus douglassi?
Rhodocrinus bozemanensis.
Poteriocrinus n. sp.
Archæocidaris sp.
Chonetes ornatus.
Chonetes loganensis.
Productus scabriculus.

Productus gallatinensis.
Cleiothyris roissyi.
Camarophoria ringens.
Platyceras sp.

2. Ruby Mountains, about fourteen miles west of Virginia City, Montana.[7]

Fucoid.
Menophyllum excavatum.
Platycrinus bozemanensis.
Platycrinus douglassi ?
Platycrinus n. sp.
Rhodocrinus bridgerensis ?
Rhodocrinus douglassi ?
Stenopora sp.
Fenestella sp. (etc.).
Leptæna rhomboidalis.
Productus scabriculus.
Spirifer centronatus.
Spirifernia solidirostris.
Seminula immatura.
Cleiothyris crassicardinalis ?
Terebratuloid shell.
Camarophoria ringens.
Camarotœchia sp.
Edmondia ? sp.
Cypricardinia ? sp.
Platyceras 2 sp.

3. Mount Surprise, Snow Crest Range, near Three Forks of Ruby, Montana.

Fucoid.
Zaphrentis cf. *dalei.*
Crinoid indeterminable.
Stenopora sp.
Fenestella sp.
Productus cora.
Productus cf. *alternatus.*
Productus cf. *mesialis.*
Productus cf. *burlingtonensis.*

[7] 1 and 2 are two collections from the same locality.

Productus sp.
Spirifer cf. *grimesi.*
Spirifer cf. *keokuk.*
Seminula subquadrata (and *trinuclea ?*).
Cleiothyris roissyi.
Dielasma sp.
Pinna ludlowi.
Allorisma elongatum.
Edmondia cf. *warsawensis.*
Straparolus cf. *similis.*
Pleurotomaria cf. *nauvooensis.*
Naticopsis sp.
Phillipsia sp.

4. Sheep Mountain, Snow Crest Range, near Old Baldy Mountain, and about ten miles south of Virginia City, Montana.
Platycrinus bozemanensis.
Platycrinus douglassi ?
Actinocrinus sp.

5. Lowest fossiliferous horizon, Mt. Surprise, Snow Crest Range.
Productus sp.
Cleiothyris roissyi.
Seminula subquadrata.
Myalina cf. *keokuk.*

6, Main divide of Rocky Mountains, south of Red Rock Lake.
Zaphrentis sp.
Orthothetes inflatus ?
Chonetes ornatus ?
Spirifer centronatus ?
Spiriferina solidirostris ?
Platyceras sp.
Euomophalus sp.
Loxonema sp.

7. Head of branch of Sage Creek, about eighteen miles south of Dillon, Montana.
Zaphrentis sp.
Lithostrotion ? sp.
Crinoid stems.
Rhipidomella burlingtonensis.
Productus setigerus.

Productus gallatinensis ?
Spirifer grimesi ?
Spirifer forbesi ?
Martinia rostrata ?
Ambocœlia ? sp.
Seminula madisonensis var. *petilla.*
Cleiothyris roissyi.
Pugnax cf. *missouriensis.*
Dielasma turgidum ?
Loxonema sp.
Pleurotomaria sp.

8. Jack Creek Cañon, Montana.
Camptonectes sp.
Two other fossils.

9. Three Fork Shales northwest of Three Forks of the Missouri, Montana.
Spirifer disjunctus.
Cleiothyris n. sp.

10. Three Fork Shales.
Spirifer disjunctus.
Cleiothyris n. sp.
Camarotœchia tethys.
Pugnax pugnus.
Goniatites (2 sp.).

"Viewing the collection in the light of present knowledge, I believe that two distinct faunas appear in those from the Carboniferous. One is the widely distributed Waverly fauna which characterizes the Madison limestone of the Yellowstone National Park and the lower part of the Wasatch limestone of Utah, and which has now been recognized in almost every western state. The lists 1 and 2 show this fauna in a very characteristic facies, though crinoids are much more abundant than they are found elsewhere. With 1 and 2 should be associated lists 4 and probably 6 and 7. The other fauna is represented by lists 3 and 5 though the latter is too scanty to be conclusive. There is little doubt but that this fauna is younger than the other. In my letter to you several years ago I referred it to the Keokuk. At present both because of its faunal characters, though they show certain affinities with Osage types, and its apparent overlap and unconformity with the Waverly beds I am inclined to believe

that it will prove to be earliest Pennsylvanian, and be equivalent to beds which in the Central and Eastern States have been variously called, now Millstone Grit, now Coal Measure conglomerate, and again the Pottsville group. As this fauna is as yet imperfectly known, my opinion is merely tentative, and the fauna from Montana may be, as I at first believed, a modification of one of the Mississippian faunas.

"(8) is Rocky Mountain Jurassic.

"(9) and (10) are evidently the same and belong to the Devonian and, I have little doubt, to the Upper Devonian."

Zeigler's Cañon, Bighole River. — This is southwest of Twin Bridges, above Zeigler's Springs. A detailed section is given on plate XV. The lowest rock exposed here is a heavy quartzyte succeeded by stratified quartzytes which in places contain fossils. The following list of species was supplied by Mr. Raymond.

"Lower Cañon of Bighole River, above Zeigler's Springs, Montana.

Lingula sp. ind.
Camarotœchia sp. ind.
C. metallica White.
Pugnax utah Marcou.
Productus sp. ind.
Cleiothyris orbicularis McChesney.
Aviculopecten cf. *A. weberensis* Hall and Whitfield.
Aviculopecten cf. *A. utahensis* Meek.

"An Upper Carboniferous faunule."

PERMIAN?

In the Zeigler's Cañon section, the Upper Carboniferous quartzytes are overlaid by shales, apparently carbonaceous, with layers of limestone, and then by 150 feet or more of thin bedded limestones with layers of shales. The limestone weathers to a uniform chocolate brown on the surface. Interbedded with these are dark slates. These limestones and slates are very fossiliferous but the fossils are mostly of one species, a *Lingula*. These beds occur also in the Frying-Pan Basin west of Dillon. I have not seen them in any other places.

Some of these fossils with other sets were sent to T. W. Stanton of the United States Geological Survey. The following is his report on them.

"Lower Bighole Cañon, below Zeigler's Springs, Montana.

Lingula.

Aviculopecten.

Myalina.

"These lots are evidently from the series called 'Permo-Carboniferous' by the Fortieth Parallel Survey, Utah, where it is well developed.

"The fauna has not been thoroughly studied, but it is probably Permian. In southeastern Idaho the beds containing it immediately underlie the Trias."

About 400 feet above the beds containing the Permian fossils are red shale, or clay and sandstone, in which a few fragments of bone, portions of turtle shells, etc., were found. These were too fragmentary to be determinable. Above this is a band of fifteen or twenty feet of limestone in which a few fossils were found. These were examined by Professor Stanton who reported on them as follows:

"Jurassic? Cañon of Bighole River, above Zeigler's Springs, Montana.

Unio sp. Imperfect young specimen of same type as *U. douglassi.*

Neritina sp.

Goniobasis? sp. Form with carinate whorls.

Goniobasis? sp. Form with rounded whorls.

"These fossils are not sufficient to determine the age of the beds, but they seem to me more recent than Jurassic. Weed obtained similar fossils from above the Cascade formation (Kootenai) in beds that he mapped as Dakota on the Fort Benton Sheet."

In the cañon of Jack Creek which flows into the Madison River below Ennis, in the Madison Mountains in a thick-bedded, compact, dark-colored limestone a few fossils were found which were also examined by Professor Stanton. They are the following:

"*Gryphæa planoconvexa* Whitfield.

Ostrea engelmanni Meek? Fragment may be a large Lima or Pecten.

Comptonectes bellistriatus Meek.

Comptonectes pertenuistriatus Hall & Whitfield.

Pleuromya subcompressa Meek.

"These species belong to the ordinary Marine Jurassic fauna of Montana and the Yellowstone National Park."

For description of the locality and geological section see 6th Annual Report, U. S. Geol. Survey of Territories, p. 162.

On the top of the Tobacco Root Mountains north of Black Butte

the Jurassic is very well exposed. Here, as stated before, it lies upon the Carboniferous. In one place on the eastern slope just below the crest of the range a little stream issuing from a spring in a swampy place has washed out bones of large Dinosaurs. Those exposed are water-worn. In the sandstones I found some poor invertebrate fossils.

LOWER CRETACEOUS?

Near Drummond in Granite County, in a compact greenish-brown rock, I found some fossil ferns resembling *Pecopteris* and leaves that look like *Sterculia*, which are probably lower Cretaceous, but they have not been determined and nothing definite can be said concerning the age. They may prove to be Kootenai.

DAKOTA.

In the various Montana Atlas folios and geological maps of Montana, strata have been mapped as doubtfully Dakota on the evidence of the position of the beds but in none of them had characteristic fossils been found. For the most part the formation mapped as Dakota contains a heavy band of limestone which is very fossiliferous, containing, wherever exposed, great numbers of bivalves and gasteropods.

In the Jack Creek (Jackass on the map) Cañon in the strata mapped as Dakota on the Three Forks Atlas Sheet, I collected fossil leaves. Part of these are in the University of Montana and the remainder in the Carnegie Museum. The latter were sent to Professor F. H. Knowlton, who determined the following:

Sequoia reichenbachi?
Quercus primordialis.
Laurus protæfolia.
Ficus lanceolata acuminata.

These are all Dakota species. The leaves came from layers of sandstone in sandy clay. Above, but, according to A. C. Peale lower geologically, is a considerable thickness of gray sandstone. This is probably the horizon which Peale says contains fragments of fossil leaves.[8] The lithological character of the rocks here is nothing like that of the beds which contain so many gasteropods, etc., in other places.

[8] Sixth Ann. Report, U. S. Geol. Surv. of Terr., p. 163.

DAKOTA?

In several places beside those mapped by the United States Geological Survey, I have observed limestones containing non-marine mollusca lying between Jurassic and upper Cretaceous strata. These are well exposed on the lower Bighole River north of Zeigler's Cañon, in the Frying-Pan Basin northwest of Dillon, on the west slope of the Tobacco Root Range, etc. A small collection of the fossils from Zeigler's Cañon was sent to Professor Stanton. The following is his report:

Field No. 131, north side of Bighole, southeast of McCarty's Mountain above Zeigler's Cañon, Montana.

Unio sp. Slender form of the type of *U. douglassi.*

Corbula sp. Very abundant. Doubtfully referred to *Corbula.* Possibly two species.

Goniobasis ? sp. Very slender, smooth form.

Goniobasis increbescens Stanton.

Viviparus ? sp.

"This collection is from the horizon probably doubtfully referred to the Dakota in the Yellowstone region. Its age is very doubtful."

Field No. 132. — From a higher horizon at same locality as 131.

Unio sp. Differs from one in lot 131.

Goniobasis ? increbescens Stanton.

Fish teeth, etc.

"This lot probably belongs to the same horizon as 131."

DESCRIPTION OF PLATE.

A–B. A Palæozoic section on Camp Creek east of Melrose, Montana. The section extends from *A* down the creek south of west to *B*, where Carboniferous limestones form the western flank of the mountains along the Bighole valley.

C–D. A section about fifteen miles to the southward of *A–B* and a little farther east. This is nearly supplementary to the Camp Creek section, though there are undoubtedly some strata lost between the two.

This section extends from above Zeigler's Springs up the Bighole from east to west. It begins with heavy Carboniferous quartzyte. The upper portion of the quartzytes contain Upper Carboniferous fossils. This is succeeded by Permian?, possibly Triassic, Jurassic and then Cretaceous strata. Then by a fault the Carboniferous quartzytes come in again, overlying the Mesozoic and dipping at the same angle. Above this the strata are repeated and continue up through Cretaceous to Laramie and ending in McCarty's Mountain in what may be Livingston or later.

This region presents a most beautiful study in dynamic geology, as the strata are so plainly exposed. A mile north of here the section would be quite different.