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GEOLOGY OF THE CLOVER DIVIDE AREA, SNOWCREST RANGE, BEAVERHEAD COUNTY, MONTANA

By

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Submitted in partial
fulfillment of the requirements
for the degree of Master
of Science in Geology,
University of Michigan, 1949.

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ABSTRACT

The Clover Divide area described in this report includes approximately 48 square miles in the south central portion of Beaverhead County, Montana. The most prominent element of the Snowcrest Range lies immediately to the east of the area. The exposed rocks range in age from Devonian (?) to Tertiary. The thickness of the combined Paleozoic and Mesozoic sequences is estimated to be 11,000 feet. No Jurassic rocks were found. The Tertiary rocks are several thousand feet thick. Volcanic rocks are restricted to three very small exposures. Alluvium is present only in restricted areas and was not mapped. The Paleozoic and Mesozoic formations have a general strike trend of N.60 E. and an average dip of 35 to 40 degrees to the southeast. Only one prominent erosion surface is recognized in the area, that being developed at about 8,200 to 8,500 feet. A prominent feature of the Blacktail (Deer) Creek (?) formation is the massive cliff-forming travertine limestone unit.

Two and possibly three phases of Laramide orogeny can be seen in the area. The first phase was the folding of the Snowcrest Range. The second phase saw the upturning of the Beaverhead conglomerate against the Snowcrest Range. At a later time, the Beaverhead conglomerate itself was folded along a northwest-southeast axis.

INTRODUCTION

Purpose of report

The purpose of this report is to describe the geology of the Clover Divide area in the Snowcrest Range of southwestern Montana. A broad program of mapping in southwestern Montana was carried out by students of the University of Michigan in the summers of 1947 and 1948 under the direction of Dr. A. J. Eardley, and the area described in this report is a small portion of the overall project. The work done provided experience both in field methods and in the preparation of written reports. The study was intended to be used as material for a Master's thesis at the University of Michigan.

Location and description of area

The area mapped is rectangular in shape and includes approximately 48 square miles. It is located in the south-central portion of Beaverhead County, Montana. The Snowcrest Range is situated immediately to the east of the report area. (See index map, p. 5.) The area includes all of the sections of T. 12 S., R. 6 W. and sections 1 through 12 in T. 13 S., R. 6 W.

The U. S. Department of Agriculture Forest Service Maps of Beaverhead National Forest (1947) includes the area mapped in this report. It shows mainly drainage and principal roads at a scale of either ¼ inch or ½ inch to the mile. The ½ inch to the mile map was used for control in the construction of the accompanying geologic map by the radial line assembly method.

No topographic map of the thesis area has yet been made. The relief in the area is quite moderate compared to some of the other areas in southwest Montana that have been mapped by students of the University of Michigan. The highest elevation, about 8700 feet, is found on the relatively flat surfaces developed on Tertiary beds in the west central portion of the area. The lowest point is at approximately 6500 feet in the valley of the West Fork of Blacktail Creek in the northern portion of the mapped area. Thus, an estimated maximum relief for the area is approximately 2200 feet. No true mountain peaks are in the area, although some are found in the Snowcrest Range immediately to the east. Much of the area is covered with grass which in some places makes outcrops hard to locate. Trees are largely conifers and are restricted in large measure to outcrops of the Quadrant formation.

The climate of the area is arid. The high elevations and northerly latitude combine to make this country suitable mainly for the summer grazing of sheep and cattle. As evidenced by aerial photographs, some hay was raised along the valley bottom of the West Fork of Blacktail Creek in previous years, although no such crop was growing in the summer of 1948. Data from the U. S. Department of Agriculture (1941, p. 955) lists the station at Lima, Montana, as having an annual average precipitation of 9.27". The average January temperature is 16.3 deg. F. The June average temperature is recorded at 62.9 deg. F.

The report area is drained by five principal streams. North of Clover Divide, in the central and northern portions of the area, the West Fork of Blacktail Creek carries the drainage northward to join eventually the Beaverhead River. The Middle Fork of Blacktail Creek drains the northeast part of the area. South of Clover Divide the Little Basin Creek and Basin Creek drain the south central and southwestern reaches of the area. In the extreme southeast corner, Clover Creek carries the drainage southward to the Lima reservoir. Most of the other streams or tributaries are generally dry in the summer months.

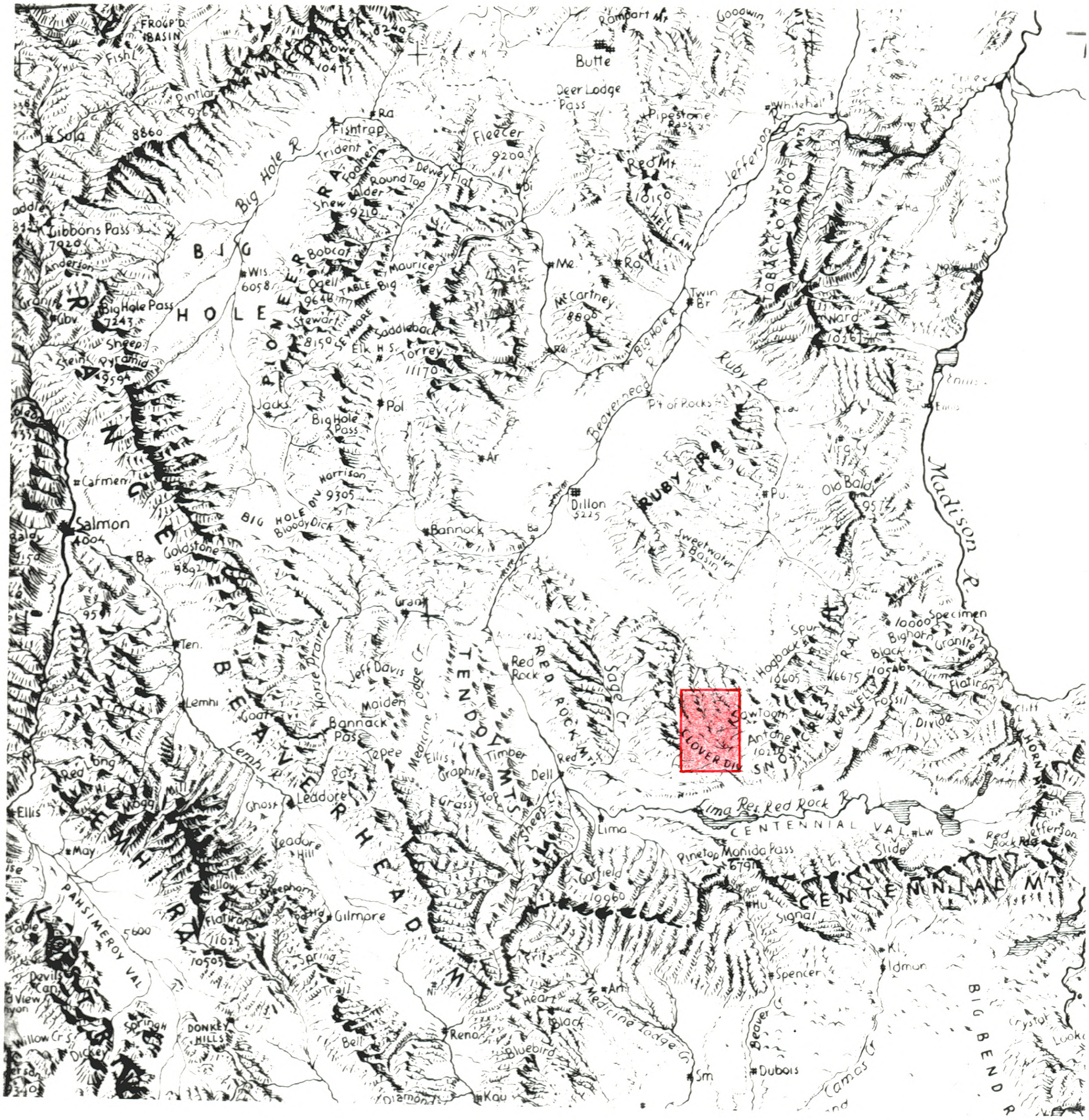
The area described in this report can be reached by fairly serviceable dirt roads, which, however, are almost impassable in wet weather. It is approximately

30 miles by road to the boundaries of the area from Lima, Montana, to the southwest, and 32 miles from Dillon, Montana, to the northwest. It is preferable to enter the area from Dillon, as this road is in better condition and has more gentle grades than the road from Lima. The nearest paved road is U. S. Highway No. 91, which is to the west in Beaverhead Valley and connects Lima and Dillon with Idaho Falls, Idaho, to the south and Butte, Montana, to the north. The Oregon Short Line division of the Union Pacific Railroad also parallels Highway 91, and provides the only railway service in this part of southwestern Montana. In the report area itself, quite a few rough roads have been developed by ranchers, although these can be negotiated only in trucks or jeeps. Over much of the high, flat surfaces in the western portion of the mapped area, trucks can be driven almost at will.

Previous work in the area

The area of this report is in the southeast corner of a larger area being studied as a Ph. D. thesis problem by Kendall Keenmon, graduate student at the University of Michigan. Other work in the area has been done by M. W. Klepper of the U. S. Geological Survey who has made a reconnaissance map of the area, as yet not available.

PLATE I



E. Raisz

INDEX MAP

Acknowledgments

The field work for this report was done during the month of July 1948, under the direct supervision of Dr. A. J. Eardley of the University of Michigan. Dr. Eardley also aided in the preparation of the map and cross-section and in the writing of this report. Dr. E. C. Stumm of the University of Michigan aided in the study of some of the fossils. Dr. E. W. Heinrich of the Mineralogy Department, University of Michigan gave helpful information concerning the pre-Cambrian rocks exposed to the northwest of the area. Thanks are due also to Thomas Piper, student in geology at the University of Michigan for the use of photographs and for help in the field. Apprecia-tion is also extended to Kendall Keenmon for many helpful suggestions both in the field and during the course of preparation of this report.

STRATIGRAPHY

General statement

The outcropping rocks range in age from a possible Upper Devonian formation to beds of Tertiary age. No rocks older than Upper Devonian are exposed in the area.

The nearest exposures of rocks of pre-Cambrian and Cambrian ages are found in areas in the Madison River country to the east and in the Blacktail Range to the northwest.

A fairly complete sequence of beds younger than Devonian can be observed in the area, except for the probable absence of rocks of Jurassic age.

The Paleozoic era in the report area is represented by beds that may be the Upper Devonian Three Forks formation, the Madison formation of Mississippian age, the Amsden formation of Mississippian and Pennsylvanian age, the Pennsylvanian Quadrant formation, and the Permian Phosphoria formation. The total exposed Paleozoic thickness is estimated to be approximately 5,100± feet.

The Mesozoic era is represented by the lower Triassic Dinwoody, Woodside, and Thaynes formations, and the Kootenai and Aspen formations of Cretaceous age. The total Triassic system is 2,004± feet thick. Beds of Cretaceous age are estimated to be 4,000 to 4,500 feet thick.

The Cenozoic era has the Beaverhead formation of Paleocene age, the Blacktail (Deer) Creek(?) formation of probable Miocene age, and volcanics of undetermined Tertiary age. Landslides and valley alluvium of Recent age, although present in some areas, were not mapped because of their small areal extent and relative insignificance on a map of small scale.

The general strike trend of the Paleozoic and Mesozoic formations is N. 60 E. across the area. They have fairly uniform steep dips which range from 25 to 60 degrees. The best exposures of the Paleozoic and Mesozoic sequences are found along the Blacktail Road, which parallels the West Fork of Blacktail Creek. This road is approximately at right angles to the general strike of the beds. Numerous road cuts made by mechanical equipment, especially in the Triassic section, helped in the study of what would otherwise be rather poor sections.

Pre-Cambrian system

The nearest exposures of pre-Cambrian rock are about 16 miles to the northwest in the Blacktail Range.

According to Dr. E. Wm. Heinrich of the University of Michigan, the pre-Cambrian rocks of this part of southwestern Montana are all pre-Beltian and can be divided into three units (personal communication). The oldest is known as the Pony series and is composed of meta-igneous material. Younger in age is the Cherry Creek series, which is composed of meta-sedimentary rocks, chiefly marbles, schists, and quartzites. According to Dr. Heinrich, the best exposures of the Cherry Creek series can be found at the southern end of the Ruby Range. During middle Proterozoic (pre-Beltian) time a gigantic intrusion into both the Pony and Cherry Creek series occurred, after regional metamorphism had begun. Dr. Heinrich has applied the name "Blacktail Granite Gneiss" to the rocks of this intrusion. This unit constitutes most of the pre-Cambrian in the Blacktail Range. Dr. Heinrich has found evidence that metamorphism also went on after the intrusion, although not to such an extent as before the intrusion.

The Blacktail Granite Gneiss has been found over an area of batholithic proportions. From exposures at Stone Creek to the northeast of Dillon, Montana, Dr. Heinrich has traced the Blacktail Gneiss for almost 60 miles down to the Idaho-Montana border, in a northeast-southwest direction.

Cambrian system

No Cambrian rocks are exposed in the area, the nearest outcrops being in Ashbough Canyon in the Blacktail Range, to the northwest of the area. A remarkably complete section was observed and described by Thomas Beard of the University of Michigan. Another fairly complete Cambrian section was observed by John Lemish (1947, pp. 9-10) along the West Fork of the Madison River, 23 miles to the east of this report area.

Flathead quartzite.- A. C. Peale (1893, pp. 20-21) named the Flathead quartzite from outcrops at Flathead Pass, near Three Forks, Montana. There is a profound unconformity between the pre-Cambrian schists and gneisses and the Flathead. It was originally thought to be Lower Cambrian in age, but has now been classed as Middle Cambrian. Beard (1949, p. 11) describes some 131 feet of quartzites and shales in Ashbough Canyon, while Lemish (1947, p. 9) found 200 feet of Flathead quartzite along the West Fork of the Madison River. Brant, Elmer, Gillespie, and Peterson (1949, p. 14) found the Flathead to be only 10 to 15 feet thick in the region near Armstead, Montana.

Wolsey formation.- The Wolsey formation was named by W. H. Weed (1900, p. 285) for exposures near Wolsey, Montana. Beard (1949, p. 12) described the outcrop of the Wolsey formation in Ashbough Canyon as a predominately gray-green shale, possibly glauconitic, and having a thickness of 147 feet.

Meagher formation.- The Meagher formation appears as a prominent cliff-former and is well exposed in Ashbough Canyon. It is in the main a tan dolomite. Beard (1949, p. 13) measured 542 feet of Meagher in Ashbough Canyon. Lemish (1947, p. 9) found the formation to be only 75 feet in thickness along the West Fork of the Madison River. Weed (1899) first described the formation from outcrops in the Little Belt Mountains of Montana.

Park shale.- Weed (1899) named the Park shale after exposures in the Little Belt Mountains, Montana. In the Ashbough Canyon section, Beard (1949, p. 14) found 121 feet of a very thin-bedded, dark green shale. The Park shale is quite widespread throughout central and southern Montana and is considered as Middle Cambrian.

Pilgrim formation.- The Pilgrim formation has been classified as Upper Cambrian by N. G. Wilmarth (1938, p. 1659). Weed (1899) applied the name Pilgrim to rocks of this age in the Little Belt Mountain region. It is approximately 75 to 90 feet thick in the Ashbough Canyon section, and is mainly a fine grained limestone, gray to white in color (Beard, 1949, p. 15).

Devonian system

Jefferson formation.- Peale (1893, pp. 27-29) applied the name Jefferson formation to rock exposures along the Jefferson River, in the Three Forks region of Montana. He placed the formation in the middle Devonian but later work by Sloss and Laird (1947, pp. 1404-1431) indicates that the Jefferson formation should be placed in the upper Devonian. Lemish (1947, p. 12) found 160 feet of a dark gray, thin-bedded to massive, fossiliferous limestone along the West Fork of the Madison River to the east of this area.

Three Forks formation.- The type locality for the Three Forks formation is at Three Forks, Montana. Peale (1893, pp. 29-32) first named the formation and placed it in the Middle Devonian. Like the older Jefferson formation, Sloss and Laird (1947, pp. 1404-1431) have reclassified it as Upper Devonian. In the Blacktail Mountains, Beard observed that the Three Forks formation may be as thick as 141 feet, although much of the formation was covered. The float in his area contained pieces of bright colored limestone and dolomite (1949, p. 16). Lemish (1947, p. 12) measured 197 feet of Three Forks formation along the West Fork of the Madison River. Lemish found four main units. In descending order, these are:

4. Limestone, tan, thin-bedded, fossiliferous

3. Limestone, gray to buff, thin-bedded, fossiliferous

2. Limestone, gray, lithographic

1. Shale, red, calcareous

Keenmon (personal communication) believes that some beds of the Three Forks formation crop out along the Middle Fork of Blacktail Creek in the extreme eastern portion of the area. The exposures were small in area, but the sandstones and black, fine-grained, almost lithographic limestones seemed quite unlike anything known to occur in the overlying Madison formation. The contact between the formation here considered as the Three Forks and the Mississippian Madison formation was covered and could not be observed. Some poorly preserved fossils were collected from this formation by Keenmon and were identified by Dr. E. C. Stumm, of the University of Michigan, as belonging to the genus Leiorhynchus, sp. Some species of this genus have been found throughout the Rocky Mountain area in Devonian beds, other species in beds of Mississippian age. Since it was not possible to pin the fossils down to species, proof of the age of these beds can not yet be established on paleontological evidence. It is hoped that later field work will uncover fossils of a more diagnostic character.

Mississippian system

Madison formation.- The Madison Range, in the central part of the Three Forks quadrangle, Montana, was designated the type locality by Peale (1893, pp. 33-39). L. L. Sloss and R. H. Hamblin (1942, p. 313) believe that a more suitable type section can be found at Logan, Montana. Although some workers believe that the Madison formation should more properly be considered a group, for the purposes of this report, it was considered a formation in the mapping and description. A. J. Collier and S. H. Cathcart (1922, p. 173) were the first to recognize two sub-units within the Madison formation. The lower unit was named the Lodgepole member, and the upper unit was designated the Mission Canyon member. Both of these names were taken from canyons on the north flank of the Little Rocky Mountains in Montana.

The Lodgepole member is not exposed in the thesis area. For the purpose of clarity, all outcrops of the Mission Canyon member were mapped simply as Madison formation. The Lodgepole member, in contrast to the massive, poorly-bedded Mission Canyon member, is a regularly and thin-bedded, limestone unit. The beds are 4 to 6 inches thick. Outcrops of the Lodgepole member along U. S. Highway 91 near Armstead show it to be highly contorted. Perhaps, this unit acted as an incompetent bed during the Laramide orogeny.

The Mission Canyon member is a conspicuous stratigraphic unit in the report area. It crops out in a broad band across the central part of the area and forms prominent cliffs in some places. Along the West Fork of Blacktail Creek, the Madison cliffs have weathered into turreted shapes. The Mission Canyon member is predominately a massive, poorly-bedded, gray to blue-gray limestone. Chert is present in some beds as nodular inclusions. Freshly broken surfaces have a fetid odor. Some beds are quite fossiliferous, with poorly preserved brachiopod valves and crinoid stems most common. The Madison in the area is estimated to be about 1800± feet thick. It is interesting to note the variations in thickness for the Madison formation from west to east in this part of Montana. Kupsch and Scholten (Kupsch, 1948, p. 22) estimate the thickness of the Madison formation in Nicholia Creek area, Beaverhead Mountains, to be about 3,000 feet. Lemish (1947, p. 13) measured 940 feet of this formation along the West Fork of the Madison River. Evidently, the writer's area is located on the edge of what was a shelf area in Mississippian time. The Madison formation is a widespread unit throughout Northern Utah, Idaho, Montana, and Wyoming.

Amsden formation.- N. H. Darton (1904, p. 396) named the Amsden formation from exposures along the Amsden branch of the Tongue River, near Dayton, Wyoming. Peale (1893, pp. 39-43) had originally included beds of what are now known as Amsden in the formation for which he proposed the name of Quadrant. There has been much discussion concerning the age of the Amsden formation. H. W. Scott (1935, pp. 1011-1032) assigned a Mississippian Chester age to the Amsden on the basis of stratigraphic and paleontological evidence. Later, Scott (1945, p. 1156) cites fossil evidence to support a Lower Pennsylvanian Morrow age for the Amsden. Berry (1943, p. 19) considers the lower part of the Amsden as Upper Mississippian and the upper part of the Amsden as Lower Pennsylvanian in age. C. C. Branson (1937, pp. 650-660) proposed that the name Sacajawea be used for the Amsden beds of Mississippian age, reserving the name Amsden for beds of Pennsylvanian age.

In the report area, beds of Amsden age are mostly covered with grass or Quadrant talus. No good outcrops were located. The thickness is estimated to be approximately 1,000± feet. Here again, it is noteworthy to observe how the Amsden thins from west to east. Lipp (1948, p. 16) measured 2,022 feet of Amsden in an area east of Sheep Canyon, near Dell, Montana. He found the formation to be composed in the main of gray limestones and shales with some orange colored sandstone beds. In the West Branch area of the Madison River, Lemish (1947, p. 14) found the Amsden formation to be only 152 feet thick.

Pennsylvanian system

Quadrant formation.- Peale (1893, pp. 32-43) used the name Quadrant after a field conference with I. P. Iddings and W. H. Weed prior to the publication of the type section selected by Iddings and Weed at Quadrant Mountain, Yellowstone Park. Peale was describing rock strata in southern Montana which he believed to be of the same age as the section on Quadrant Mountain. Scott (1935, p. 1013) believes that Peale included rocks of Amsden age under the name Quadrant (basal 100 feet of Peale's Quadrant section). Scott maintains that the Quadrant is a westward extension of the Tensleep sandstone. He has shown that the upper calcareous zones in the Tensleep grade into siliceous limestone and finally into a relatively pure limestone in the upper part of the Quadrant formation. Scott (1935, p. 1018) believes that "at Quadrant Mountain at least 95 per cent of the formation represents marine deposited or reworked material."

In the thesis area, the Quadrant is conspicuous because of the high ridges that it supports and because the only sizeable growth of conifers in the area is found along the outcrop band. It would appear that the acid nature of the soil on the Quadrant is helpful to vegetation in this harsh climate. The formation consists of quartzite, sandstones and dolomites. In places the Quadrant forms talus slopes of large angular blocks. In other sections, especially along the outcrop on the high ridges, the Quadrant has weathered into actual sand dunes of limited area. The Quadrant of this part of Montana seems to be considerably more friable and less well cemented than the equivalent Tensleep formation in the Camp Davis area of the Gros Ventres Range. Along the West Fork of Blacktail Creek, slickensides were noticeable in several places. In general, however, the exposed sections were too scattered for a detailed stratigraphic study. An estimated thickness for the Quadrant formation, as studied along the Blacktail road is about 1700± feet. In the Tendoy-Medicine Lodge area to the west, W. Smith (1948, p. 17) found the Quadrant thickness to be over 3,300 feet. In contrast, Lemish (1947, p. 15) measured only 195 feet of Quadrant formation in the area around the West Branch of the Madison River. D. D. Condit, E. H. Finch, and J. T. Pardee (1928, pp. 795-796) measured a section in the Snowcrest Range 13 miles to the northeast of this report area. This section is probably typical also of the Quadrant in the report area and has fewer covered intervals.

Section measured in the Snowcrest Range, sec. 26, T.10 S., R.4 W. by Condit, Finch, and Pardee.

16.	Limestone, dolomitic, gray sandy layers (approximate thickness).	80.0 feet
15.	Sandstone, quartzitic, gray	138.0
14.	Shale, calcareous, mottled gray and brown	5.0
13.	Sandstone, quartzitic	36.0
12.	Shale, calcareous, mottled gray and brown	5.0
11.	Sandstone, quartzitic	25.0
10.	Limestone, cherty, dolomitic, thin sandy layers.	29.0
9.	Sandstone, quartzitic, gray	40.0
8.	Shale, black.	2.0
7.	Sandstone, quartzitic, gray, dolomite layers and thin layers of fine-textured dark gray limestone	205.0
6.	Limestone, dark gray, quartzitic layers.	55.0
5.	Quartzite, pinkish.	30.0
4.	Limestone, dark colored, shaly, with some massive layers, brown to black chert nodules	253.0
3.	Covered interval.	50.0
2.	Sandstone, conglomerate at base	20.0
1.	Covered interval.	25.0
	Total thickness	998.0 feet

Permian system

<u>Phosphoria formation</u>.- The type locality for the Phosphoria formation is at Phosphoria Gulch, near Meade Park, Idaho, (Richards and Mansfield, 1912, pp. 683-689). Extensive studies of the Phosphoria formation have been made in the northern Rocky Mountain area for the purpose of gaining an estimate of the economic value of the phosphate rock contained in the formation. Condit, Finch, and Pardee (1928, p. 167) mention that "the entire upper part of the Phosphoria formation is quite phosphatic with several beds of concentrated oolitic phosphate associated with 50 feet or so of black or brown carbonaceous shale." These workers find that this is characteristic of all of the exposures from Dillon, Montana, to northern Utah. In general, the lower beds of phosphate material are considerably less extensive than beds higher up in the formation. The lower beds in the formation are characterized by phosphatized shells of certain mollusks, especially the genus <u>Lingulidiscina sp</u>. Condit, Finch, and Pardee (1928, p. 169) find that in the Dillon-Dell area, a prominent phosphate bed averages four feet in thickness. However, numerous shale laminae cut the tricalcium phosphate content down to a range of 42 to 52 per cent. This is probably too low a content to warrant exploitation at the present time.

The Phosphoria formation in the report area was examined and measured by Keenmon, Piper, and the writer. In general, it was a poor section, with many covered intervals. An estimated thickness along the West Fork of Blacktail Creek is about 500 feet. Keenmon and the writer later had an opportunity to examine and measure a Phosphoria section at Wadham's Springs, 3½ miles to the southwest of the thesis area. A trench had been dug out of the hillside for the U. S. G. S. with the aid of a bulldozer. The entire section of the Phosphoria formation, from the Quadrant contact to the base of the overlying Dinwoody formation was exposed. In a personal communication from M. W. Klepper of the U. S. G. S. to Keenmon, the following section was given. Certain details of stratigraphy still remain as confidential information tq the U. S. G. S., according to Keenmon.

Section measured by M. W. Klepper
at Wadham's Springs in SW¼ of sec.
22, R.7 W., T.13 S., August, 1948.

5. Sandstone, quartzitic, and limestone, cherty.	110.0±
4. Mudstone, phosphatic mudstone, and limestone, cherty	65.0±
3. Siltstone, calcareous, and sandstone, in part cherty; massive chert near the base.	290.0±
2. Siltstone, cherty, dolomitic, with one bed of phosphate rock (4 to 5 feet) . . .	75.0±

1. Sandstone and siltstone, in part cherty, apparently gradational through about 10 feet of the underlying Quadrant formation. 60.0±

Total thickness 600.0±

Another section was measured by Klepper at Smallhorn Canyon in the west end of the Blacktail Mountains. As at Wadham's Springs, Klepper divided the formation into five units. The upper two units are very similar to same units at Wadham's Springs in both thickness and lithology. However the lower three members at Smallhorn Canyon are considerably thinner than the corresponding units at Wadham's Springs, being 140 feet, 25 feet, and 20 feet thick from top to bottom. In member no. 2, a few one inch bands of phosphate rock occur, and Klepper considers these to be correlative with the four to five foot phosphate bed at Wadham's Springs.

Triassic system

Introduction.- In the report area, the rocks belonging to the Triassic system are the best exposed for study of any in the stratigraphic column. Keenmon, Piper, and the writer measured a complete Triassic section along Blacktail road, which runs approximately at right angles to the general strike of the Paleozoic and Mesozoic formations. Later in the summer, Keenmon, Piper, Reed Hollister and Carl Moritz of the Phillips Petroleum Company remeasured the Triassic section, making certain revisions. The section here presented is the second measurement of the Triassic system in the area and is the most accurate one available. In some field studies near the Lima Peaks to the south of Lima, Montana, E. Dillon (1949, pp. 30-45) made some important changes in the stratigraphic boundaries of the Triassic system for this general area in Montana. Based on careful paleontological evidence, especially with cephalopod remains, Dillon finds that previous workers in the area have been including part of the lower Thaynes formation in the older Woodside and Dinwoody formations. Although the narrow Meekoceras bed that Dillon describes (p. 41) was not found along the Blacktail road in the writer's area, the thicknesses of the formations of the Triassic system, based on lithologic evidence, seem to be in general agreement with those measured by Dillon.

Dinwoody formation.- E. Blackwelder (1918, pp. 425-426) applied the name Dinwoody to outcrops of thin dense sandstones and greenish gray shales in the canyon of Dinwoody Lakes, in the Wind River Range of Wyoming. N. D. Newell and B. Kummel (1942, pp. 937-996) in studies of the lower Triassic stratigraphy in southeastern Idaho and western Wyoming, found that the Triassic appears conformable on the Permian formations in most places. A long erosion interval almost certainly occurred, according to these workers, in spite of "the lack of convincing evidence for hiatus at most exposures throughout Wyoming and southeast Idaho" (p. 938).

In the report area, the Dinwoody is divisible into three main units: a basal brown, calcareous shale unit, 69 feet in thickness (units 2 and 3); a middle limestone unit 321 feet thick (units 4 through 13), which is reddish-brown and shaly; and an upper siltstone (units 14 through 16) which is calcareous, gray, and 279 feet thick.

Section measured on Blacktail Road, NW¼, sec. 35, T.12 S., R.6 W. by Moritz, Keenmon, Piper, and Hollister, August 1948.

	Feet
15. Covered, contact indefinite, probably the uppermost Dinwoody.	31.0
14. Siltstone, light gray, slightly calcareous, partly covered	93.0
13. Covered, probably interbedded light tan shale and siltstone	155.0
12. Limestone, reddish brown, massive; beds 18 inches thick.	11.0
11. Siltstone, reddish brown; beds 1 to 6 inches thick; thin interbedded limestones, reddish brown	49.0
10. Shale, reddish brown; interbedded thin limestones, weathers to light tan clay. .	21.0

	Feet
9. Limestone, reddish brown; beds 1 to 12 inches thick; thin shaly siltstone layers, reddish brown.	10.0
8. Limestone, reddish brown; beds 6 to 18 inches thick.	8.0
7. Shale, reddish brown; thin bedded; thin interbedded limestones, reddish brown.	17.0
6. Limestone, reddish brown, silty; beds 1 to 12 inches thick	4.0
5. Covered, probably reddish brown limestones or shales	148.0
4. Limestone, reddish brown, shaly, massive, resistant; beds 2 to 12 inches thick	10.0
3. Limestone, reddish brown, shaly, marine fossils, beds 1 to 18 inches thick, blocky; few thin interbedded reddish brown shales	43.0
2. Shale, dark brown, calcareous, weathers light gray in color.	63.0
1. Siltstone, dark brown, massive	6.0
Total thickness	669.0

Woodside formation.- J. M. Boutwell (1907, p. 446) gave the name Woodside to outcrops of fine-grained, thinly-bedded dark red shale in Woodside Gulch, Park City District, Utah. No good outcrops were observed in the report area. The Woodside, composed of relatively soft material, forms gentle, grass covered slopes in the area. From a distance, the red color of the soil is quite noticeable. The Woodside is predominantly a red shale, although shales of various other colors are present. Along the West Fork of Blacktail Creek, the Woodside was measured by Moritz, Keenmon, Piper, and Hollister, and was found to be 186 feet.

Thaynes formation.- The type locality of the Thaynes formation is at Thaynes Canyon, in the Park City District of Utah. J. M. Boutwell (1907, pp. 448-452) first described the formation and placed it in the Lower Triassic. The formation is well known in northern Utah, western Wyoming, eastern Idaho, and has been extended up into southern Montana. It is essentially a calcareous formation and is highly fossiliferous in certain zones. Newell and Kummel (1942, pp. 937-996) have found that in general the fossils found in the Thaynes formation are of a shallow water type. Pelecypods are abundant, especially the genus Pecten sp. More important, however, for a marker bed, is the Meekoceras zone, which Newell and Kummel (p. 947) find is usually confined to a layer 20 feet or less in thickness and generally about 100 feet above the Woodside-Thaynes contact. This checks quite well with the findings of Dillon (1949, p. 41), who observed the Meekoceras zone to the north of Deep Creek in the Lima Peaks area south of Lima, Montana. Dillon noted that the zone was 8½ feet thick and located approximately 120 feet above the base of the Thaynes formation.

In the writer's area, the Thaynes formation is best studied along the West Fork of Blacktail Creek. It is composed in the main of tan siltstones, which are in places calcareous. Several units in the formation are quite resistant, forming prominent ridges, the back sides of which are dip slopes. The <u>Meekoceras</u> zone was not observed in the report area. Based mainly of lithology, a study of the formation revealed it to be 1,149 feet thick.

Section measured by Moritz, Keenmon, Piper, and Hollister along Blacktail Road, NW¼, sec. 35, T.12 S., R.6 W., August, 1948.

	Feet
15. Covered interval.	155.0
14. Limestone, light tan, dolomitic, light gray chert nodules contained in it, beds 2 to 12 inches thick	62.0
13. Siltstone, gray, weathers rusty brown, cherty, beds 2 to 3 inches thick.	31.0
12. Covered interval.	31.0
11. Siltstone, light tan to buff, weathers dark brown.	31.0
10. Siltstone, white.	8.0
9. Covered interval.	23.0
8. Siltstone, calcareous, light tan to buff, weathers dark brown	174.0
7. Limestone, white, fine-grained.	4.0
6. Siltstone, light tan to buff, calcareous, weathers dark brown	50.0

	Feet
5. Siltstone, light tan, massive beds.	2.0
4. Siltstone, light tan to buff, calcareous, weathers dark brown, beds $\frac{1}{2}$ to 4 inches, some poorly preserved fossils (not collected).	31.0
3. Covered interval, probably shale, light tan	153.0
2. Limestone, silty, light tan, beds 1 to 6 inches, weathers dark gray, often with mottled rusty surfaces.	69.0
1. Siltstone, light buff, calcareous, thin beds $\frac{1}{4}$ to 1 inch, weathers a dark, oily gray. Unit largely covered	325.0
Total thickness	1,149.0

Jurassic system

No rocks of Jurassic age were identified in the area. There may have been a thin Jurassic unit in a covered section above the uppermost Thaynes layer. Trenching was done in this covered unit along the Blacktail Road, but nothing indicative of a Jurassic bed was uncovered. In his thesis area about 20 miles to the east, Lemish (1947, p. 19) mapped 244 feet of shale, limestone, and sandstone as undifferentiated Jurassic, but which, on the basis of lithology, may have been portions of the Ellis, Reirdon, and Morrison formations. Beard (1949, p. 25) found 200 feet of fine-grained, red siltstones and interbedded shales in Small Horn Canyon in the Blacktail Range. He believes that this may represent the non-marine Upper Jurassic Morrison formation.

Cretaceous system

Kootenai formation.- J. W. Dawson first published on the Kootenai formation (1885, pp. 531-532), describing it as a thick series of coal-bearing shales and sandstones in the Bow Valley region of southern Alberta. G. M. Dawson suggested naming the formation after the tribe of Kootenai Indians who hunted in that part of the Rocky Mountains. On fossil floral findings, G. M. Dawson classified the Kootenai as Lower Cretaceous. C. A. Fisher (1908, pp. 77-79) defined the Kootenai formation as consisting of two main units: a lower sandstone, red shale, and sandstone series; and an upper series of red shales alternating with thin limestone beds. G. W. Berry (1943, pp. 1-30) in his work in the Three Forks, Montana, region, found the Kootenai to consist of 1500 feet of mostly non-marine red and green shale and sandstone. He also found two limestone members, and some thin lignite seams in the upper portion of the formation. Berry believes that the lower part of the Kootenai may be the equivalent of the Morrison and Cloverly formations.

In the Clover Divide area, the Kootenai formation is estimated to be approximately 1000 feet thick. Much of the formation is covered, and the contact between the Kootenai and the overlying Aspen formation was not visible. At the base, the prominent and well known basal conglomerate was observed. It consisted of 40 to 50 feet of a coarse gray to tan "salt and pepper" sandstone with many chert pebbles. The bedding was massive, and the unit weathered into large, angular blocks. About half way up into the Kootenai formation, the so-called "gastropod limestone" marker bed was observed at several widely scattered points along the strike. It would appear to be a relatively thin bed, probably less than a foot in thickness. In most places, the bed could not be found, although float from the bed was common.

Aspen formation.- A. C. Veatch (1907, p. 56) applied the formation name of Aspen to exposures of gray and black shales near Aspen Station, Uinta County, Wyoming.

In the Clover Divide area, outcrops of Aspen beds are scattered. That the formation is very soft is evidenced by the fact that everywhere it forms stream and valley bottoms. At various exposures along Little Basin and Clover Creeks, outcrops of bentonite, "salt and pepper" sandstones, and clays were observed. No beds of the characteristic porcellanite of the Camp Davis area in Northwestern Wyoming were discovered, although they very probably are present. Dillon (1949, p. 62) found numerous, variously colored porcellanite beds in an area south of Sawmill Creek, to the south of Lima, Montana. Keenmon (personal communication) estimates the thickness of the Aspen formation to be over 3,000 feet in the Clover Divide area, and perhaps as much as 3,500 feet.

Tertiary system

Beaverhead conglomerate.- This name has been applied to a coarse, orogenic conglomerate by M. W. Klepper of the U. S. Geological Survey and W. R. Lowell of the University of Montana. They have a paper, soon to be published, in which the name Beaverhead conglomerate is used (personal communication to Keenmon). Students of the University of Michigan working in this area under Dr. A. J. Eardley have heretofore tentatively called the conglomerate the Red Rock conglomerate from prominent cliff exposures of this unit along Red Rock Creek to the north of U. S. Highway 91, near Lima, Montana.

The Beaverhead conglomerate crops out south of Clover Divide, in the extreme southern portion of the thesis area. In general, the formation is covered with grass and soil, the only rock outcrops are high in the formation along the southern boundary of the area, No great cliffs are present in the area, such as can be studied along Red Rock Creek. The Beaverhead conglomerate rests unconformably on the highest Cretaceous beds, and east of Dell, Montana, it is overlain unconformably by beds of Upper Eocene age, and probably by beds of Lower Oligocene and Middle Miocene age.

The lithology of the Beaverhead conglomerate is varied in character. Smith and Cummins (Smith, 1948, p. 33) studied the conglomerate along the east front of the Tendoy Range, and reported finding pebbles and cobbles of pre-Cambrian quartzite, as well as material that was likely Madison limestone. Lipp (1948, p. 30) discovered lenses of friable, tan, limey sandstone, which he postulated might have come from the Phosphoria formation.

The size and angularity of the cobbles and boulders in the Beaverhead conglomerate would indicate that the source must have not been very far away. Boulders have been found up to 2 feet in diameter (Dr. Eardley, personal communication), although the largest boulder observed by the writer was a little less than a foot in diameter.

The red color of the Beaverhead conglomerate is due to the red limonitic cement, which is quite calcareous. The red color is very striking from a distance, especially where the Beaverhead conglomerate forms prominent cliffs or peaks.

The age of the conglomerate has been tentatively considered by Dr. Eardley, and students working under him, as Paleocene. This age estimate is based upon structural relationships and stratigraphic position. No fossils have yet been uncovered in it.

The Beaverhead conglomerate thickness can only be estimated. Dr. Eardley believes that near Lima, Montana, the unit is about 2,000 feet thick. Klepper and Lowell (personal communication to Keenmon) believe that the conglomerate may be as thick as 9,000 feet in places.

Blacktail (Deer) Creek (?) formation.- C. W. Hibbard and K. A. Keenmon (unpublished paper) have proposed the name for beds of Lower Miocene age that are exposed 4½ miles northwest of the area, on the west side of the West Fork of Blacktail Creek. It is not known for certain that these are the same beds that are found in the northern portion of the thesis area, as no fossils have yet been found to date the beds in the area. It is assumed, however, that the beds, for which the name Blacktail (Deer) Creek formation has been proposed are the same found in the area.

E. Douglass worked the same section, in 1902, that Hibbard and Keenmon are proposing for a type locality (1902, pp. 227-279). At that time Douglass assigned an age of White River (Oligocene) to these beds on the basis of vertebrate fossil evidence. Subsequent field work has served to reclassify the formation from a White River age to a Lower Miocene age. Additional vertebrate forms found by Hibbard and Keenmon during the summer of 1948 were new species of a rodent and a titanothere.

Douglass named the formation from local usage, when he called the beds the Blacktail Deer Creek formation in 1902. However, the Dillon topographic quadrangle sheet, published by the U. S. Geological Survey in 1887, refers to the creek as Blacktail Creek. Hibbard and Keenmon believe that the name, Blacktail (Deer) Creek should continue to be applied to these Miocene beds, as Douglass has originally named them.

In the area, the Blacktail (Deer) Creek formation blankets the northwestern and northcentral portion. It overlies the Mississippian Madison formation unconformably, and it is postulated that this Lower Miocene formation also rests unconformably on Devonian, Cambrian, and pre-Cambrian formations (see cross-section, plate II). Over most of the northwestern portion of the area, the Blacktail (Deer) Creek formation is covered with gravels, and some soil and grass. In relatively few areas are outcrops visible. Prominent exceptions are the massive fresh water limestone cliffs forming the highest elevations on both sides of the West Fork of Blacktail Creek in the center of the area. A coarse basal conglomerate was also noticed along the contact of the formation with the Madison limestone. The conglomerate had a predominantly red color and contained very poorly sorted gravels, cobbles, and boulders. Some of the boulders that were observed along the Middle Fork of Blacktail Creek in the northeast corner of the area, were over a foot in diameter. The conglomerate was well cemented and appeared to be relatively resistant.

The fresh water limestone cliffs along the West Fork of Blacktail Creek are actually travertine. They probably represent a fairly local unit that was laid down in a fresh water lake in Miocene time. The easternmost cliff exposures were measured by Piper and the writer, and found to be over 180 feet in thickness. The limestone varied from white to tan, and was of a fairly coarse, glassy crystalline nature. The unit weathered into large, angular blocks. No fossils were found in this unit, but it rests conformably on beds that are continuous with the type Blacktail (Deer) Creek formation. Because of their conspicuous nature, the basal conglomerate and the travertine limestone were mapped as separate units.

Tertiary volcanics.- Only three small exposures of volcanic rock were observed in the area, all of them fairly close together along Little Basin Creek

Travertine cliffs to the west of
the West Fork of Blacktail Creek.
10 degree dip to the west.

T. Piper

Aerial view of massive travertine cliffs
between the West and Middle Forks of
Blacktail Creek.

in the south-central portion of the area. These can be dated only as post-Jurassic, as they are surrounded by the Kootenai formation of Cretaceous age. Keenmon (personal communication) found two of these exposures to be of basaltic nature, while the third was a rhyolite lava. These appeared to be discontinuous and were probably surface flows. No indication of a volcanic vent was observed. Because of their limited outcrop area, these exposures have been mapped and designated simply as Tertiary volcanics.

Depositional history

The history of deposition of the exposed sediments in the Clover Divide area begins in the Late Devonian. After deposition of thick Cambrian sediments in the subsiding Cordilleran trough, there was a retreat of the seas until the beginning of Devonian time. During Devonian this portion of southwestern Montana was on the edge of the Utah-Wyoming shelf and slightly more than 1000 feet of sediments were laid down. This is shown on a paleotectonic map for the Devonian by A. J. Eardley (1949, p. 659).

During Mississippian time there occurred a great subsidence throughout the whole of the northern Rocky Mountain region. Great thicknesses of Madison limestone were laid down. The Clover Divide area was evidentally on the edge of the shelf area again. To the west, thicknesses of greater than 3,000 feet were deposited. In the report area, an estimated 1800 feet of Madison was laid down, whereas a little over 20 miles to the east only about 940 feet accumulated.

After deposition of the Amsden formation in Late Mississippian-Early Pennsylvanian time, there was an elevation of the sediments above water, and deposition consequently ceased for a time (Eardley, 1949, p. 664).

Some of the lowermost Quadrant formation may have been deposited on land as terrestrial deposits, although the upper part was deposited in the sea. The area again appears to have been on the shelf during Upper Pennsylvanian time as evidenced by the thicknesses of Quadrant to the west and east of the area. A fairly thick sequence of Quadrant was laid down 20 to 25 miles to the west, while less than 1000 feet of sediments were deposited 23 miles to the east.

During Permian time, the seas expanded and spread over vast areas of the west (Eardley, 1949, p. 670). The Clover Divide area, as well as large areas in this part of Montana, was evidentally part of a shallow, partially land-locked basin. It is generally believed that stagnant water conditions are necessary for the deposition of phosphate beds.

The Mesozoic era in this section of Montana probably saw constantly shifting shorelines and fairly shallow shelf zone waters. Some of the deposits must have been laid down on the land, others at a considerable distance from the nearest shore. Eardley's Paleotectonic map of the Triassic (1949, p. 670) shows a land mass to the northwest of the area, and a trough to the south of this portion of Montana. In the Clover Divide area, the apparent absence of beds of Jurassic age would seem to indicate a temporary withdrawal of the seas at that period. Cretaceous sediments appear, in a large part, to be of terrestrial origin. Evidence of great volcanic activity at this time is present in the deposits of bentonite, and, in places not far from the area, of porcellanite beds.

Tertiary time saw deposition on the land and in fresh water lakes. Continued volcanic activity went on, although most of the lavas are now to be found outside of the area to the north, northwest, and west.

STRUCTURE

Introduction

A glance at the index map (p. 5) will indicate the complex nature of the orogenic history of the region. Various trends in the mountain ranges can be noted. The Centennial Range trends east-west. The Snowcrest, Ruby, and Gravelly Ranges trend southwest-northeast. A northwest-southeast trend is evident in the Lemhi, Beaverhead, and Tendoy Mountain Ranges.

The Laramide Revolution in southwestern Montana has been divided into three phases by Dr. Eardley and students of the University of Michigan working in the area. An early Laramide orogenic phase resulted in the folding of the Paleozoic and Mesozoic sediments with axes trending northeast-southwest in the Snowcrest, Ruby, and Gravelly Ranges. A mid-Laramide orogenic phase saw further compression in the same direction, and upfolding of the Beaverhead conglomerate along the Snowcrest Range. During a late orogenic phase, three thrust sheets, which strike north and northwest, cut elements of the previously formed northeast-southwest trending folds. These thrusts have been correlated with thrusts in a similar direction in southeast Idaho and northwest Wyoming. The lavas of the Snake River downwarp prevent a study of the actual linkup of these associated thrusts. In mid-Tertiary time, a number of high angle block faults developed in the general region, all of them having a north-south or northwest-southeast trend.

Laramide deformation

The early Laramide folding in the thesis area involved all of the pre-Beaverhead conglomerate formations. Dips on these formations were found to be as steep as 60 degrees, although the average dip was 35 to 40 degrees. The beds strike in a general northeast-southwest direction and probably represent the southeast flank of a large anticline. Beard (1949, p. 33) observed beds of Cambrian, Devonian, and Mississippian age in the Blacktail Mountains with a strike parallel to the formations in the area, and having a northwest dip of 15 to 20 degrees. In Beard's area, no beds younger than Mississippian were involved in the folding. He observed a later Laramide orogeny in beds of Quadrant, Amsden, and Madison formations, having a strike of N.40 W. Beard has correlated this folding with the same compressional forces that produced the northwest trending Tendoy and Beaverhead Mountains.

Keenmon (personal communication) observed evidence for what appears to be a small anticline along the Middle Fork of Blacktail Creek in the extreme eastern portion of the area. In beds of what are postulated to be the Devonian Three Forks formation, he observed fairly steep dips, up to 24 degrees, in both a northwest direction and a southeast direction. The axis of this anticline, or perhaps, small flexure, lies parallel to the general trend of the Snowcrest Range, and probably plunges to the southwest.

Evidence for a mid-Laramide orogeny is found in the southern portion of the area, where the Beaverhead conglomerate of tentative Paleocene age laps up on the Mesozoic formations in the Snowcrest Range. Dips up to 24 degrees were observed in the Beaverhead conglomerate.

Later compressional forces that post-date the folding of the Beaverhead conglomerate up along the Snowcrest Range are evident. The Beaverhead conglomerate is itself folded along an approximate north-northwest axis (Keenmon, personal communication). This structure, to the south of the thesis area, has been tentatively called the Clover Creek anticline.

There may be a northwest trending fold in the beds of the Blacktail (Deer) Creek formation. Gentle dips of 8 to 10 degrees to the southwest and east were observed on the travertine limestone beds. The significance of these dips, and any possible relation to the Clover Creek anticline to the south is not clear at the present time.

No large high angle faults, such as the one found along the northwest face of the Blacktail Range, are in the area. Several small high angle faults in the southern portion of the area were mapped. The trend of these small faults is generally north-south and northwest-southeast, which is parallel to the trend of the larger faults in this part of southwest Montana.

PHYSIOGRAPHY

<u>General location</u>.- Fenneman (1931, pp. 183-224) includes this portion of southwest Montana in his Northern Rocky Mountain Province. However, the presence of long parallel ranges separated by arid basins, particularly in areas to the west and southwest of the writer's area, are believed by some workers to be more typical of the Basin and Range Province (Kupsch, 1948, p. 70).

<u>Erosion surface</u>.- Only one erosion surface, of great prominence, is recognized in the area. It is found mainly in the northwest portion of the area. Remnants of this surface can also be observed in the north central part of the area between the Middle and West Forks of Blacktail Creek. The surface elevation varies from about 8,200 to 8,500 feet, and is formed on the Miocene Blacktail (Deer) Creek formation.

Beard (1949, p. 37) found three surfaces in the Blacktail Range at elevations of 8,500 to 9,000 feet, 7,000 to 7,500 feet, and at 6,000 feet. Beard's highest surface is probably similar to the surface found in the area.

Beautiful pediment surfaces are to be observed north of the area in the region of the junction of the three forks of Blacktail Creek. These pediment surfaces may correlate with Beard's middle surface, and are being studied by Keenmon, as that section is included in his Ph. D. thesis area.

Streams.- The Middle and West Forks of Blacktail Creek present beautiful examples of superimposed streams. Especially along the West Fork of Blacktail Creek can this be observed. Here the stream cuts across the entire exposed Paleozoic and Mesozoic sequences at right angles to strike. Small subsequent streams join the Blacktail Creek at right angles, having been developed in softer rock units parallel to strike. Clover Creek and Little Basin Creek are more prominent subsequent streams developed in the weak Aspen formation.

The West Fork of Blacktail Creek is in an early mature stage of development, where it is developed in the soft Miocene formation in the northern portion of the area. Here it has formed a small floodplain several times the width of the meander belt. The sides of the valley form a fairly gentle V. However, farther south in the harder Paleozoic and Mesozoic rocks, the stream is still in a late youthful stage of development. No floodplain has been developed, and the meander belt impinges against the sides of the valley. The valley walls are steep, forming fairly sharp V's.

SUMMARY OF EVENTS

Cretaceous and Tertiary history of southwestern Montana

The following outline is the result of several special meetings of Dr. A. J. Eardley and graduate students of the University of Michigan who have been working on geologic problems in southwestern Montana.

1. Uplift (probably orogenic) of Cordilleran geanticline and deposition of Kootenai clastics; conglomerate generally at base.
2. Uplift (probably orogenic and lasting through most of Upper Cretaceous) of Cordilleran geanticline and deposition of Colorado group clastics.
3. Early Laramide orogeny to form northeast trending folds. Snowcrest Range is prominent element.
4. Deposition of Beaverhead conglomerate. Position of highland possibly to southwest in Idaho, but relation to northeast trending folds not yet clear. The distribution and lithologic variations of the conglomerate must be better understood before the location and character of the highland can be discerned.
5. Mid-Laramide orogeny; second episode of northeast folding resulting in upturning of Beaverhead

conglomerate along the Snowcrest Range and folding of the conglomerate in other places.

6. Late Laramide orogeny; formation of three thrust sheets athwart the northeast trending folds. Thrusts strike northerly and northwesterly and contain elements of the northeasterly folds. All override the Beaverhead conglomerate. Thrust from east to west are Tendoy (north of Sheep Creek Canyon), Medicine Lodge (from Medicine Lodge Pass, Idaho-Montana line to Armstead and beyond), and Beaverhead (pre-Cambrian, pink, granite gneiss sheet and klippen in Medicine Lodge Valley west of Armstead).

7. Long episode of erosion and possibly some additional crustal movements during lower middle and early late Eocene time, which resulted in great, broad, intermontane valleys.

8. Volcanism broke out in nearby regions, focussing in Yellowstone Park and Absaroka Range. Started in late Eocene. Volcanism of superior magnitude also in the Coast Range region of Oregon and Washington at this time. Resulted in damming of drainage ways and abundant ash and dust falls. Alluviation of great intermontane valleys of Southwestern Montana was heavy. Deposition of Sage Creek formation (late Eocene) in Southwestern Montana, and other formations of equivalent age elsewhere over a wide region.

9. Local gentle deformation and erosion in early Oligocene.

10. Continued volcanism nearby and deposition of Cook Ranch beds in middle Oligocene time, on Sage Creek beds. Contact obscure and extent of erosion not known.

11. Early episode of block-faulting. Volcanism broke out at north end of Blacktail Range and extensively in Snake River Valley and Yellowstone Park and Columbia Plateau. Deposition of lower Miocene Blacktail (Deer) Creek beds and associated basalts, tuffs, and agglomerates in Upper Sage Creek, along northwest flank of Snowcrest Range and in Ruby Basin. Called Passamau by Dorr and Wheeler.

12. Erosion to extensive surface of moderate relief. In places the pre-Sage Creek surface may have been reexhumed and become coextensive with this post-Blacktail surface. Present now in summit areas of Blacktail Range where lower Miocene basalts and tuffaceous beds are gently beveled.

13. Second episode of block-faulting.

14. Deposition of upper Miocene and lower Pliocene Madison Valley beds in Ruby Basin.

15. Regional uplift, in places possibly more block faulting, and erosion of extensive pediments. Those on the northwest side of Snowcrest Range most extensively and perfectly developed. Pediments on basin beds of back valleys in Beaverhead Range (graben valleys) are of this age. In valleys like Beaverhead

River, Blacktail Creek and Sweetwater, downfaulting was so extensive that alluvial aprons were deposited along the base of the fault scarps.

16. Third episode of block faulting and alluviation in places. Gentle uplift in places and dissection of pediments. Two episodes of glaciation in Beaverheads, probably one before dissection, and one after.

17. Continuation of block faulting at front of Tendoy Range, in modern times.

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Thesis of

Stratton Bull

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Thesis accepted by :

A. J. Eardley June 9, 1949

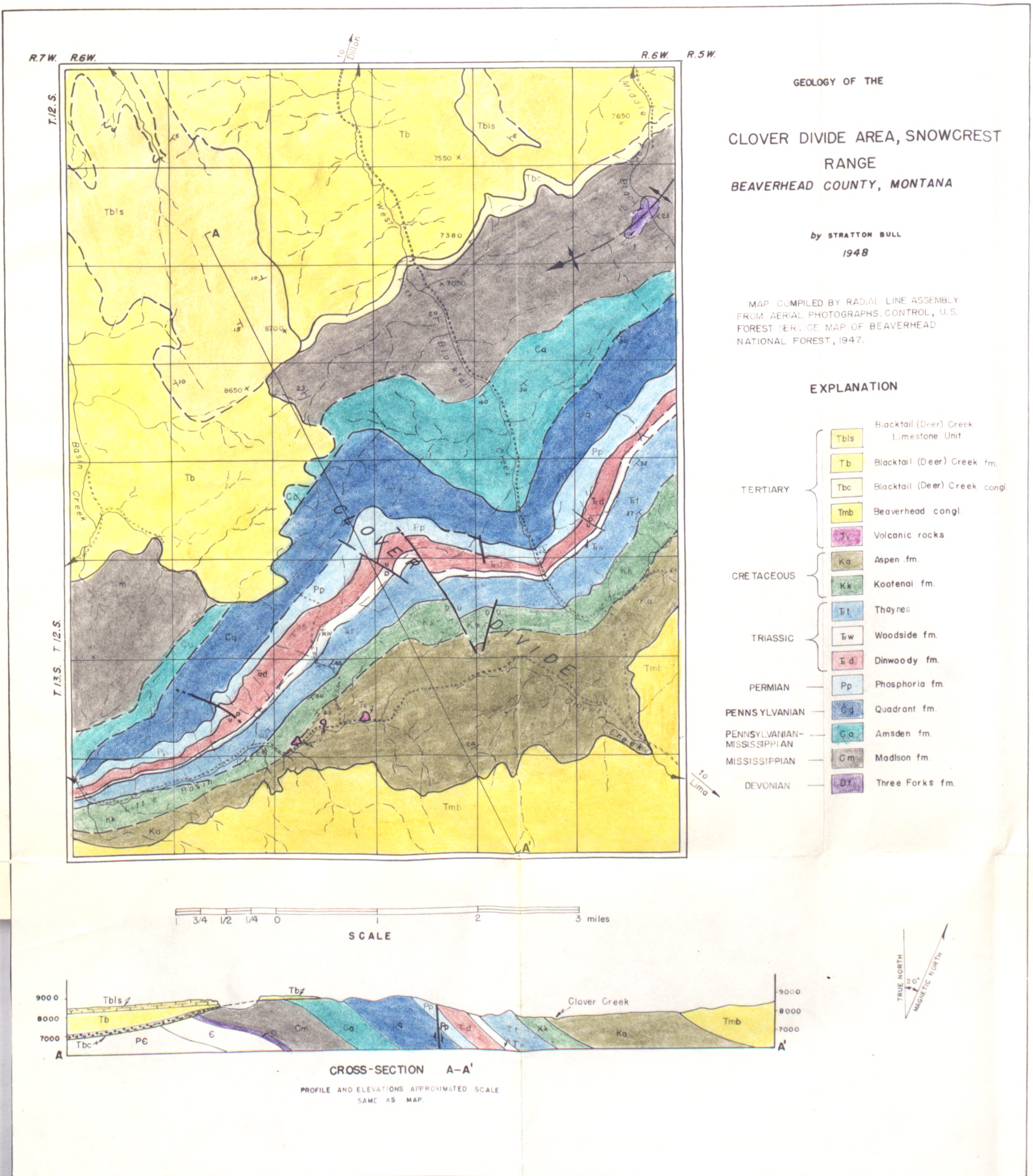
Signature Date

Eugene H. Walker June 11th, 1949

Signature Date

Signature Date

PLATE II


GEOLOGY OF THE
CLOVER DIVIDE AREA, SNOWCREST RANGE
BEAVERHEAD COUNTY, MONTANA
by STRATTON BULL
1948
MAP COMPILED BY RADIAL LINE ASSEMBLY FROM AERIAL PHOTOGRAPHS. CONTROL, U.S. FOREST SERVICE MAP OF BEAVERHEAD NATIONAL FOREST, 1947.
EXPLANATION
TERTIARY
Tbls Blacktail (Deer) Creek Limestone Unit
Tb Blacktail (Deer) Creek fm.
Tbc Blacktail (Deer) Creek congl.
Tmb Beaverhead congl.
Tv Volcanic rocks
CRETACEOUS
Ka Aspen fm.
Kk Kootenai fm.
TRIASSIC
Tt Thaynes
Tw Woodside fm.
Td Dinwoody fm.
PERMIAN
Pp Phosphoria fm.
PENNSYLVANIAN
Cq Quadrant fm.
PENNSYLVANIAN-MISSISSIPPIAN
Ca Amsden fm.
MISSISSIPPIAN
Cm Madison fm.
DEVONIAN
Df Three Forks fm.
R.7W. R.6W.
R.6W. R.5W.
T.12 S.
T.13 S. T.12 S.
to Dillon
to Lima
CLOVER DIVIDE
West Blacktail Creek
Middle
Basin Creek
Little Basin
Clover Creek
7650
7550
7380
7050
8700
8650
A
A'
1 3/4 1/2 1/4 0 1 2 3 miles
SCALE
TRUE NORTH
MAGNETIC NORTH
20°
9000
8000
7000
CROSS-SECTION A-A'
PROFILE AND ELEVATIONS APPROXIMATED. SCALE SAME AS MAP.
Clover Creek

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TO RENEW PHONE 764-1494

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The geology of the Clover Divide Area...
1949

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