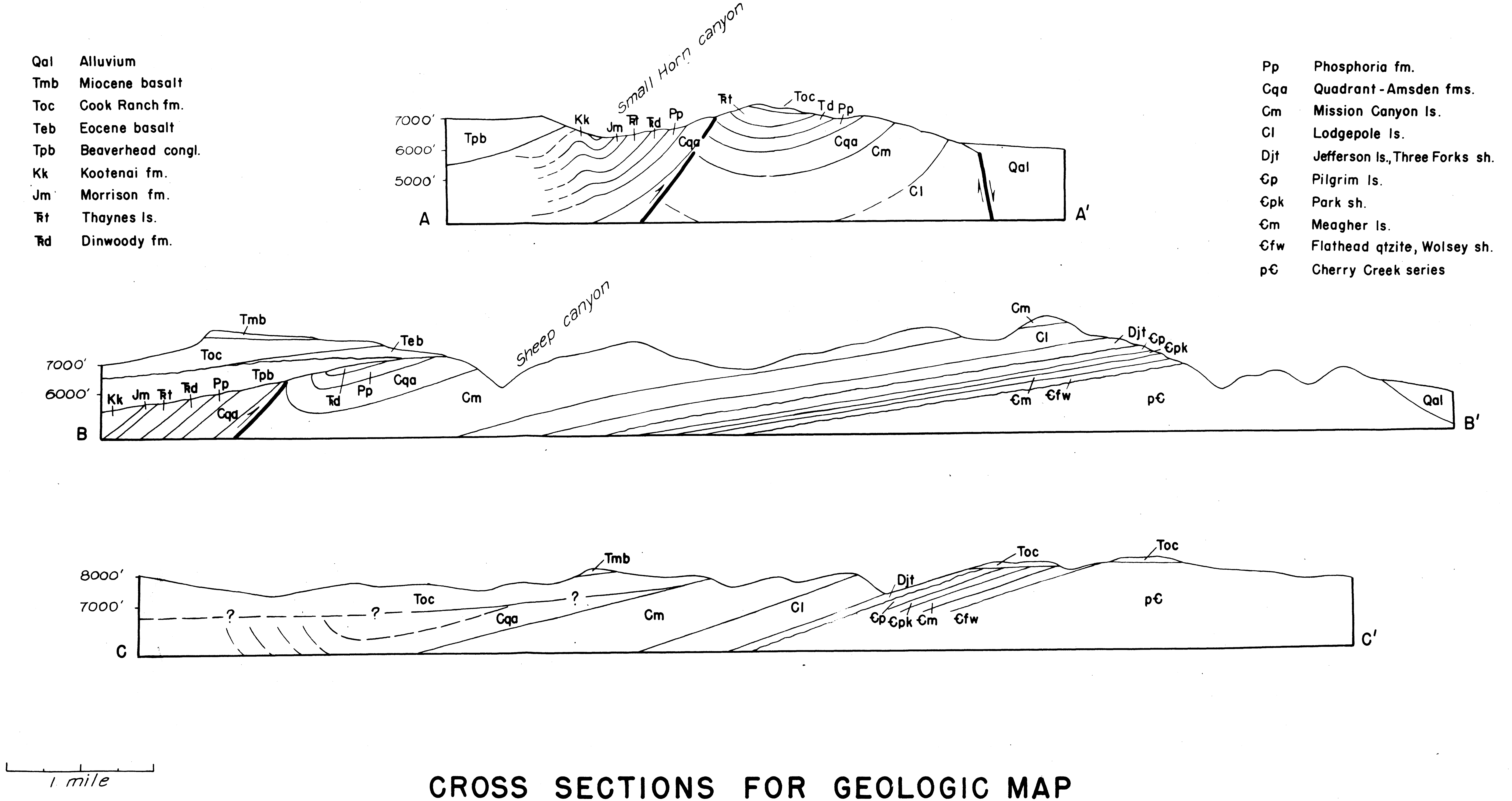
I have read and approve the acceptance of the thesis submitted by Thomas Beard in fulfillment of the requirements for the M. A. in Geology.

May 26th, 1949

Eugene H. Walker

I recommend that this thesis be accepted. Tom deserves to be complimented for hard work and persistance in bringing this report to its present form.

A. J. Eardley



CROSS SECTIONS FOR GEOLOGIC MAP

GEOLOGY OF PART OF THE BLACKTAIL RANGE, BEAVERHEAD COUNTY, MONTANA

By

Thomas Beard

Submitted in partial fulfillment
of the requirements for the
degree of Master of Science
in Geology, University of
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Fig. 1. Index map.

ABSTRACT

This report describes the geology of part of the Blacktail Range, 18 miles southwest of Dillon, Beaverhead County, Montana. The strata exposed within the area range in age from pre-Cambrian to Quaternary. The Paleozoic section consists of more than 4600 feet of strata and the Mesozoic section over 2300 feet. The thickness of the Tertiary Beaverhead conglomerate, basalt flows, and tuffs and breccias, and the Quaternary alluvium is unknown. The most extensive formation in the region is the Madison limestone. The most resistant formation is the Quadrant sandstone which caps Blue Mountain, the highest peak in the Blacktail Range.

The Laramide folding of two phases is recognized, and the folds thus produced are transected by a mid-Tertiary high angle fault which blocked out the Blacktail Range. The fault is the major structure of the region.

INTRODUCTION

Location of the Area

The Blacktail Mountains are located in Beaverhead County, Southwestern Montana. They compose a rectangular relief feature, the long axis of which extends northwest and southeast. The region investigated composes approximately 175 square miles. For boundaries of the area mapped, see Index Map, figure 1.

The area was divided into two units for the purpose of mapping. The region east and southeast of Ashbough Canyon was mapped by John O'Conner and Wallace Howe, with the assistance of Louis Heyman and Jack Mills. The region northwest of and including Ashbough Canyon was mapped by the author and Lawrence Mannion, with the assistance of Louis Heyman.

Access to the Area

The area is accessible by automobile from the north by Blacktail Creek Road that parallels Blacktail Creek. The road joins U. S. Highway 91 at the outskirts of Dillon, Montana. U. S. Highway 91

Fig. 2. Angular unconformity between Flathead formation and pre-Cambrian metamorphics. West wall of Ashbough Canyon, Beaverhead County.

runs through Dillon and is the main arterial in the region. It connects Idaho Falls, Idaho with Butte, Montana. A number of rut roads, some of which are referred to as county roads, are found within the Blacktail region, but most of these are unusable for they have had little or no use within recent years. Two of these small roads in the northwest connect Blacktail Creek Road with Small Horn Canyon and Sheep Canyon. The Sheep Canyon road penetrates into the area only about a mile, and the Small Horn Canyon Road is said by local residents to be usable through to Lima, a distance of 55 miles.

The interior has a few, mostly unused, rut roads, but it is well intra-connected with foot trails. From the south, the area is accessible by automobile only as far as Divide Creek. To reach Divide Creek from the north requires a trip of well over 60 miles. One must follow Sage Creek Road, leaving U. S. Highway 91 one mile north of Dell, Montana, for approximately five miles and then travel along lesser roads to Divide Creek.

Dillon is reached by the Union Pacific Railroad on the Oregon Short Line, which connects Idaho Falls and Butte. Bus transportation is also available on U. S. Highway 91.

Available maps for the area are:

(1) Forest Service Map of the U. S. Department of Agriculture. Map of Beaverhead National Forest, 1940. Scale: 1/2 or 1/4 inch to the mile.

(2) Dillon Topographical Quadrangle, edition of 1893, reprinted 1901. Useful for upper third of thesis area only. This map is out of print.

(3) Map of the Montana Highway System, Montana State Highway Commission; edition of 1936, revised 1943 and 1945. Scale: 1 inch to 22 miles.

Previous and Present Work

Very little geological field work other than that relating to economic geology has been done in the Blacktail Mountains. A topographical survey was made in 1887-1888 by H. Gannet, of the U. S. Geographical and Geological Survey. A similar survey is in progress at the present time, but the work is not complete. A..N. Winchell, 1914, described the economic geology of the Dillon Quadrangle. Billingsley, 1915, mentioned the Blacktail Mountains in describing the Boulder Batholiths of Montana. H. Sinkler, 1942, described deposits of nickel ore a short distance to the east of the area. The U. S. Geological Survey from time to time has made studies of an economic character and is at present working on phosphate in the region. W. R. Lowell is making a study of the area, especially that to the west. Work on this and adjacent regions will be found in the bibliography.

Field work in the Blacktail Mountains was done between July 25, 1948, and August 16, 1948. Mapping of the geology was done directly on aerial photographs with a scale of about 2-1/2 inches to the mile or 1:20,000. As mentioned previously, the area was subdivided into two units for purposes of mapping by individual parties. Also, the area overlapped into the area of K. A. Keenmon, doctoral candidate at the University of Michigan. The northern limit of his area is the 45th parallel. This report is prepared as a master's thesis at the University of Michigan, Ann Arbor.

Geography of the Area

Topography On the north, a high escarpment rises sharply from Blacktail Creek valley floor with a maximum relief of 3300 feet. The Blacktail Mountains are moderately rugged and extend longitudinally northwest and southeast. South of these is a plateau-like surface of generally low relief which extends along a dip slope toward Divide and Sage Creeks. Since this region is east of the Continental Divide, all drainage passes ultimately into the Missouri River. Locally, north of the Blacktail Mountains, creeks empty into Blacktail Creek and thence into Beaverhead River. South of the

Blacktail Mountains, drainage is to Sage Creek which empties into Beaverhead River.

Climate. Climate data for Dillon (elevation 5106 feet) and vicinity as obtained from page 955 of the Yearbook of Agriculture, Climate and Man, 1941, published by the U. S. Department of Agriculture is as follows:

January average temperature: . . 24.4° F.
July average temperature:. . . . 65.1° F.
Maximum temperature: . . . . . . 98.0° F.
Minimum temperature: . . . . . .-40.0° F.

Length of record for the above data is 39 years. Length of growing season is 118 days. Average annual precipitation is 16.67 inches. Killing frost average dates:

Last in spring: . . . May 22
First in fall:. . . . September 12

Flora and fauna. Timber in the area is predominately coniferous with which is mingled a few varieties of deciduous trees. A high quality grazing grass is found especially along the back slope of the Blacktail Range. Sage brush grows profusely in parts of the lower valleys.

Wild animals, with the exception of rabbits, apparently inhabit the area rather sparsely. Prairie dogs, ground squirrels, gophers, a few elk, prairie chickens, pheasants, grouse, and sage hens were seen. At the time of mapping an extensive effort was being made to eliminate coyotes.

Culture. The higher regions along the back slope of the Blacktail Mountains are frequented by sheepherders and cattle riders during the summer months. In the lower regions, there are a few large ranches and several smaller ones. Dillon, the county seat of Beaverhead County, with a population of about 5000, is situated about 18 miles to the northwest.

Acknowledgments

Field work for this report was done in late July and August, 1948, under the direction of Dr. A. J. Eardley, Professor of Geology at the University of Michigan. Valuable field assistance was rendered by Mr. K. A. Keenmon, graduate student of the University of Michigan. He also offered many suggestions and data included in the report. Acknowledgment is due Mr. C. A. Moritz of the Phillips Oil Company who measured a section in the area. Mr. L. Heyman, graduate student of the University of Michigan, assistant to the author and Mr. Mannion, was also very helpful in the field.

The author is indebted to Dr. E. C. Stumm, University of Michigan, who identified fossils and to Dr. E. W. Heinrich of the Department of Mineralogy who supplied information on the pre-Cambrian of the area.

STRATIGRAPHY

Introduction

Approximately nine miles northeast of the Blacktail Mountains, in the southern limits of the Ruby Range, Heinrich (personal communication) examined in detail the pre-Cambrian rocks that crop out there. He identifies them as the Pony and Cherry Creek series and assigned them tentatively Archeozoic and Proterozoic ages, respectively. The older series consists of banded gneisses of uncertain thickness. The overlying series consist of marbles, schists and quartzites about 5 miles thick. Following the deposition of the Cherry Creek series, an intrusion of the Blacktail Granite gneiss occurred which cut both series of the metamorphics. Pegmatite dikes then transected the units. In post-dike time, regional metamorphism took place throughout both series. In post-metamorphism time there were intrusions of small granitic and pegmatitic bodies, unmetamorphosed, and possibly Laramide in age. A reconnaissance was also made by Heinrich in the vicinity of Jake's Canyon on the eastern boundary of the thesis area. Here only the scattered remnants of Pony?

series with the granitic and pegmatitic intrusions were found. During late pre-Cambrian, there was uplift and deformation followed by profound erosion. This was followed by an invasion of Middle Cambrian seas depositing sediments to produce a great angular unconformity with the pre-Cambrian.

The Middle Cambrian was followed by uplift and extensive erosion producing a major disconformity between Middle Cambrian and Devonian. With the exception of a few more or less minor disconformities, deposition of sediments was apparently continuous throughout the remainder of the Paleozoic.

Deposition of sediments during the Mesozoic is conformable with the exception of Triassic Woodside formation which is not found in the area. The presence of the Morrison formation is problematic. At the close of the Mesozoic, the Laramide orogeny occurred, and this was followed by erosion and deposition of a conglomerate probably of Paleocene age.

In the Tertiary, at least two distinct periods of vulcanism can be established. The older is probably Eocene and the other probably Miocene. Intermittently, there was deposition of continental deposits in intermontane basins.

In recent times, landslides, terrace gravels and alluvium make up the main depositional features.

Pre-Cambrian Sequence

The rocks of pre-Cambrian age extend east and northeastward from Ashbough Canyon. Since the author and Mr. Mannion worked Ashbough Canyon and westward only, the pre-Cambrian sequence will not be discussed in this paper other than what has been mentioned in the introductory paragraphs.

Cambrian System

Flathead quartzite. The Flathead quartzite was first described by A. C. Peale (1893, pp. 20-21) for exposures in Flathead Pass in the northeast corner of the Three Forks Quadrangle, Montana. Peale recognized the formation to be of Lower Cambrian age, but it is now generally considered to be Middle Cambrian. A profound angular unconformity separates the pre-Cambrian Cherry Creek series and the Flathead. (See fig. 2.)

A considerable lateral variation in thickness and lithology occurs in the surrounding region. Peale measured between 1500 and 1600 feet in the Three Forks area to the east. Kupsch and Scholten (Kupsch, 1948, p. 13) measured 900 feet of Flathead in the vicinity of Trail Creek in the Beaverhead Mountains, to the southwest; and Brant, Elmer, Gillespie and Peterson (Brant, 1949, p. 5) found a thickness between 0 and 150 feet in the region of

Armstead to the west. In the local area of this report it is about 130 feet thick.

In the area investigated good exposures of the Flathead can be found in Ashbough Canyon along the west wall. The contact is exposed for only a short distance. Talus from the Meagher and other overlying formations cover most of the area. At the base of the formation is a thin-bedded conglomerate stained reddish to brownish and made up of pre-Cambrian gravel and regolith. The cement is an iron-stained shale. The conglomerate increases in coarseness upward. The size of the matrix varies from 1 inch to 3-1/2 inches in diameter. The thickness of the conglomerate is four feet. It is purplish-brown to maroon in color. Grains are well sorted, some frosted with many layers evenly cross-bedded. The rock, although massive, is banded apparently by differences in cementation. The cement is silica. Approximately 8 feet above the first quartzite bed is 5 feet of conglomerate similar to that previously described. The total thickness of the Flathead, as measured here by the writer, Moritz, Keenmon and Mannion, is 131 feet. The Flathead is a distinct cliff-former, and, as noted in Ashbough Canyon, it is highly fractured in places. No fossils were found in this formation.

Flathead section in Ashbough Canyon, S.W. 1/4 sec. 27, T.9S., R.8W., Beaverhead County, measured by Moritz, Keenmon, Mannion, Beard, August, 1948.

5.	Covered Flathead (?)	100.0'
4.	Quartzite.	14.0'
3.	Conglomerate	5.0'
2.	Quartzite.	8.0'
1.	Conglomerate (base of Flathead). . . .	4.0'
Total:	. . . .	131.0'

Wolsey shale. The Wolsey shale was named by W. H. Weed (1900, p. 285) for exposures near Wolsey, Montana. He originally included this formation and the Flathead into the term "Flathead Formation", but later usage has segregated the beds into two separate formations. The Wolsey is well exposed in the west wall of Ashbough Canyon overlying the Flathead. It is a green to grayish-green shale, probably glauconitic. An appearance of coarseness is given to glauconitic pellets or nodules. It is sandier near its base but becomes dolomitic as it grades into the overlying Meagher. The Wolsey, although nearly everywhere covered in its upper part, has a thickness of 147 feet.

Meagher limestone. The Meagher limestone was originally described by Peale (1893) as part of the Gallatin formation and was called the Trilobite limestone. Weed (1899), in mapping the Fort Benton Quadrangle, assigned the Cambrian rocks to the

Barker formation and renamed the Trilobite limestone the Meagher on the basis of fossil and stratigraphic evidence.

The Meagher is well exposed in the west wall of Ashbough Canyon overlying the Wolsey. In this region, it is predominatly a dolomite. It is salmon-tan to brown in color and sparsely, if at all, fossiliferous. Its weathered surface is pitted and yellow in color. It is a cliff-former but yields talus in considerable amounts. At the base, the Meagher is thin-bedded and shaly and becomes massive upward. This in turn gives way, near the top, to thin bedding and shaliness where a few glauconitic pellets were noted. Some solution cavities with linings of small but well-formed calcite crystals are found in the formation. The thickness is 542 feet.

Meagher section in Ashbough Canyon, S.W. 1/4 sec. 27, T.9S., R.8W., Beaverhead County, measured by Moritz, Keenmon, Mannion, Beard, August, 1948.

6. Dolomite and shale.	32.0'
5. Shale	10.0'
4. Platy dolomite.	49.0'
3. Dolomite, massive	150.0'
2. Dolomite.	133.0'
1. Dolomite, thin-bedded	168.0'
Total	542.0'

Park shale. Approximately 375 miles to the northeast, in the Little Belt Mountains, Weed (1899) described the Park formation as a very thin-bedded, soft, crumbly rock, which in most places contains glistening grains of mica. The color is greenish-gray, but also shows various shades of red and purple. He included the Park, together with the Meagher and Pilgrim, in the Barker formation. Although the derivation of the name is not stated, the Barker formation is mapped over a large part of Belt Park in the northwest corner of Little Belt Mountains Quadrangle and the southwest corner of Fort Benton Quadrangle, as well as on the east and west sides of Big Park in the Fort Benton Quadrangle. Weed estimated the thickness of the Park at 800 feet and determined the age as Middle Cambrian.

A good exposure of the Park shale is in the west wall of Ashbough Canyon. Here, it is a very thin-bedded, fine, dark green shale, paper-like in places. It is slightly calcareous. The Park contains indistinct markings, possibly graptolites. It contains some limonite (?) in the form of thin, circular plates up to 1-1/2 inches in diameter. The shale becomes progressively more calcareous as it grades upward into the Pilgrim formation. Thickness, as measured in Ashbough Canyon, is 121 feet.

Pilgrim limestone. Weed (1899) described the Pilgrim in the Little Belt Mountains as a dense gray, massively bedded limestone with shaly layers which are in places spotted with green glauconite. Conglomerates of flat pebbles of green or buff limestones are found in several layers. The Pilgrim limestone in the Fort Benton Quadrangle averages about 140 feet thick. The limestone is named for fine exposures in the valley of Pilgrim Creek in the southwest corner of Fort Benton Quadrangle. According to N. G. Wilmarth (1938, p. 1659), the age of the Pilgrim is Upper Cambrian.

The Pilgrim is well exposed in Ashbough Canyon where 75 to 90 feet of light gray to white, fine-grained limestone crops out. At the base it is somewhat shaly and mostly thin-bedded. Upward it becomes massive and blocky with regular jointing. Calcite seams are found along the joint planes. Weathering gives the surface a chalky appearance. It forms strong cliffs and a rather coarse talus. No fossils were found.

Devonian System

Jefferson limestone. The Jefferson limestone was first described by Peale (1893, pp. 27-29), as Middle Devonian and was named after the Jefferson

River where a good exposure of the formation extends along both banks for a few miles above its mouth. Later work by L. L. Sloss and W. M. Laird (1947, pp. 1404-1431) indicates that the Jefferson is Upper Devonian.

Good exposures of the formation are approximately a quarter of a mile west of Ashbough Canyon where it rests disconformably upon the Middle Cambrian. Here, two members are found; the lower is a medium gray and brown, dense limestone that weathers to a yellow brown, and the upper is a dolomite that is black and massive at its base and that grades upward into medium to light gray. The dolomite weathers brownish and it contains calcite veins. Striking it yields a distinct petroliferous odor. A brecciated zone is found at the top.

Three Forks formation. Peale (1893, pp. 29-32) first described the Three Forks formation and named it where it is well exposed at the junction of the three forks of the Missouri River. Sloss and Laird (1947, pp. 1404-1431) recently placed the Three Forks in Upper Devonian.

In the section measured by Moritz in the Blacktail Mountains, 1947, 141 feet of Three Forks shale was measured. Much of this, however, was covered. The float contains pieces of red, orange, yellow, white and dark gray limestones and dolomites. The thickness

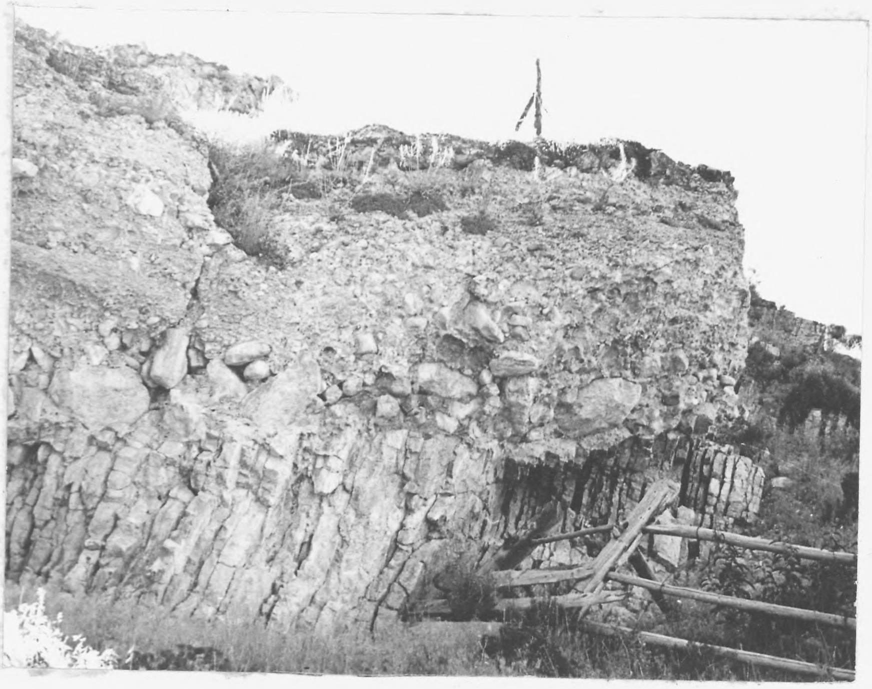

Fig. 3. Part of northwest trending upturned beds of Lodgepole limestone, overlain by recent consolidated fan gravels. Photograph taken near mouth of Sheep Canyon, Blacktail Mountains.

is maximum and probably includes some of the Jefferson formation. The following fossils from Three Forks have been identified by Dr. Stumm:

Brachiopoda:

Cleiothyridina devonica (Raymond)
Cyrtospirifer whitneyi (Hall)
Leptaena "rhomboidalis" (Wilckens)
Chonetes sp.

Anthozoa:

Aulopora sp.
Solitary horn corals

Gastropoda:

Platyceras sp.

Bryozoa:

Fenestella sp.

Crinoidea:

Crinoid stems

Mississippian System

Lodgepole limestone. A. J. Collier and S. H. Cathcart (1922, p. 173), named the formation for an exposure in Lodgepole Canyon in the Little Rocky Mountain Region of Montana. They found that the Madison limestone was divisible here into two separate formations, the lower Lodgepole and the overlying Mission Canyon. The thickness is 800 feet.

In the Blacktail Mountains the Lodgepole is exposed over wide areas. However, none of these

Fig. 4. Northeast trending folds in incompetent "wavy" member of Mission Canyon limestone, near head of Sheep Canyon, Blacktail Mountains.

exposures were sufficiently good to obtain a measurement of the thickness. The weathered surface appears buff to grayish-brown with fresh surface appearing dark grayish-brown to gray. It is a fine-grained, crystalline limestone, thinly laminated and very fossiliferous. Beds range in thickness from two to ten inches. Some beds are separated by clay partings. The estimated thickness is 600 feet.

Mission Canyon limestone. In the Little Rocky Mountain Region of Montana, Collier and Cathcart named and measured 500 feet of Madison limestone exposed in Mission Canyon. The area investigated in the Blacktail Mountains shows a thicker series which was estimated to be approximately 1400 feet. Since the upper and lower contacts were not observed by the writer, the estimate is maximum. No more than 400 feet of the Mission Canyon was observed in sequence. Kupsch and Scholten (Kupsch, 1947), in Nicholia Creek Basin, measured 980 feet, but they estimated that at least 3000 feet of Mississippian beds occur there. Brant (et al, 1949) observe some 1700 feet of Mission Canyon in the Armstead Anticline.

The Mission Canyon formation in the Blacktail Range may be divided into two members, a lower massive member (see figs. 5, 6) and an upper "wavy" member. Bedding, with thicknesses between 1 and 4 feet, and sharp crenulations is characteristic of the upper

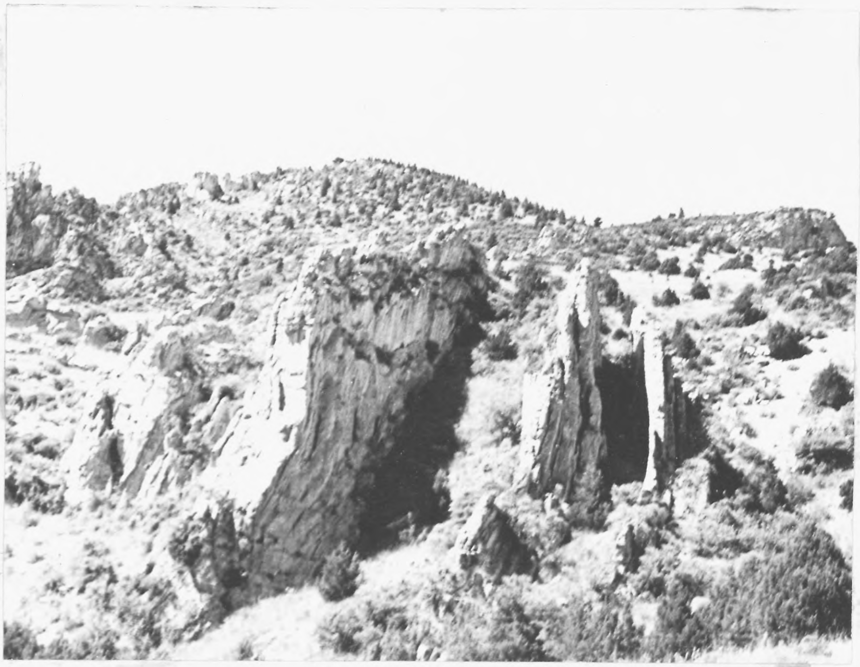

Fig. 5. Northwest trending beds of Mission Canyon limestone, west wall of Sheep Canyon, Blacktail Mountains.

Fig. 6. Upturned beds of Madison formation on east wall of Sheep Canyon, showing contact between Mission Canyon limestone and Lodgepole limestone. Photograph taken near mouth of canyon.

member. Some beds were distinctly fossiliferous, but others contained few to no fossils. This member also has been described by Brant (et al, 1949) in the area of Armstead, where a thickness of 450 feet was measured. This is comparable to the estimate of that found near the head of a small eastern tributary to Sheep Canyon Creek in the northwestern part of the Blacktail Mountains (see fig. 4).

The Mission Canyon weathers light gray with yellowish to brownish blotches and orange and black lichens. The fresh surface is darker and varies in its crystalline texture. It is somewhat pocked and contains nodules of brown chert. Freshly broken rocks yield a fetid odor.

Pennsylvanian System

Amsden formation. N. H. Darton (1904, pp. 394-401) named the formation for the Amsden Branch of Tongue River, west of Dayton, Wyoming. Berry (1943, pp. 1-30) indicates that the lower part of the Quadrant in the area of Three Forks, Montana, corresponds to the Amsden investigated by Darton. For the most part, the Amsden represents a covered interval in the Blacktail Mountains, conspicuous only by red stain in the overlying soil. However, a section was obtained from a gulch on the west side of Sheep Canyon. The beds here are nearly vertical, but because of vivid red staining, tight folding and crushing of the beds, and erosion in the gulch, bedding contacts are fairly well obliterated. The formation consists of limestone conglomerate, shaly limestones, limestones interbedded with shales varying in color from yellow to deep purplish red, and sandy limestones. It is estimated to be 83 feet thick. Fossils collected suggest that the Amsden formation is transitional from Mississippian into Lower Pennsylvanian. Those identified by Dr. Stumm are:

Spirifer sp.
Dictyoclostus sp.
Rhipidomella sp. (abundant)

Amsden section, measured in sec. 24, T.9S., R.9W. by Mannion, August 4, 1948.

7.	Interbedded limestones and sandy limestones	?
6.	Yellowish, fossiliferous, limy shale	1.0'
5.	Light gray limestone, weathering yellowish-brown, underlain by a purplish-red limestone	42.0'
4.	Greenish limestone conglomerate	5.0'
3.	Purplish-red limestone	25.0'
2.	Coarsely crystalline, greenish limestone, weathering sandy	10.0'
1.	Coarse conglomerate	?
Total	. . . .	83.0'

Fig. 7. Contact of Amsden formation with Madison limestones, showing upturned beds related to northwest trending regional folding. Photograph taken in gulch, west wall of Sheep Canyon, Blacktail Mountains.

Quadrant sandstone. Weed (1896) named the Quadrant formation for exposures, averaging 400 feet in thickness, in Quadrant Mountain in Gallatin Range, northwest corner of Yellowstone Park, Wyoming. H. W. Scott (1935, pp. 1011-1032) states that the Quadrant is the westward extension of the Tensleep sandstone and that stratigraphic and paleontologic evidence indicates that it is basal Pennsylvanian in age. He further states that the lower zone, originally referred to as "talus", is the Amsden formation. In most areas, the Quadrant lies conformably upon the Amsden. This is typical in Sheep Canyon of the Blacktail Mountains where limestones of the Amsden gradually grade into sandstones of the Quadrant. In this region, the Quadrant is a friable, weakly-cemented sandstone. It is white to tan with limonite stains and it supports black lichens. It weathers from light brown to reddish-brown. The sandstone forms 200 to 400 foot cliffs on the south side of Sheep Canyon. The talus consists of massive blocks and of the individual sand grains which are released by a poor calcareous bond. These average about a millimeter in size and are spread throughout the floor of the canyon giving close resemblance to beach sand. The formation is very sparsely fossiliferous. Only one fossil was found at the Amsden-Quadrant contact. It was identified by Dr. Stumm as Juresania sp. The formation is about 700 feet thick.

Permian System

<u>Phosphoria formation</u>. R. W. Richards and G. R. Mansfield (1912, pp. 683-689) named the Phosphoria formation for its typical exposure at Phosphoria Gulch, which joins Georgetown Canyon 2-1/2 miles northwest of Meade Park, Idaho. In a personal communication to Keenmon, M. W. Klepper of the U. S. Geological Survey stated that he found the Permian in Beaverhead County, Montana, was divisible into five units. At Wadham's Springs, east of Lima, Montana, it is approximately 600 feet thick. In Small Horn Canyon, west end of Blacktail Mountains, the Permian is 185 feet thick. No fossils were identified from the Permian.

Permian section, measured by Klepper, August, 1948; sec. 28, T.13S., R.7W., east of Lima, Montana.

5.	Quartzitic sandstone.	100.0'
4.	Mudstone and phosphate rock	65.0'
3.	Cherty sandstone and siltstone, massive chert near base	270.0'
2.	Cherty siltstone and phosphate bed (4-5 feet).	75.0'
1.	Sandstone and siltstone (cherty) and gradational through about 10 feet with the underlying Quadrant formation	10.0'
Total	. . . .	520.0'

Permian section, measured by Klepper, August, 1948; sec. 14, T.9S., R.9W., Small Horn Canyon, Blacktail Mountains.

5.	Similar to Unit 5, Wadham's Springs, in lithology and thickness.	100.0'
4.	Similar to Unit 4, Wadham's Springs, in lithology and thickness.	65.0'
3.	Similar to Unit 3, Wadham's Springs, but thinner	140.0'
2.	Similar to Unit 2, Wadham's Springs, but thinner (containing 1" bands of phosphate possibly equivalent to 4 to 5 foot layer at Wadham's Springs)	25.0'
1.	Similar to Unit 1, Wadham's Springs, but thinner	20.0'
Total.	. . . .	350.0'

Triassic System

<u>Dinwoody formation</u>. Blackwelder (1918, p. 425) named the Dinwoody formation for the canyon of Dinwoody Lakes, in the Wind River Range, Wyoming. The Dinwoody here is completely exposed and has been measured in detail. The thickness is 250 feet. Blackwelder described the formation as consisting of greenish-gray shales with many thin plates of dense calcareous sandstone or argillaceous dolomite, which weathers brown to black. The age of the formation is Lower Triassic.

The Dinwoody formation is the basal Triassic group in the Blacktail Mountains. It overlies the Phosphoria formation and underlies the Thaynes. In the Small Horn Canyon region, where these formations are best exposed, the Woodside, generally overlying the Dinwoody, is absent. The base of the Dinwoody is a medium-grained, dark brown sandstone with interbedded layers of shale. The shale is dark gray and weathers dark gray-brown. The shale grades upward into a light gray crystalline limestone which weathers brownish. The only fossil obtained from the formation was identified by Dr. Stumm as _Lingula borealis_ (Bittner). The formation is estimated to be 400 to 450 feet thick.

Thaynes formation. Boutwell (1907, pp. 448-452) gave the name Thaynes to exposures found in Thaynes Canyon, Park City District, Utah. In Idaho and Wyoming, the name was later applied to strata from the base of the _Meekoceras_ limestone up to the Ankarah shale (Kummel, 1943, p. 316). It is Lower Triassic in age.

The Thaynes formation in the Blacktail Mountains region lies disconformably over the Dinwoody formation and crops out in the area northwest of Small Horn Canyon. The formation is predominantly a coarsely crystalline, gray-brown limestone, that weathers brown. It contains interbedded brown siltstones. Much of the formation is covered by a brown soil. Where exposed, the bedding is poor. Keenmon found approximately 1000 feet of Thaynes on the West Fork of Blacktail Creek, southeast of the Blacktail Mountains. The formation apparently thickens to the south and southwest, since Dillon and McUsic (Dillon, 1949) measured 1940 feet of Thaynes in their area at Deep Creek near Lima, Montana.

Jurassic System

<u>Morrison(?) formation</u>. The name Morrison was applied by G. H. Eldridge (1896, p. 60) to fresh-water marls found near Morrison, Colorado, which is the type locality for the formation. The Morrison is a non-marine formation of Upper Jurassic age.

The presence of the Morrison formation in the Blacktail Mountains is problematical. In other nearby areas, it has been identified previously on the basis of its color and relation to other formations above and below it. According to Dr. Eardley, this formation may be the Cloverly which is typically found in Central Southern Montana (Wilmarth, p. 470). This would place the formation in the Lower Cretaceous.

The only exposure of the formation in the Blacktail Range is along the east side of the road in Small Horn Canyon, about five miles from the mouth. Here, the formation is composed of about 200 feet of fine-grained, red siltstones with interbedded shales.

Cretaceous System

Kootenai formation. The Kootenai formation was first described by J. W. Dawson (1885, pp. 531-532) from exposures in Southern Alberta which contained sandstones, shales and conglomerates with coal seams in places. The name was proposed by G. M. Dawson (1885, p. 162B) for a tribe of Indians of that name. G. M. Dawson placed the formation in the Lower Cretaceous on evidence of fossil flora.

In the northwestern part of the Blacktail Mountains, the formation was found lying unconformably upon the Morrison formation and under the Beaverhead conglomerate. Although the Kootenai is considerably folded and largely represents a covered zone, the thickness is estimated to be approximately 700 feet. Near the line of contact of the Kootenai and Beaverhead formations, a thin bed of limestone was found which contained a number of gastropods. This is probably related to the "gastropod limestone" member that Dillon (1949, p. 53) found near the middle of a section measured along a tributary to Sawmill Creek in section 14, T.15S., R.8W., near Lima, Montana. He describes the limestone as gray, weathering light brown and containing small, low spired gastropods.

The basal bed of the formation is a conglomeratic "salt and pepper" sandstone. It is gray to tan, and weathers light gray. The bed becomes increasingly conglomeratic toward the base. Winchell (1914) reported some 300 feet of this basal member in his paper on the mining districts of Dillon.

Tertiary System

Beaverhead conglomerate. M. W. Klepper of the U. S. Geological Survey and W. R. Lowell of the University of Montana (personal communication to Keenmon) have recently completed a paper, now in press, in which they apply the name Beaverhead to the coarse, orogenic conglomerate of Paleocene age. Previously, graduate students of the University of Michigan, who have worked in Southwestern Montana where it was described, tentatively called it the Red Rock conglomerate.for exposures where it was first found along Red Rock Creek, north of U. S. Highway 91 near Lima, Montana.

The lithology of the Beaverhead conglomerate is considerably varied. At the contact of the Aspen formation with the Beaverhead, south of Sawmill Creek near Lima, Montana, Dillon and McUsic (Dillon, 1949) find the conglomerate to be a coarse grained sandstone with conglomeratic lenses. Along the divide between Sawmill and Beaver Creeks in that area, they find bedding in the conglomerate varying in thickness from a few inches at the bottom to several feet near the top. Smith and Cummins (Smith, 1948) state that the conglomerate, along the east front of the Tendoy Mountains, is made up of a wide variety of pebbles and cobbles of Paleozoic and Mesozoic rocks, with some pre-Cambrian quartzite boulders. This is similar to that found in the Blacktail Mountain region. The formation is well exposed in the hilly region northwest of Small Horn Canyon. It unconformably overlies the Kootenai formation. Here, the rock consists of particles varying in size from 1/4 inch to over a foot in diameter. The varicolored particles are sub-angular to angular. Color of the formation is red-brown. The cementing material is limonitic and very calcareous. Weathering of the Beaverhead conglomerate results in a boulder talus. The thickness of the formation is estimated to be about 2500 feet.

Since no fossils have been found in the formation, the age of the Beaverhead conglomerate is uncertain. However, Dr. Eardley places it in the Paleocene on the basis of stratigraphic position and structural relationships.

<u>Cook Ranch formation</u>. The name Cook Ranch was proposed by H. E. Wood (1934, p. 254) for exposures in sections 27 and 34, T.12S., R.7W., Beaverhead

County, Montana. Wood established the age of the formation as middle Oligocene on the basis of vertebrate fossil remains which included *Leptomeryx evansi*, *Peratherium*, *Hyracodon*, *Paleolagus haydeni*. Wood describes the beds as consisting of buff clays, containing sandstone lenses, with an exposed thickness of 125 feet.

In the region of the Blacktail Mountains, the Cook Ranch formation is quite unlike that 8 miles to the southeast in the type area. It is made up mainly of reworked tuffs, with a lesser amount of angular particles or breccia. Beds of bentonite are sparsely distributed throughout the formation. The brilliant white appearance of the formation makes it easily distinguished. In parts of sections 11 and 14 of T.10S., R.9W., there is a massive lens of gravel, situated at or near the upper limits of the tuffs and breccias. Origin of this is unknown.

No fossils have been found in the tuffs and breccias. Nevertheless, they are believed to represent a facies change from the Cook Ranch formation further south. From the type area, the formation gets sandier, northward and northwestward until it goes under younger basalt flows. The facies change is believed to occur under the younger basalt flow in the region of Divide and Sage Creeks along a northwest-southeast trend. Beds of this formation have a 5 to 10 degree southwestward dip.

In places, at the top of the tuffs and breccias, there is found a local distribution of rhyolites. The rock contains phenocrysts, appears porous in places, and is pink to lavender. It is not known whether these flows are an intermittent stage between the tuffs and breccias and the upper basalt flow but such position seems plausible. This is in agreement with evidence found by Benner (1948, p. 37).

Basalt flows. In the Blacktail Mountains, basalt flows are well exposed in the south and west. An older flow and a younger flow are believed to be present in the area. The older basalt is situated directly beneath the Cook Ranch tuffs and breccias. Evidence of this was found in section 11 of T.9S., R.9W., where a remnant was found lying unconformably on the Quadrant and Madison formations. Keenmon considers the older flow to be of Eocene age. The younger basalt is much more widely distributed. It overlies the Cook Ranch tuffs and breccias and was assigned to the lower Miocene.

In general the basalts are grayish to chocolate brown to black. In places soils have been produced due to decomposition. Lavas of both ages are massive and tend to form cliffs. Some of the lava is vesicular, with quartz and calcite filling some of the vesicles.

Where the flows are not covered by soils, they appear slabby. The basalt is generally fine-grained with phenocrysts inconpicuous or absent. The thickness of the flows is not known.

Quaternary System

Alluvium. Blacktail Valley contains thick beds of alluvium in the form of fans and stream deposits. Alluvium is also found in the Divide Creek area as well as on the floors of the canyons.

Figure 8

GENERAL STRATIGRAPHIC COLUMN FOR THE BLACKTAIL RANGE

Era	Time Units	Formation	Character	Thickness
CENOZOIC	Recent	Alluvium	Unconsolidated and unsorted material deposited chiefly as alluvial fans.	?
CENOZOIC	Miocene?	Basalt flows	Hard, black extrusive rock with olivine phenocrysts weathers brown.	100-200
CENOZOIC	Oligocene?	Cook Ranch	Volcanics; white breccia, tuffs, scoria, rhyolite.	?
CENOZOIC	Eocene?	Basalt flows	Similar to above with quartz in vescicles.	?
CENOZOIC	Paleocene?	Beaverhead (Red Rock)	Conglomerate, coarse with quartzite, limestone, sandstone pebbles and cobbles, calcareous cement.	2,500
MESOZOIC	Cretaceous	Kootenai	Sandstones, salt and pepper, weather white, shales, red and brown, some limestones.	700 exposed
MESOZOIC	Jurassic	Morrison	Shales, siltstones and sandstones, reddish, brown and greenish slabby; much ripple marking, mud cracks.	200

Era	Time Units	Formation	Character	Thickness
MESOZOIC	Triassic	Thaynes	Sandstones, siltstones, some limestones.	800-1000
		Dinwoody	Sandstones, tan cherty; limestones gray to purplish brown. Few fossils.	400-450
PALEOZOIC	Permian	Phosphoria	Sandstone and cherty siltstone, with some phosphate rock and mudstone.	350
	Pennsylvanian	Quadrant	Sandstone, massive, white, porous, some limestone near top. Weathers buff to almost black in talus.	700
	Pennsylvanian-Mississippian	Amsden	Shales and limestones, reddish, purplish and greenish. Fossiliferous.	75-100
	Mississippian	Mission Canyon	Limestone, massive to medium bedded, gray weathers light gray to white often with a bluish stain. Fossiliferous.in some beds.	1100
		Lodgepole	Limestone, thin bedded 2" to 8", gray. Fossiliferous.	600
	Devonian	Three Forks	Limestone, thin bedded, shaly, very fossiliferous in middle portion.	40
		Jefferson	Limestone, black crystalline, massive with some thin bedding.	82

Era	Time Units	Formation	Character	Thickness
PALEOZOIC	Cambrian	Pilgrim	Limestone, white massive, cliff forming.	91
		Park shale	Shale, crumbly, greenish gray, inter-bedded limestone at top.	300
		Meagher	Limestone, light gray, dolomitic, weathering to light orange gray cliffs.	700
		Wolsey	Shale, micaceous, greenish gray, glauconitic.	100
		Flathead	Quartzite and sandstone, tan to reddish with shaly layers.	125
PRE-CAMBRIAN	Proterozoic	Cherry Creek	Gneisses and schists, orange, red, and brown, with some pegmatitic granites.	?

STRUCTURE

Introduction

The system of mountains in Southwestern Montana, is quite irregular. Gravelly, Ruby, and Snowcrest Ranges trend northeastward. The Centennial Range trends nearly east-west. Red Rock Mountains run northwesterly, nearly parallel to the Tendoy, Beaverhead, and Blacktail Ranges. The structure of these mountains is more or less interrelated and indicates a complex orogenic history.

The region of the above mentioned mountain system falls generally within the area of the boundary of the Eastern Shelf Zone and Cordilleran Geosyncline. The Blacktail Range itself is situated in the shelf zone. During the Paleozoic and Mesozoic eras, the region of Eastern Idaho and Southwestern Montana was depressed, resulting in the deposition of more than 18,000 feet of sediments.

During the Laramide orogeny the sediments were folded, faulted, and thrust. The orogeny is separated into three periods, with the structures of the early and middle in the form of northeastward trending folds. A group of northwestward trending thrusts, which cut the folds at nearly right angles, were formed during the latter part of the orogeny. The thrusts have been traced into Idaho where they are lost under the Snake River Downwarp. They reappear on the south side and extend into Northwestern Wyoming.

A series of post-Laramide high-angle faults are found in the general region described above. These faults, according to Eardley (1947, p. 1176) are a part of a zone of fault trenches that extend from Arizona into British Columbia. The faults bound horsts, grabens, and tilted blocks.

Laramide Deformation

Folds. Evidence of early Laramide orogeny in the thesis area has been found in section 12 of T.10S., R.9W., and in the southeastern part of the area. The beds, especially those to the southeast, strike approximately north 35 degrees east and have a 15-20 degree northwestward dip. The position of these beds indicates that a structural relation exists with the sediments of the Snowcrest Range. Here, the strike of the beds is generally the same as in the Blacktail Mountains, but the dip is eastward (Eardley, personal communication). Thus, the spatial relation between the two ranges is that of a large northeast trending anticlinal fold. In the Blacktail Mountains, Mississippian, Devonian, and Cambrian sediments were involved. Although not examined by the author, it is assumed that beds of the same ages were affected in the Snowcrest Range.

In the northwest part of the Blacktail Mountains, near Small Horn and Sheep Canyons, a major series of upturned beds strike approximately north 40 degrees west. Some of the formations involved are acutely folded with dips up to 80 degrees southwest. Formations involved in the upturned beds are Quadrant sandstone, Amsden formation, and Madison limestone. In Sheep Canyon, where these folds are distinctly noticeable, the sharp dips gradually diminish to the southeast. The folds have the same general strike as the major northwest trending thrusts of Southwestern Montana. It is believed that the compressional effects of the thrusts produced these folds. The early Laramide northeast trending folds are transgressed by the compressional folds. The major thrusts are late Laramide in age (Smith, 1948, p. 41; Wallace, 1948, p. 40). Thus, the relation of the folds in the Blacktail Range to the major thrusts, plus the fact that they cross early Laramide folding, indicates the age of these folds to be late Laramide.

<u>Thrust</u>. In the northwest part of the Blacktail Range, between Small Horn and Sheep Canyons, a small thrust has been found. The author and Mr. Mannion have called it Small Horn Thrust. It extends north and south between sections 11 and 35 of T.9S., R.9W.

(see map). The competent beds of the Quadrant sandstone are the basal unit of the thrust sheet and these override the Phosphoria formation a short but undetermined distance. This is evidenced by the fact that the thrust sheet has not completely overridden the Phosphoria formation. Dips in the formations along the back of the thrust sheet suggest a dip of the thrust sheet from 35 to 70 degrees. To the east, directly in front of the thrust, a small syncline occurs which trends north and south and is related to the thrust sheet. The fault breaks the west limb of the syncline. Beds involved in the syncline are Thaynes, Dinwoody, Phosphoria, and Quadrant.

The Small Horn Thrust is not related in age to the series of major thrusts in Southwestern Montana. In view of the fact that Paleocene Beaverhead conglomerate lies on eroded, upturned beds of the thrust sheet, the thrust is pre-Paleocene and, therefore, belongs to the early Laramide orogeny.

Tertiary Block Fault

The major structure in the area is a high angle fault, here called the Blacktail. It bounds the northwest face of the Blacktail Range and is known to be at least 10 miles long. It cuts all formations from pre-Cambrian to Oligocene. The topographic relief of the scarp indicates the minimum throw of the fault to be 3000 feet. Due to uplift, formations along the back slope of the fault have suffered a change in dip and strike. Average dip of the beds along the face of the escarpment is 35 degrees. Since the Cook Ranch formation was unaffected by Laramide folding, dips of 5-10 degrees in these beds were probably caused by faulting and tilting of the mountain block. The age of the Blacktail Fault is therefore post-Oligocene.

Movement of the Blacktail Fault has been found to occur in three separate episodes as evidenced by three distinct erosion surfaces (see fig. 8). Although recent alluvial fans are found along the foot of the escarpment, there are no fresh scarplets to indicate modern movement. Discussion of erosion surfaces will be taken up in the following section.

Comparison of the Blacktail Fault with block faults in nearby areas indicates a structural relationship. Wallace (1948, p. 41) has found four faults in the Tendoy Mountains area, all of which have the same general northwest-southeast strike and therefore are roughly parallel to the Blacktail Fault.

EROSION SURFACES

Three erosion surfaces appear to be present in the Blacktail Mountains (see fig. 8). The oldest, or summit surface (see point 12 below in Post-Jurassic History), is found at an elevation between 8500 and 9000 feet. Evidence of this level is well demonstrated by the flat cap of Quadrant sandstone on Blue Mountain to the east of Sheep Canyon. A similar level is found on the northwest side of Sheep Creek. Between 7000 and 7500 feet, the second erosion surface may be found (refer to point 15 below in Post-Jurassic History). This also is well exhibited on either side of Sheep Canyon. The surfaces of this level appear in the form of pediments. The youngest level with an elevation of approximately 6000 feet, is found at stream level in the basins. Modern flood plains are found at this level with recent and modern fans being built in certain areas.

Cummins and Smith (Smith, 1948, p. 46) found similar erosion surfaces in the Tendoy-Medicine Lodge area. They believe the levels to correspond to the erosional surfaces in Wyoming as described by E. Blackwelder (1918, pp. 417-426). They tentatively assigned Blackwelder's names, Black Rock, Circle and present, oldest to youngest, respectively, to similar surfaces in their area. In the Blacktail Mountains, the erosional surfaces are distinctly similar to those mentioned by Cummins and Smith. Hence, on the basis of similarity alone, the surfaces in the Blacktail region could logically be related to Blackwelder's Wyoming surfaces.

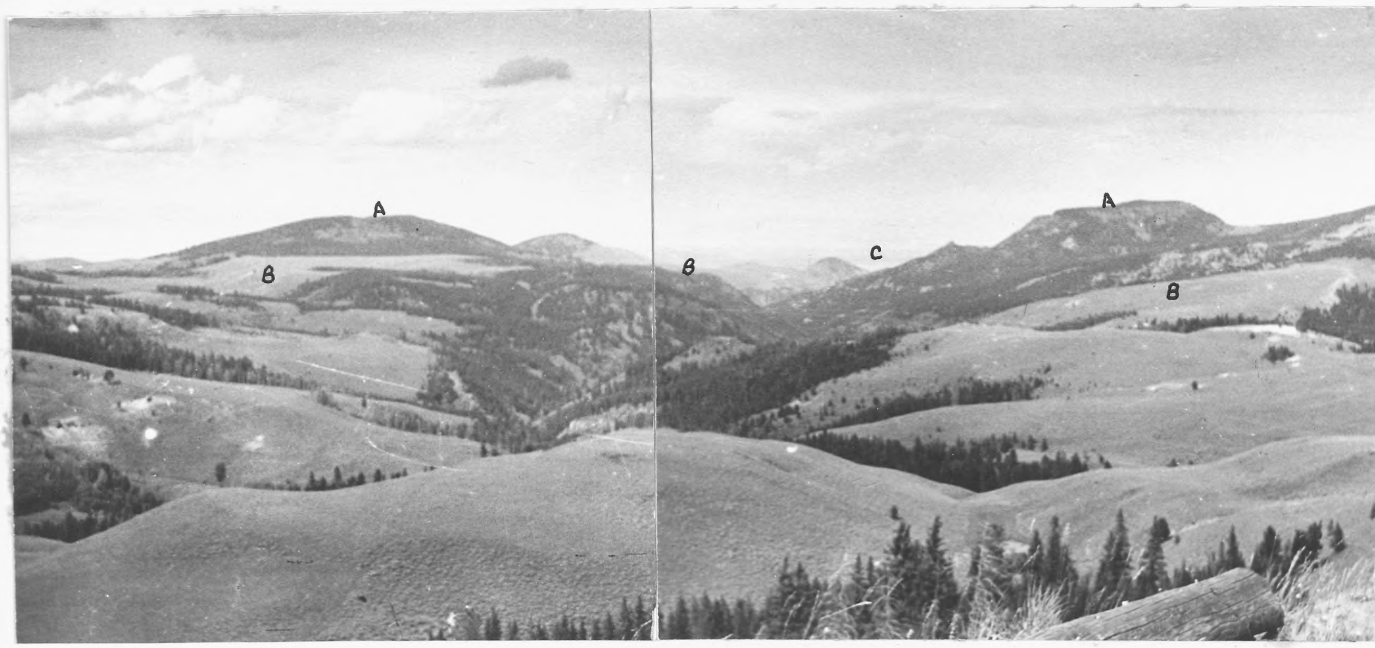

Fig. 8. Panoramic view looking toward mouth of Sheep Canyon. Notice terrace levels. "A" represents summit level, "B" represents intermediate level, "C" is present level of Blacktail Valley.

SUMMARY OF EVENTS

Post-Jurassic History

The following outline of the post-Jurassic history of Southwestern Montana was prepared by Dr. Eardley and students at a series of special meetings at the University of Michigan, Ann Arbor.

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. Thrusts from east to west are Tendoy (north of Sheep Creek Canyon), Medicine Lodge (from Medicine Lodge Pass, Idaho-Montana 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 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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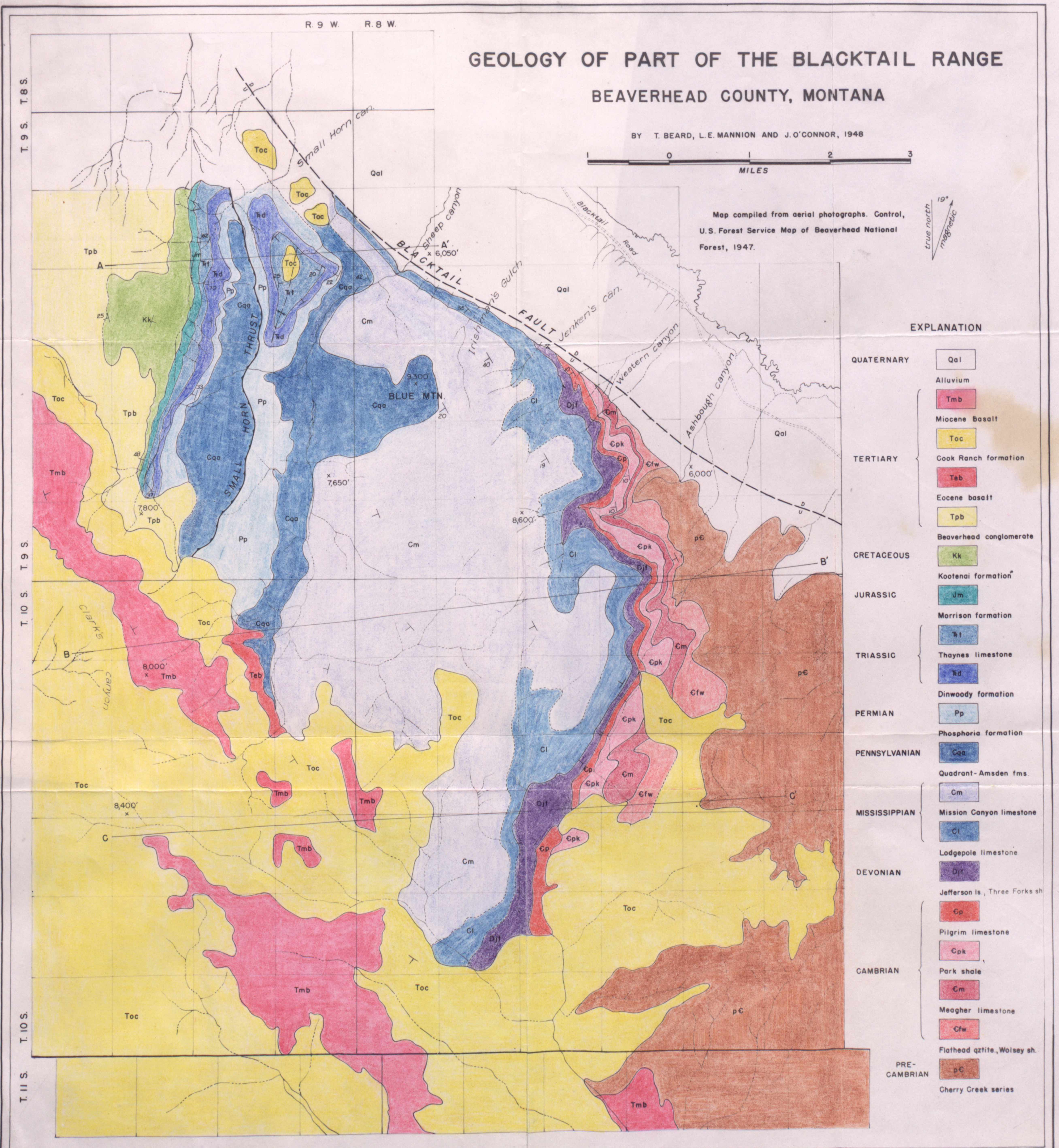
GEOLOGY OF PART OF THE BLACKTAIL RANGE
BEAVERHEAD COUNTY, MONTANA
BY T. BEARD, L. E. MANNION AND J. O'CONNOR, 1948
1 0 1 2 3
MILES
Map compiled from aerial photographs. Control, U. S. Forest Service Map of Beaverhead National Forest, 1947.
true north
magnetic
19°
R. 9 W.
R. 8 W.
T. 8 S.
T. 9 S.
T. 10 S.
T. 11 S.
EXPLANATION
QUATERNARY
Qal
Alluvium
TERTIARY
Tmb
Miocene basalt
Toc
Cook Ranch formation
Teb
Eocene basalt
Tpb
Beaverhead conglomerate
CRETACEOUS
Kk
Kootenai formation
JURASSIC
Jm
Morrison formation
TRIASSIC
Trt
Thaynes limestone
Trd
Dinwoody formation
PERMIAN
Pp
Phosphoria formation
PENNSYLVANIAN
Cqa
Quadrant-Amsden fms.
MISSISSIPPIAN
Cm
Mission Canyon limestone
Cl
Lodgepole limestone
DEVONIAN
Djt
Jefferson ls., Three Forks sh.
CAMBRIAN
Cp
Pilgrim limestone
Cpk
Park shale
Cm
Meagher limestone
Cfw
Flathead qtzite., Wolsey sh.
PRE-CAMBRIAN
pC
Cherry Creek series
BLACKTAIL FAULT
SMALL HORN THRUST
BLUE MTN.
Small Horn can.
Sheep canyon
Irishman's Gulch
Jenkerr's can.
Western canyon
Ashbough canyon
Blacktail Road
Clark's canyon
A
A'
B
B'
C
C'
6,050'
9,300'
7,650'
8,600'
6,000'
7,800'
8,000'
8,400'