GEOLOGY
OF PART OF THE
BLACKTAIL RANGE
BEAVERHEAD COUNTY, MONTANA

by

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Thesis of

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Univ. of Michigan

THE GEOLOGY OF PART OF THE BLACKTAIL RANGE

BEAVERHEAD COUNTY, MONTANA

By John E. O'Connor

Submitted in partial fulfillment
of the requirements for the degree
of Master of Science in Geology,
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ILLUSTRATIONS

ABSTRACT

This report describes the geology in a portion of the Blacktail Mountains ten miles south of Dillon, Beaverhead County, in extreme southwestern Montana. The region is in the Northern Rocky Mountain physiographic province and is characterized by steep V-shaped valleys and generally flat-topped mountains. The rocks exposed within the area range in age from pre-Cambrian to Tertiary. Late-Tretiary lavas cover a large portion of the area.

Laramide folding and mid-Tertiary block faulting have produced the major structural features. The Laramide structures include a minor thrust in the western part of the area, the Small Horn thrust, and the eroded west limb of a major anticline in the eastern part of the area. The east limb of this anticline is located in the Snowcrest Range four miles to the southeast. In the northwest corner of the area earlier northeast striking beds are turned northwestward by later Laramide folding. The major structural feature of the area is the Blacktail fault, a mid-Tertiary block fault that bounds the northeast front of the range. It has brought up pre-Cambrian to Oligocene rocks in a northwest-southeast striking escarpment.

Late-Tertiary regional uplift and subsequent erosion and dissection have produced the present mountains and canyons of the Blacktail Range. Three erosion surfaces may be recognized in the area.

INTRODUCTION

Location of area

The Blacktail Mountains are located in extreme southwestern Montana. See index map, plate 1. The part of the Blacktail Mountains mapped lies about ten miles south of Dillon in Tps. 8,9,10, and 11 S.,R8 and 9 W. The range is bounded on the north and northeast by the Blacktail fault and on the east, south, and west by the overlap of the Tertiary on the Paleozoic and Mesozoic rocks.

Accessibility

The thesis area is reached by the Blacktail Road, southeastward from Dillon it follows a course parallel to the front of the Blacktail Mountains. There are various wagon roads extending from Blacktail Road up to the mountain front. Two roads provide access to the western interior of the area. One of these may be reached from Blacktail Road and enters by way of Small Horn Canyon in the northernmost portion of the area; the other comes into the area on the west side by way of Clark Canyon. The Clark Canyon road joins the Old U. S. Highway three miles north and one mile east of Armstead. The Old U. S. Highway parallels U. S. Highway 91 and joins it at Armstead, the two being separated by the Union Pacific Railroad and the Red Rock

PLATE I

INDEX MAP

River. The roads to the interior of the area are passable only to motor vehicles equipped with a low-low gear and/or front wheel drive. All access roads are generally impassable during rainy weather.

Description of area

The topography within the thesis area is quite varied and a variety of landscapes may be found. The northern portion of the area backing the Blacktail Fault has been deeply dissected by intermittant streams flowing northward over the escarpment. In the interior of the region is an extensive area of about 20 square miles of Madison limestone that forms the greater part of the high back slope of the Blacktail Range. The Madison limestone also forms high east facing cliffs in the southeast central portion of the area. The southern portion of the area is characterized by rounded hill topography drained by intermittant streams. The elevations range from about 6,000 to 9,300 feet with the greatest relief in the northern portion.

Some extensive conifer forests occur in the northern half of the thesis area, and sagebrush is the dominant type of vegetation on the alluvial piedmont of the escarpment and in the southern portion.

Previous work

Very little previous work has been done in the thesis area. A topographic survey made in 1887-1888 by H. Gannet of the U. S. Geographical and Geologic Survey covered a small portion of the thesis area in the north; a similar survey is in progress at the present time. In 1914 A. M. Winchell described the economic geology of the Dillon Quadrangle, which work includes the northern quarter of the thesis area. A few prospect holes were found in the area. At the present time the U. S. Geological Survey is making a study of the phosphate rock of the region in which the thesis area is located. The author could find no record of detailed mapping of the area in the literature and it is, therefore, assumed that none has previously been undertaken.

Purpose of study

The purpose of the study of this area was to map it in detail and work out the geology, thereby partially fulfilling the requirements for the degree of Master of Science in Geology at the University of Michigan.

Acknowledgements

The field work for this report was done during the month of August, 1948 under the supervision of Dr. A. J. Eardley, Professor of Geology at the University of Michigan. Dr. Eardley

also supervised the writing of this report and has given considerable help in the preparation of the accompanying map. The field work for the southern portion of the area was done in conjunction with Wallace Howe, a former student at the University of Michigan. Valuable assistance in the field was offered by Louis Heyman, a graduate student at the University.

This report and accompanying map were prepared in close conjunction with Thomas Beard and Lawrence Mannion, both graduate students at the University, who mapped the northern portion of the area involved.

The author is indebted to Kendall Keeman, a graduate student at the University within whose Ph. D. thesis area the author's area is located, for assistance in the field and in the preparation of the accompanying map. Dr. E. C. Stumm of the University of Michigan aided in the identification of fossils. Carl Moritz of the Phillips Petroleum Company gave advice in the field and a Mesozoic section in Ashbough Canyon was measured under his direction.

STRATIGRAPHY

General statement

The rocks in the thesis area consist of consolidated sedimintary rocks, extrusive ignious rocks, pre-Cambrian schists and gneisses, and unconsolidated gravels.

The formations range in age from pre-Cambrian to recent and have a total thickness of about 10,000 feet. Outcrops of rocks of all ages were found; the Paleozoic section is visible in Ashbough and Sheep Canyons, the Mesozoic section in Small Horn Canyon, and the Cenozoic section in the overlap on the pre-Cambrian, Paleozoics, and Mesozoics in the south and west.

The Devonian, Mississippian, and Pennsylvanian yeilded fossils. Most of these could be distinguished only as to genera, with very few being identified as to species. This is due in part to poor preservation, but due more to the fact that the fauna of the formations involved are largely undescribed.

Pre-Cambrain system

Rocks of pre-Cambrian age are at the surface in the south-eastern portion of the thesis area and outcrop at the mouth of Ashbough Canyon. Rocks of the Cambrian system rest unconformably on them. They consist of granite gneiss with garnet gneisses,

GENERAL STRATIGRAPHIC COLUMN FOR THE BLACKTAIL RANGE				
Time Units		Formation	Character	Thickness
CENOZOIC	Recent	Alluvium	Unconsolidated and unsorted material deposited chiefly as alluvial fans.	?
	Miocene?	Basalt flows	Hard, black extrusive rock with olivine phenocrysts weathers brown.	100-200
	Oligocene?	Cook Ranch	Volcanics; white breccia, tuffs, scoria, rhyolite.	?
	Eocene?	Basalt flows	Similar to above with quartz in vesicles.	?
	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
	Jurassic	Morrison	Shales, siltstones and sandstones, reddish, brown and greenish slabby; much ripple marking, mud cracks.	200
	Triassic	Thaynes	Sandstones, siltstones, some limestones .	800-1000
		Dinwoody	Sandstones, tan cherty; limestones gray to purplish brown. Few fossils.	400-450
PALEOZOIC	Permian	Phosphoria	Sandstones, quartzitic, cherty, black and brown chert, some phosphatic rock.	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
	Cambrian	Pilgrim	Limestone, white massive, cliff forming.	91
		Park shale	Shale, crumbly, greenish gray, interbedded 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.	?

biotite schists, and pegmatitic granites. The thickness of pre-Cambrian rocks is unknown.

Cambrain system

Flathead quartzite. The Flathead quartzite was named by A. C. Peale (1893, p. 20) for exposures in Flathead Pass in the northeast corner of the Three Forks quadrangle, Montana. It is Middle Cambrain in age and rests unconformably on the pre-Cambrain rocks. It consists of whitish to tan, massive fine grained, quartzitic sandstone with reddish inclusions. It is cross-bedded and in one locality distinctly ripple marked and contains lenses of coarser grained, white, quartzitic sandstone. It is 130 feet thick. The following section was measured in Ashbough Canyon:

5.	Sandstone, with considerable shale forming a covered slope	100'
4.	Quartzite, tan, weathers reddish	14'
3.	Quartzite, conglomeratic, pebbles to 1 $\frac{1}{4}$" diameter, reddish sandy shale matrix	5'
2.	Sandstone, crossbedded, fine grained, tan	8'
1.	Conglomerate, basal, pebbles to $\frac{1}{4}$" diameter	4'

Wolsey shale. The Wolsey shale was named by W. H. Weed

Plate II Ripple marked Flathead quartz-
ite from an exposure 2 miles south of
Ashbough Canyon. Hammer handle at lower
left illustrates comparative size.

(1900, p. 285) for exposures near Wolsey, Montana. It is Middle Cambrian in age, overlying the Flathead quartzite and underlying the Meagher formation. It consists of green, slightly micaeous, sandy shale and is 150 feet thick.

Meagher formation. The Meagher formation was first described by W. H. Weed (1899) in the Fort Benton folio and was Mapped as part of the Barker formation which also included the Wolsey and Park shales. The derevation of the name was not stated but there are large exposures in Meagher County, Montana. It is Middle Cambrian in age and measures 550 feet in thickness. It consists of massive dolomitic limestone with calcite stringers. It is bluish on fresh surfaces and weathers gray to buff with reddish patches.

Park shale. The Park shale was first described by W. H. Weed (1899) and was included in the Barker formation of which there are large exposures in Belt Park in the southwest corner of the Fort Benton quadrangle, Montana. It is Middle Cambrian in age and has a thickness of 155 feet in Ashbough Canyon where it forms covered slopes above the Meagher formation. It consists of thin-bedded, crumbly, medium to greenish gray shale with some slightly micaeous reddish layers. It is conformably overlain by the Meagher formation.

Pilgrim formation. The Pilgrim limestone was named by W. H. Weed (1899) for exposures in the Valley of Pilgrim Creek in the southwest corner of the Fort Benton quadrangle, Montana. In Ashbough Canyon it consists of massive, dense gray, dolomitic limestone weathering white. Unconformably overlain by the Jefferson formation it has a thickness of 90 feet and is Upper Cambrian in age.

Devonian system

Jefferson formation. The Jefferson formation was named by A. C. Peale (1893, pp. 25-32) from exposures on both sides of the Jefferson River a few niles above its mouth in the Three Forks quadrangle, Montana. It was considered by Peale to be Middle Devonian in age and the over-lying Three Forke formation Upper Devonian. However, Sloss and Laird (1947, pp. 1404-1431) place both the Jefferson and the Three Forke formation in the Upper Devonian. The formation consists of a massive to thin bedded, brown to black, crystallene limestone, 82 feet thick.

Fossils collected were identified as follows:

1. Athyris sp.
2. Delthyris sp.

The rocks of the Devonian system disconformably overlie the Cambrian Pilgrim formation in the thesis area.

Three Forks formation. The Three Forks formation was named by A. C. Peale (1899, p. 29) for the fine developement of the formation at the junction of the three forks of the Missouri River near Three Forks, Montana. The formation is 140 feet thick in the thesis area and consists of a dark gray, thin bedded shaley limestone that weathers to a dull brown. It is Upper Devonian in age.

Mississippian system

Madison group. The Madison group was named by A. C. Peale (1893, p 32) for the Madison Range, Montana where it is conspicuously developed. It is considered Lower Mississippian (Kinderhook) in age.

The Madison is divided into two formations in the thesis area: the Lodge Pole formation which is the lower, thin bedded member, and the Mission Canyon formation which is the upper, more massive member.

Lodge Pole formation. The Lodge Pole formation was named by A. J. Collier and S. H. Cathcart (1922) for exposure along Lodge Pole Canyon in the Little Rocky Mountains, Montana. It consists of a medium gray, fine grained, compact, thin bedded limestone that weathers light gray and brown. It is quite fossiliferous yeilding brachiopods, fenestella bryozoa, and crinoid stems in abundance. It is about 600 feet thick.

Mission Canyon formation. The Mission Canyon formation was named by A. J. Collins and S. H. Cathcart (1922) for exposures in Mission Canyon in the Little Rocky Mountains, Montana. The lower part consists of a massive gray limestone that weathers gray; going up it becomes more cherty with brown and black nodules and weathers a blotchy buff to yellow.

The Mission Canyon forms high cliffs and the greater part of the high back slope of the Blacktail Range. It is not as fossiliferous as the Lodge Pole but yields a large number of brachiopods, particularly productids. Several coralline units are located near the top and there is a conglomeratic zone at the contact with the overlying Amsden formation.

Fossils collected were identified as follows:

1. Spirifer centronatus (Winchell)
2. Spirifer Striatus Var. Madisonensis (Girty)
3. Platyceras sp.
4. Dictyoclostus sp.

Pennsylvanian system

Amsden formation. The Amsden formation was named by N. H. Darton (1904, pp. 379-396) for exposures along the Amsden Branch of the Tongue River, Wyoming. The basal portion of the formation is considered Upper Mississippian in age and the upper portion Lower Pennsylvanian.

At one time the Amsden was included in the lower portion of the Quadrant formation described by Peale (1893), later investigations by Berry (1943) revealed the lower portion to be equivalent to the Amsden described by Darton. It is conformable on the underlying Mission Canyon formation. The thickness is less than 100 feet.

The only good exposure in the thesis area in the west wall of Sheep Canyon where the following section was measured.

7.	Sandstone, interbedded with sandy limestone and lime transitional with the Quadrant formation	
6.	Limestone, yellowish, shaley, fossiliferous	1'
5.	Limestone, yellowish brown, weathering light gray at the top and reddish purple at the base	42'
4.	Limestone, congloneratic, greenish gray	
3.	Limestone, reddish purple, slabby	25'
2.	Limestone, coarsely crystalline, weathers sandy and white	10'
1.	Limestone conglomeratic transition with the Madison formation	10'

Fossils collected were identified as follows:

1. Spirifer sp.
2. Dictyoclostus sp.
3. Rhipidomella sp.
4. Juresania sp.

Quadrant formation. The Quadrant formation was named by A. C. Peale (1893, pp. 39-43) for exposures in the Quadrant

Mountains in the Gallatin Range, Montana.

According to Peale it rested conformably on the Madison formation and so included all rocks of Upper Mississippian and Pennsylvanian age in the Montana area. However, A.W. Scott (1935, p. 109) and Berry (1943, pp. 19-20) consider the basal portion of the Quadrant as equivalent to the Amsden formation described by Darton (1904). The upper portion of the Quadrant formation is considered by Darton (1904) and D.D. Condit (1919, pp. 111-121) as a westward extension of the Tensleep formation of Wyoming.

The Quadrant formation consists of a very massive sandstone, dominantly white or buff, weathering to reddish brown or black in talus slopes. The lower portion is particularly massive and often crossbedded, whereas the upper portion becomes calcareous and contains some cherty limestone beds. The formation is about 700 feet thick.

Permian system

Phosphoria formation. The Phosphoria formation was named by R. W. Richards and G. R. Mansfield (1912, pp. 683-689) for exposures in Phosphoria Gulch, two and one-half miles northwest of Meade Park, Idaho. The formation unconformably overlies the Quadrant formation. It forms grassed slopes above the Quadrant formation in Sheep Canyon and has been trenched by the U. S. G. S. in Small Horn Canyon.

The thickness is 350 feet and may be divided as follows:

5.	Sandstone, quartzitic, tan	100'
4.	Mudstone and phosphate rock	65'
3.	Sandstone and siltstone, black, cherty, with massive black chert bed near base	140'
2.	Siltstone, banded with 1" layers of phosphate rock, cherty	25'
1.	Sandstone and siltstone, tan, slabby, gradational with the Quadrant formation	20'

Triassic system

Dinwoody Formation. The Dinwoody formation was named by E. Blackwelder (1918, p. 425) for exposures in the Canyon of Dinwoody Lakes in the Wind River Range, Wyoming where it is completely exposed. The formation is Lower Triassic in age and unconformabley overlies the Phospheria formation. It consists of brown sandstone and sandy shales with some thin bedded, light gray limestone that weather brown or purplish brown in the lower portion. Lingola Borealis (?) (Bittner), a characteristic blue chitinous lingula was found in several beds of this limestone. The formation is about 450 feet thick.

Thaynes formation. The Thaynes formation was named by J. M. Boutwell (1907, pp. 448-458) for exposures in Thaynes Canyon, Park City District, Utah. It is Lower Triassic in age and unconformably overlies the Dinwoody formation. It consists primarily of siltstones with silty limestones and gray shales. The thickness is about 1,000 feet.

Jurassic system

Morrison formation. The Morrison formation was named by G. H. Eldridge (1896) for exposures near Morrison, Colorado where it is typically developed. The Ellis group which is present to the south and west of the Blacktail Range is not present in the thesis area and so the Morrison unconformably overlies the Thaynes formation. It is about 200 feet in thickness and consists largely of fresh water limestones and continental deposits. On the west side of Small Horn Canyon it outcrops as reddish, brown, and greenish shale, sandstones, and siltstones characterized by a large number of mud cracks and ripple marked slabs.

Cretaceous system

Kootenai formation. The Kootenai formation was first described by J. W. Dawson (1885, pp. 531-532) from exposures in southern Alberta where it contains coarse sandstones, siltstones, shales and conglomerates with seams of coal in some places. The name Kootenai was proposed by G. M. Dawson (1885, p. 162B) for a tribe of Indians of that name who hunted over this part of the Rocky Mountains. It is Lower Cretacous in age, unconformably overlies the Morrison formation, and is about 700 feet thick.

The basal beds of the formation are white arkosic sandstone somewhat friable and porus. These are followed by tan, cross-bedded, poorly cemented sandstones and then more beds similar to the basal beds. A wide band of red shale separates this unit from the last distinguishable unit which is a thin bedded, light gray sandstone. Some limestones containing gastropods occur near the upper limit of the formation and may correlate with the limestone found by J. M. Drexler (1949, p. 28) in the middle of the Kootenai formation in the Red Peaks area.

Tertiary system

Beaverhead (Red Rock) Conglomerate. The name Red Rock conglomerate was first tentatively assigned by Dr. A. J. Eardley to a thick, coarse, generally red conglomerate that outcrops north, south, east and west of Lima, Montana, espicially in the Red Rock Peaks area and in the Red Rock River valley. Lowell and Klepper of the U. S. Geological Survey have studied the conglomerate extensively and are about to name it the Beaverhead conglomerate in a new publication. No fossils have been found that might serve to determine the age of the formation, but it is known to pre-date late Laramide thrusting and post-date the first major Laramide movements. It is therefore tentatively considered Paleocene or early Eocene in age.

The formation consists for the most part of sub-rounded cobbles and pebbles of quartzite and some of the more resistant Paleozoic and Mesozoic limestones and sandstones in a calcareous matrix. Dr. Eardly has estimated the thickness to be about 2000 feet.

Eocene basalt. A black weathering to brown basalt underlies the Cook Ranch formation and overlies the Quadrant formation on the west side of Sheep Canyon. See cross section B-B', plate 4. It appears, therefore, to be upper Eocene in age and probably correlates with the Sage Creek formation which is upper Eocene in age (Kendall Keeman, personal communication)

Cook Ranch formation. The Cook Ranch formation consists of volcanic clastics, breccias, tuffs, scoria and interbedded rhyolite flows. The formation weathers to a characteristic white and overlaps the thesis area on the east, west and south. Several collections of vertibrate fossils show the beds to be middle Oligocene (Kendall Keenman, personal communication).

Miocene basalt. A hard, black basalt that weathers brown unconformably overlies the Cook Ranch formation over large areas in the south and west portions of the thesis area. The basalt caps the high points in the southern portion with summit levels dipping about 10 degrees southwest. It is vesicular with fillings of quartz in some places, and in other places amygdaloidal with olivine phenocrysts. The age is probably Miocene because it appears to be continuous with the Blacktail Deer Creek formation of lower Miocene age (Kendall Keenman, personal communication).

Quaternary system

Recent deposits. The most recent deposits in the thesis area are due to the last movement along the Blacktail fault. They consist of alluvial fans that are spread out at the foot of the escarpment.

Depositional environment

In the thesis area the Paleozoic and Mesozoic formations have a total thickness of about 6,300 feet indicating that they were deposited in a shelf or marginal zone.

During Cambrian, Ordovician and Silurian time the Cordilleran geosyncline was subsiding, the thesis area is located on the shelf of this syncline. There are about 1,300 feet of Cambrian sediments in the thesis area, but by Ordovician time the sea had retreated and there was no further deposition until the Devonian. In Mississippian time there was a great subsidence and the Madison limestone was deposited in British Columbia, Montana, Idaho and Utah. It reaches a thickness of about 2,000 feet in the thesis area, and exceeds 5,000 feet further west. The subsidence continued into Upper Pennsylvanian time and the Quadrant formation (700') was deposited. The Phosphoria formation was deposited during Permian time when a broad, deep trough seperated Montana from an orogenic belt to the west. As the Permian drew to a close the sea advanced over southwestern Montana. In the Mesozoic Era there was general shelf deposition in the thesis area with some terrestrial beds also being deposited. In general, as time went on, the sedimentary deposition was heavier to the south and west of the thesis area than to the north and east. The Tertiary was a period of terrestrial deposition and lava flows; the material being supplied by the Laramide orogeny, Mid-Tertiary disturbences and associated uplifts.

STRUCTURE

Regional features

The mountain ranges of southwestern Montana have a diverse arrangement and a complex structural history. The Centennial Mountains trend east-west, the Tendoy, Red Rock, Beaverhead and Blacktail Mountains trend northwest-southeast, and the Snowcrest, Ruby, and Gravelly Ranges trend northeast-southwest.

The structural features of the region indicate two major periods of crustal movement: - Laramide and Mid-Tertiary. The Laramide structures are a series of great thrust sheets and associated folds trending generally northwestward that over-ride and contain elements of earlier Laramide structures that trended north-eastward. In Mid-Tertiary time a series of high angle normal faults, approximately paralleling the Laramide structures produced horst and graben topography and simple black fault mountains. These faults are particularly responsible for the Tendoy and Beaverhead mountains and for the Muddy Creek, Lemhi, and Red Rock basins.

Laramide structure of the Blacktail Mountains

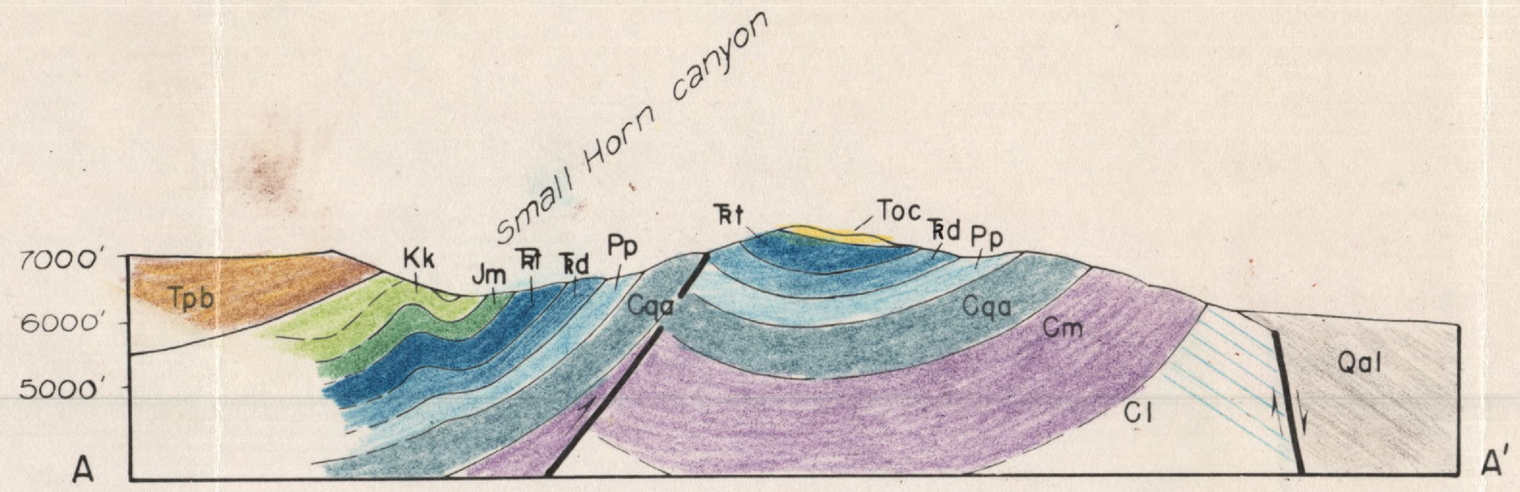
The Paleozoic beds in the east central portion of the thesis area strike generally north and dip 15 to 20 degrees west. They form an uplifted block of Cambrian, Devonian and Mississippian beds that rise abruptly from the eroded surface of exposed pre-Cambrian rock to form the east front of the range. This is considered to be the west limb of a major anticline the east limb of which is located in the Snowcrest Range four miles southeastward. In the Snowcrest Range the same Paleozoic beds dip 30 degrees southeast and their strike closely parallels that in the Blacktail Range. This correlation places the folding of these beds in the early stages of Laramide orogeny, probably pre-Paleocene.

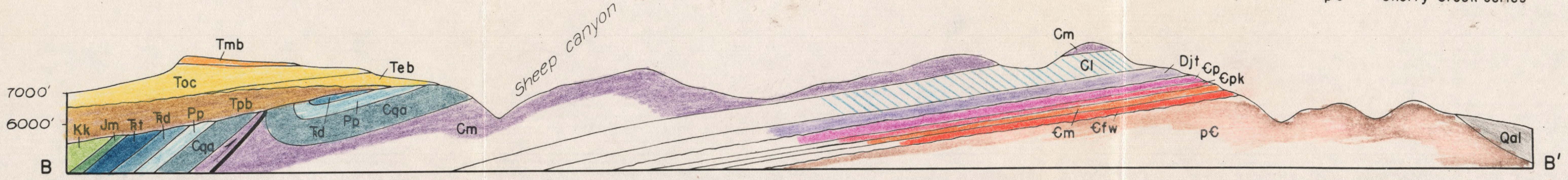
There is further folding in the vicinity of Small Horn and Sheep Canyons in the northwest portion of the thesis area. In this locality a northeast trending syncline is developed in the westerly dipping formation. The formations involved are the Quadrant, Phosphoria, Dinwoody and Thaynes.

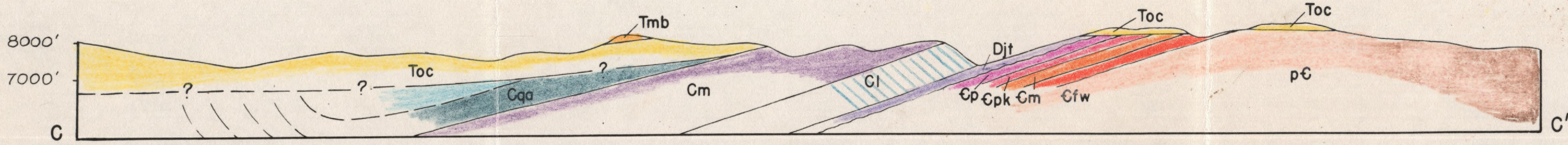
The west limb of the above syncline is broken by a thrust, the Small Horn thrust, that has an angle of thrust of about 40 to 45 degrees. It trends generally north-south and has an exposed length of about five miles being covered on its southern extremity by the Cook Ranch formation and on the north by the Beaverhead conglomerate. There is a maximum stratigraphic displacement of more than 1,000 feet where the Quadrant formation has been thrust over the Phosphoria. The Red Rock conglomerate unconformably overlies the thrust sheet establishing the same age for thrust as for the folding: pre-Paleocene and belonging

Qal	Alluvium
Tmb	Miocene basalt
Toc	Cook Ranch fm.
Teb	Eocene basalt
Tpb	Beaverhead congl.
Kk	Kootenai fm.
Jm	Morrison fm.
TRt	Thaynes ls.
TRd	Dinwoody fm.

Pp	Phosphoria fm.
Cqa	Quadrant - Amsden fms.
Cm	Mission Canyon ls.
Cl	Lodgepole ls.
Djt	Jefferson ls., Three Forks sh.
Єp	Pilgrim ls.
Єpk	Park sh.
Єm	Meagher ls.
Єfw	Flathead qtzite, Wolsey sh.
pЄ	Cherry Creek series







1 mile

CROSS SECTIONS FOR GEOLOGIC MAP

to the early stages of the Laramide orageny.

The north end of the previously mentioned syncline in the vicinity of Small Horn and Sheep Canyons is closed by northwest-southeast trending upturned beds. This folding involves the Madison limestone and the Amsden and Quadrant formations. The dip varies, but ranges as high as 80 degrees while dimishing rapidly to the southeast until the beds assume their general westward dip once again. This upturned structure besides crossing and disturbing earlier folding has a strike very similar to the late Laramide thrusts located to the northwest and southeast of the Blacktail Range and so is related to the same orogenic episode. The abrupt change of 40 degrees to the west in the strike of the Paleozaic beds at the vicinity of Western Canyon is a product of the stage of late Laramide deformation, being imposed on an earlier stage.

Mid-Tertiary structure

The fact that a major fault is present along the northeast boundary of the thesis area is very apparent; the escarpment of the Blacktail Range rises abruptly several thousands of feet above Blacktail Valley and stands deep in alluvial fans. The escarpment is faced with rocks that range from pre-Cambrian to Oligocene in age and strikes northwest-southeast remaining fairly straight while indiscriminately cutting through previous structures. The displacement along the fault is unknown as the downthrown block is covered with a veneer of unknown thickness of Quaternary alluvium; however, the displacement must be very great as the relief due to the fault is well over 3,000 feet at the present time. The age of the Blacktail fault is placed at post-Middle Oligocene. The best evidence for this is the fact that the Oligocene Cook Ranch formation is tilted.

Slightly dissected alluvial fans at the foot of the escarpment indicate that there has been movement along the fault until recent times. An effect of this movement can be seen in the warping to a southwesterly dip, along the escarpment, of the Paleozaic and Mesozaic beds that dip generally westward off the pre-Cambrian. A further effect is the development of three erosional levels that are discussed under post-Jurassic history.

The Blacktail fault is similar to the other normal faults in the region. They all strike northwest-southeast, cutting the earlier Laramide structures, are all high angle normal faults and appear to belong to the same system. The erosion surfaces found on the various fault blocks also indicate that a similar series of movements took place. Other faults mapped in the region include those in the Medicine Lodge Basin (Adam, 1948), the Muddy Creek Basin and the Red Rock faults (Wallace, 1948).

RESUME OF POST-JURASSIC HISTORY OF THE REGION

The following outline of events for the region of southwestern Montana was worked out by Dr. A. J. Eardley and students of the University of Michigan who did field work during the summer of 1948. Evidence for all of them is not found in the Blacktail Range but those indicated by an asterisk represent phases of the hisory which are shown in the area. These particular events have been elaborated upon.

*(1) Uplift (probably orogenic) of the Cordilleran geanticline and deposition of the Kootenal clastics; conglomerate generally at the base.

(2) Uplift (probably orogenic and lasting through most of upper Cretaceous) of the Cordilleran geanticline and deposition of the Colorado group of clastics.

*(3) Early Laramide orogeny to form northeast trending folds. Snowcrest Range is a prominent element.

To this period belongs the uplift of the Paleozoic and pre-Cambrian in the east part of the area and also the folds and thrust fault in the west part.

*(4) Deposition of the Beaverhead (Red Rock) conglomerate. The position of the highland was possibly to the southwest in Idaho, but the relation to the northeast trending folds

is not yet clear. The distribution and lithologic varieties of the conglomerate must be better understood before the location and character of the highland can be discerned.

In the thesis area a very coarse conglomerate consisting mainly of quartzitic boulders caps a small outcrop of upturned Lodge Pole limestone in the mouth of Sheep Canyon. It is rather poorly cemented with calcium carbonate and may represent recemented material derived during the block faulting from the Beaverhead. It rests upon structures which are considered to havebeen formed during late Laramide time. Therefore the conglomerate is probably not Beaverhead as it is affected by the late Laramide orogeny.

(5) Mid-Laramide orogeny; a second episode of northeast folding resulting in upturning of the Beaverheard 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. The thrusts strike northerly and northwesterly and contain elements of the northeasterly folds. All over-ride the Beaverhead conglomerate. The thrusts from east to west are the Tendoy fault, (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).

To this period of orogeny is assigned the folded structure at the northwest end of the area which cuts across the earlier Laramide structures.

*(7) Long erosion and possibley some additional crustal movements during lower middle and early upper Eocene time which resulted in the formation of great, broad intermontane valleys.

The surface now found as high remnants on the Madison and Quadrant near the fault face may have been produced in this period.

*(8) Vulcanism broke out in nearby regions, focussing in Yellowstone Park and THE Absaroka Range. This started in late Eocene. Vulcanism of superior magnitude also occurred in the Coast Range region of Washington and Oregon at this time. It resulted in damning of drainage ways and abundant ash and dust falls. The alluviation of the 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 took place over a wide region.

To this era of vulcanism may the basalts that underlie the Cook Ranch beds MAY be assigned.

(9) Gentle deformation and erosion in early Oligocene.

*(10) Continued vulcanism nearby and depostion of Cook Ranch beds in middle Oligocene time on the Sage Creek Beds. Contact is obscure and the extent of erosion is not known.

In the Blacktail Range the Cook Ranch beds are volcanic clastics interbedded with flows of rhyolite. These cover the south portion of the area. Isolated beds of rhyolite beyond the fault scarp at the north end of the area may also belong to this period of vulcanism.

*(11) Early episode of block faulting. Vulcanism broke out at the north end of the Blacktail Range and extensively in the Snake River Valley and Yellowston Park and the Columbia Platoau. Depos..tion of Lower Miocene Blacktail Deer beds and associated basalts, tuffs and agglomerates in Upper Sage Creek, along the northwest flank of the Snowcrest Rangeand in the Ruby Basin. These have been called Passamari by Dorr and Wheeler.

This was the time of deposition of the olivine basalt on top of the Cook Ranch volcanics.

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

This surface is best seen in the basalt capped hills of the southern part of the area where erosion has proceeded slowly. The gentle dip of less than 10 degrees seen on the summit of Blue Mountain near the fault face is shown also in the rear of the fault block on the basalts. The elevation of this surface varies from over 9,300 feet on Blue Mountain to over 8,500 feet in the south. The tilt is due to later block faulting. The highest surface mentioned by Adam (1948) as being related to the block faulting in the Tendoy Mountains is at 7,500 to 8,5000 feet. He also states that some of the ridges of the Tendoys rise to 9,000 feet. Thus the surfaces recognized by Adam are rather similar to that noted in the Blacktail Range, and the differences may be related to the extent of the normal faulting in the Ranges.

*(13) A second episode of block faulting.

This was followed by a rather extensive erosion of shallow valleys by strams draining the faulted block. The valleys now appear as gently sloping surfaces intermediate between the highest surface and the present valleys. The formation of the rather broad valleys was controlled to a certain extent by stripping on the dip slope of the Mission Canyon formation. The elevation of the surface varies from 6,700 feet to over 7,000 feet.

Adam (1948, p. 56) has recognized an intermediate erosion surface in the Tendoy Mountains at 6,700 to 7,000 which apparently correlates with this one.

(14) Deposition of upper Miocene and lower Piliocene 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 the Snowcrest Range were the most extensively and perfectly developed. Pediments on the basin beds of the 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.

These alluvial aprons are well exposed on the north side of the Blacktail Range. In addition the fact that the streams, such as those that drain Ashbough Canyon and Sheep Canyon, cut downward vigorously to form V-shaped valleys. The valley bottoms have a general elevation of over 6,000 feet. Adam (1948, p. 56) recognizes a similar system of valleys in the Lima Peaks Area with similar elevations.

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

Since there is no evidence for further block faulting in the Blacktail Range, the gentle uplift of the region may have been resposible for the slight dissection of the alluvial aprons at the foot of the fault scarp. Blacktail Creek and its tributaries have cut down some twenty feet into the fans.

(17) Continuation of block faulting at the front of the Tendoy Range in modern times.

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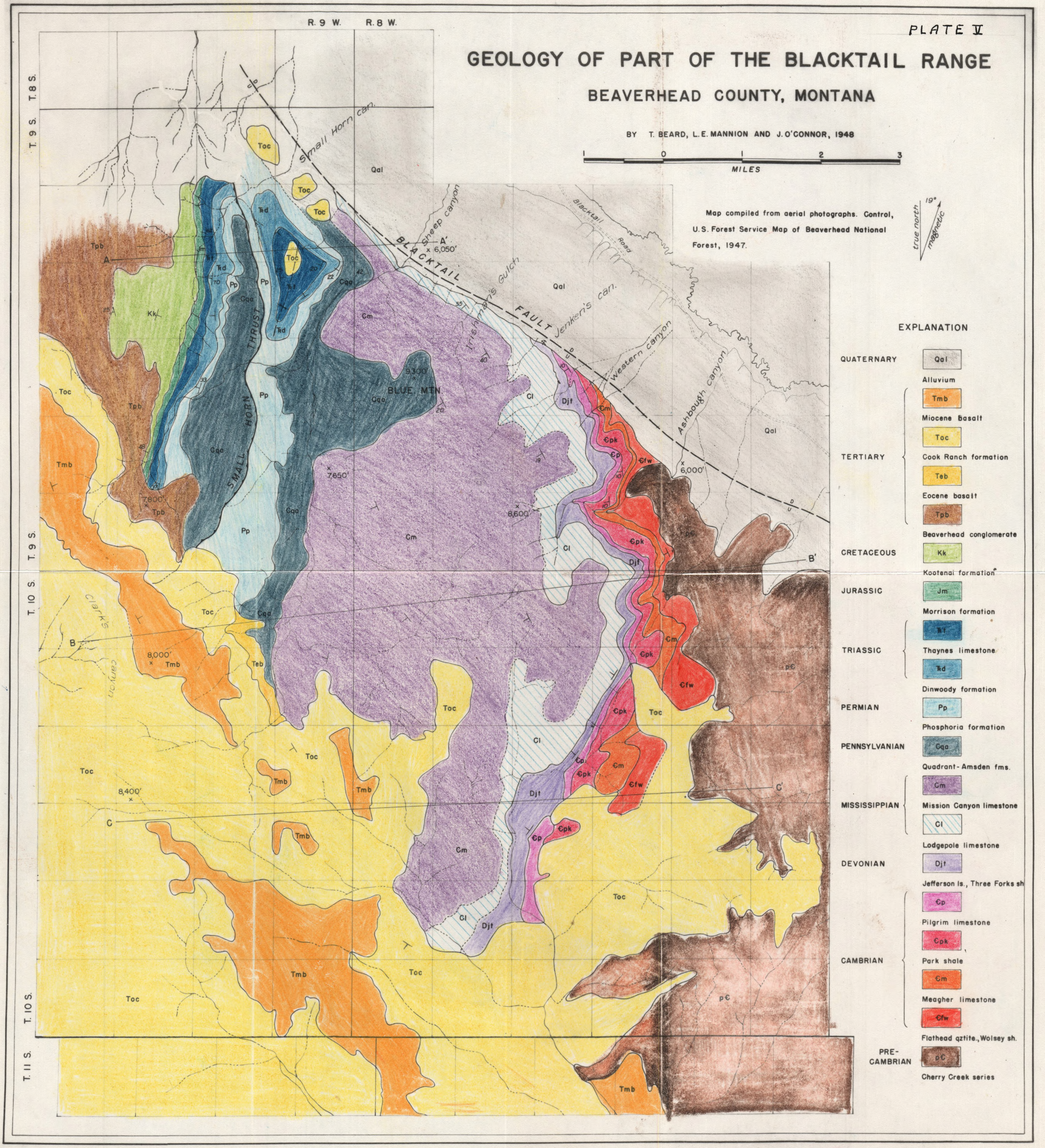
PLATE V
GEOLOGY OF PART OF THE BLACKTAIL RANGE
BEAVERHEAD COUNTY, MONTANA
BY T. BEARD, L.E. MANNION AND J. O'CONNOR, 1948
1 0 1 2 3
MILES
Map compiled from aerial photographs. Control, U.S. Forest Service Map of Beaverhead National Forest, 1947.
true north
magnetic
19°
R. 9 W.
R. 8 W.
T. 8 S.
T. 9 S.
T. 10 S.
T. 11 S.
BLACKTAIL FAULT
SMALL HORN THRUST
BLUE MTN.
Small Horn can.
Sheep canyon
Irishman's Gulch
Jenkin's can.
Western canyon
Ashbaugh canyon
Blacktail Road
Clark's canyon
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
Ћt
Thaynes limestone
Ћd
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
Єp
Pilgrim limestone
Єpk
Park shale
Єm
Meagher limestone
Єfw
Flathead qztite., Wolsey sh.
PRE-CAMBRIAN
pЄ
Cherry Creek series

AutoKlasp

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