GEOLOGY OF PART OF THE TENDOY MOUNTAINS BEAVERHEAD COUNTY, MONTANA

by

Stewart R. Wallace

GEOLOGY OF PART OF THE TENDOY MOUNTAINS

BEAVERHEAD COUNTY, MONTANA.

by

Stewart R. Wallace

Submitted in partial fulfillment
of the requirements for the degree
of Master of Arts in Geology,
University of Michigan, 1948.

CONTENTS

CONTENTS (continued)

CONTENTS (continued)

ILLUSTRATIONS

ILLUSTRATIONS (continued)

ABSTRACT

The Tendoy Mountains are located in the extreme southwestern portion of Montana about 15 miles east of the Beaverhead Mountains whose crest here forms the Idaho - Montana boundary. The rocks exposed in the area are mainly Upper Paleozoic and Mesozoic strata. Some Tertiary extrusives and fresh water sediments are also present. The structural features developed during two major periods of orogeny: - Laramide and Mid-Tertiary. The major Laramide structure is the Tendoy thrust. Laramide folding and thrusting was followed by the deposition of the Red Rock conglomerate. Late Laramide folding deformed the Red Rock conglomerate. Erosion and/or warping developed broad basins which received Mid-Tertiary extrusives and fresh water sediments. The major Mid-Tertiary structures are high angle normal faults, the Red Rock, the Muddy Creek and two unnamed ones that bound the southwest side of Muddy Creek Basin. Movement along these faults resulted in a horst and graben topography. Faulting was followed by erosion resulting in the development of extensive pediments in the Pliocene. Since Pliocene time, renewed erosion has cut deeply into the soft Tertiary sediments and exhumed the old fault planes to form fault-line scarps. Two partial cycles of erosion

are indicated by dissected pediments. Well developed triangular facets and small fault scarps cutting alluvial fans indicate continued movement along the Red Rock fault.

INTRODUCTION

Location of area

The Tendoy Mountains are located in Beaverhead County in extreme southwestern Montana. See index map, plate 1. The part of the Tendoy Mountains mapped lies about three miles northwest of Dell in Tps. 12 and 13 S., R 10 W. The area is bounded on the south by Sheep Creek and on the east by the front of the Tendoy Mountains. The western boundary is marked by an irregular fault scarp that forms the west side of Muddy Creek Basin. A northeast - southwest line through Timber Butte is the northern boundary.

Accessibility

The area is reached by U. S. Highway 91 which here parallels the Union Pacific Railroad (old Oregon Short Line). The Sheep Creek road from Dell (on U. S. 91) provides easy access to the south side of the area and the Muddy Creek road serves a similar purpose along the western edge of the area. The few wagon roads are generally impassable to motor vehicles and the interior of

PLATE I

E. Raisz

INDEX MAP

the area must be reached on foot.

Description of area

The topography of the area is quite varied. The interior is generally marked by steep slopes delimiting strike valleys. The eastern edge of the area is limited by the bold front of the Tendoy Mountains, and along the south side Sheep Creek has cut a deep narrow canyon. The gorge is especially striking where it cuts through the Quadrant quartzite which forms high steep talus slopes of dark weathering sandstone. The canyon broadens into an alluvium filled valley where Sheep Creek crosses the southern end of Muddy Creek Basin. The Lower Harkness Ranch is located in this valley which provides good hay meadows. The slopes of the Muddy Creek Basin are gentle except where badlands are locally developed.

Most of the area is drained by Sheep Creek and its tributary, Muddy Creek. Sheep Creek empties into the Red Rock River just east of Dell, but its volume is very small at that point. Most of the discharge is used for the irrigation of fields between the mountain front and the Red Rock River.

Sagebrush is the dominant type of vegetation although small conifers generally cover the high north slopes.

Previous work

Very little work had been done in this area prior to 1946. During the summer of 1946, Eugene S. Perry and Uuno M. Sahinen made a reconnaissance map of the Tendoy Mountains and the area to the west and south as far as the state line. W. Lowell mapped part of the area in detail during the same season but the results of his work are still unpublished at this writing.

Purpose of study

The purpose of the study was to map in detail and work out the geology of a small critical area in the Tendoy Mountains. This report is written as a Master's thesis for the author at the University of Michigan.

Acknowledgments

The field work for this report was done during the month of August, 1947 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 much help in the preparation of the accompanying map from aerial photographs. Henry H. Krusekopf, graduate student of the University of Michigan, accompanied the author in the field and worked with him in mapping the geology. The author is also indebted to Edward G. Lipp and Robert Becker, graduate students at the University of Michigan, who measured some of the sections.

STRATIGRAPHY

Stratigraphic column

Not all of the formations listed in the following stratigraphic column are present in the area mapped but they are exposed in adjacent areas and are therefore included. See table 1.

The stratigraphy of the area was relatively unknown to the author and the first few days were spent in becoming familiar with the formations present. During this time the stratigraphic sections were measured. The problem of obtaining accurate and complete measured sections was difficult because the only complete section in the area showed considerable distortion of beds. At other places the sections were cut off by faults or covered by thrusts. The heavy talus slopes of the Quadrant quartzite obscured many contacts. Some of the sections that might have been very good were partially covered by Tertiary volcanics and the outcrops were generally poor and discontinuous. The following descriptions of formations come in part from the work of associates who mapped in nearby areas and to date are the best that can be presented.

TABLE 1

Stratigraphic Column

Age	Formation	Thickness
Quaternary	Alluvium	Unknown
Miocene ?	Muddy Creek Basin beds	Unknown
Paleocene ?	Red Rock conglomerate	2,000' ±
Lower Cretaceous	Kootenai formation	2,200'
Jurassic	Rierdon formation	116'
Jurassic	Sawtooth formation	252'
Triassic	Thaynes formation	791'
Triassic	Woodside formation	353'
Triassic	Dinwoody formation	553'
Permian	Phosphoria formation	802'
Pennsylvanian	Quadrant quartzite	3,319'
Pennsylvanian and Mississippian ?	Amsden formation	2,022'
Mississippian	Madison limestone	2,000' ±
Devonian	Threeforks formation	300'
Ordovician	Kinnikinic quartzite	100'
Cambrian	Flathead quartzite	300'

Pre-Mississippian rocks

The oldest rock unit exposed in the area mapped is the Madison limestone. The rocks older than the Madison limestone are described from exposures in the Beaverhead Mountains to the west.

Flathead quartzite. The Flathead quartzite of Middle Cambrian age was named by A. C. Peale (1893, p. 20-21) for exposures in Flathead Pass in the northeast corner of the Three Forks quadrangle, Montana. It generally rests unconformably on pre-Cambrian rocks and varies in thickness and lithology. Walter Kupsch and Robert Scholten, graduate students of the University of Michigan, measured 300 feet of Flathead quartzite in the Beaverhead Mountains but the base was not exposed (personal communication). The quartzite is a dark purple to maroon color and contains some stretched pebble beds. It is generally massive but highly fractured and in places shows cross bedding.

Kinnikinic quartzite. The Kinnikinic quartzite of Ordovician age was named by C. P. Ross (1934, p. 947) for exposures along Kinnikinic Creek at Clayton, Custer County, Idaho. It is described as a massive, light colored quartzite with lenses of dolomite and shale. The thickness is given as 3,500 feet. Walter Kupsch and Robert Scholten (personal communication) found 100 feet of hard white quartzite above the Flathead quartzite in their area southwest of the Tendoy Mountains. This was identified on lithologic grounds by C. P. Ross upon a field visit as the Kinnikinic. The total thickness is unknown as the upper part has been removed by erosion.

Threeforks formation. The Threeforks formation of Upper Devonian age was named by A. C. Peale (1893, p. 29) for exposures at the junction of the three forks of the Missouri River near Three Forks, Montana. Walter Kupsch and Robert Scholten (personal communication) found a 300 foot thickness of yellow and gray calcareous shales and argillaceous limestones underlying the Madison limestone in the Beaverhead Mountains. It is apparently unconformable on the Kinnikinic quartzite. This has tentatively been called the Threeforks although no fossils have been found.

Mississippian system

Madison limestone. The Madison limestone of Lower Mississippian age was named by A. C. Peale (1893, p. 33-39) for exposures in the Madison Range, Montana. Peale described it as a light, bluish-gray to dark colored, compact limestone 575 feet thick. The Madison limestone outcrops at several places in the area mapped but no complete section is exposed, and the thickness is unknown. It has a lithology similar to that noted in the Madison Range. It is generally fossiliferous and most specimens give a strong fetid odor when freshly broken. The Madison limestone is resistant and forms steep cliffs where it crops out in two fault-line scarps along the west side of Muddy Creek Basin.

Pennsylvanian system

Amsden formation. N. H. Darton (1904, p. 398-401) named the Amsden formation for exposures along the Amsden Branch of the Tongue River in Wyoming. The exact age of the Amsden formation is a matter of controversy. Both Mississippian and Pennsylvanian fossils have been found. C. C. Branson (1936, p. 391-392) proposed the name Sacajawea formation for the lower Amsden but no attempt is here made to differentiate the Amsden from the Sacajawea. In the Tendoy Mountains, the Amsden formation is underlain by the Madison limestone of unquestioned Mississippian age and overlain by the Quadrant quartzite of Pennsylvanian age.

The Amsden formation consists of a thick series of interbedded dark gray, light gray to buff weathering limestones and calcareous shales with some calcareous sandstones in the upper part. A few gypsum fragments were found at one horizon but the well defined white and pink gypsum layers and the red shales so characteristically developed in parts of Wyoming are absent. The total thickness is over 2,000 feet.

Amsden formation measured in NW ¼, Sec. 36, T. 13 S., R. 10 W.

29.	Limestone, dark gray weathering to light gray, fine grained	2.0'
28.	Sandstone, light tan, friable	6.0'
27.	Limestone, dark gray weathering to light gray, fine grained	8.0'
26.	Covered interval	58.0'
25.	Limestone, dark gray weathering to light gray, massive, dense	10.0'
24.	Covered interval	139.0'
23.	Limestone, dark gray weathering to buff color, crystalline, well bedded; contains numerous thin bands of chert	43.0'
22.	Shale, gray; grades upward into brown shales; upper part of bed covered	389.0'

21. Sandstone, light brown, thin bedded, calcareous; well bedded but the thickness of individual beds varies considerably; in places weathers a reddish purple color ----- 120.0'

20. Sandstone, tan, weathers to rusty brown, massive, friable ------------------------- 24.0'

19. Covered interval - covered by Quadrant quartzite talus ------------------------- 269.0'

18. Limestone, gray, finely crystalline; contains numerous organic fragments -------- 12.0'

17. Limestone, dark gray weathering to buff, argillaceous, thin bedded with some interbedded chert ------------------------- 38.0'

16. Limestone, gray brown weathering to buff, finely crystalline, fossiliferous ---------- 62.0'

15. Shale, gray, thin bedded, calcareous; contains numerous pelecypods ---------------- 80.0'

14. Sandstone, light tan weathering to orange-buff, hard ------------------------------ 3.0'

13. Shales, gray calcareous, thin bedded ------- 29.0'

12. Limestone, dark gray weathering to buff, crystalline; contains productids ----------- 21.0'

11. Gray shales interbedded with limestones; grades upwards into brownish and buff colored beds ------------------------------ 106.0'

10.	Limestone, argillaceous, gray; interbedded with shales, dark gray weathering to light gray, thin bedded, calcareous; some gypsum fragments	245.0'
9.	Limestone, medium gray, medium grained, highly fractured	29.0'
8.	Shale, dark gray weathering to light gray, calcareous, thin bedded; interbedded argillaceous limestones	67.0'
7.	Limestone, light to medium gray weathering to buff, finely crystalline, highly fractured; fractures filled with secondary calcite	14.0'
6.	Shale, dark gray weathering to light gray, calcareous, thin bedded; interbedded argillaceous limestones	43.0'
5.	Limestone, gray, thin bedded, argillaceous	67.0'
4.	Limestone, buff colored, thin bedded, silty	10.0'
3.	Limestone, dark gray, fine grained, petroliferous	4.0'

2. Shale, gray weathering to light gray, thin bedded, calcareous; contains pelecypods ---- 86.0'

1. Limestone, dark gray weathering to buff, dense, compact ------------------------------ 48.0'

Total thickness ------ 2,022.0'

The above section was measured by Brunton compass by S. R. Wallace and H. H. Krusekopf.

Quadrant quartzite. A. C. Peale first applied the term Quadrant formation to those beds lying between the Madison limestone of Mississippian age and the Ellis formation of Upper Jurassic age, in the Three Forks, Montana region. Since Peale first named the formation, W. H. Weed (1896, p. 5), D. D. Condit (1918, p. 111), and H. W. Scott (1935, p. 1013) have defined the Quadrant as including rock units of different ages and lithology. As used here, the Quadrant quartzite is restricted to those beds of Pennsylvanian age lying between the Amsden formation and the Phosphoria formation, and is approximately equivalent to the Tensleep sandstone of Wyoming. It consists of a thick succession of light tan to white, quartzitic sandstones with a few dolomite beds toward the top. It breaks up into dark-weathering, angular blocks that form conspicuous talus slopes. No fossils were found. The total thickness is over 3,300 feet.

Quadrant quartzite measured in E. ½, Sec. 35, T. 13 S., R. 10 W.

12.	Sandstone, dark gray, massive; calcareous cement	26.3'
11.	Covered interval; dolomite and chert layers present	280.9'
10.	Limestone, more pitted than lower beds, otherwise similar	8.8'
9.	Dolomite	15.5'
8.	Limestone, gray to light buff, weathers white to buff; finely crystalline, dense, slightly pitted	5.0'
7.	Dolomite, light gray to white, dense at base, sandy and cherty near top	54.9'
6.	Sandstone, white, friable, weathers to even slope	131.0'
5.	Sandstone, white to light gray, weathers to brownish tan; grades upward into light tan weathering beds	1724.9'
4.	Sandstone, dark tan, weathers to light tan	913.6'
3.	Sandstone, light tan, weathers to light gray; friable, massive; interbedded with 2" layers of quartzitic sandstone; some thin dolomitic layers	109.4'

2. Sandstone, gray to buff, weathers to tan; thinly bedded, quartzitic; some thin shaly sandstone layers ---------------------- 5.0'

1. Sandstone, white to buff, weathers light gray, occasionally mottled slightly reddish, friable, massive, cross bedded -------- 43.8'

Total thickness ------ 3,319.1'

The above section was measured by Brunton compass by H. H. Krusekopf, R. Becker, and E. G. Lipp.

Permian system

Phosphoria formation. The Phosphoria formation was named by R. W. Richards and G. R. Mansfield (1912, p. 683-689) for exposures in Phosphoria Gulch near Meade Park, Idaho. The Phosphoria formation in the Tendoy Mountains consists of interbedded shales, dolomites, limestones, sandstones and siltstones. The typical phosphatic shales and beds of pisolitic phosphorite are missing. Most of the beds contain large chert nodules, characteristic of the Rex chert member in Idaho. The total thickness is over 800 feet.

Phosphoria formation measured in Sec. 35, T. 13 S., R. 10 W.

20. Limestone, tan to medium gray, weathers gray, very hard, fine grained, crystalline, mottled white with calcite, partly covered -- 10.0'

19. Dolomite, gray, weathers gray to reddish brown, cherty, massive, hard, fractured ---- 191.6'

18. Covered interval -------------------------- 88.0'

17. Sandstone; mostly covered by small angular talus blocks of brown sandstone ------------ 66.0'

16. Limestone, gray, weathers to yellow-tan, massive, hard ------------------------------ 15.7'

15. Shale, gray to buff; mostly covered -------- 31.6'

14. Siltstone, red, slightly calcareous, massive at bottom and top, thin bedded in between, forms small cliff ---------------- 45.1'

13. Limestone, yellow-tan, fine grained, thin bedded to massive ------------------------- 10.0'

12. Dolomite, dark gray, weathers to light gray; contains large bluish chert nodules -- 8.4'

11. Sandstone, light gray to white, weathers buff to light gray, calcareous, shows faint color banding ---------------------------- 6.3'

10. Dolomite, light gray, arenaceous, massive, highly fractured, contains some chert nodules ---------------------------------- 92.6'

9. Covered interval -------------------------- 11.7'

8. Bedded chert, gray-green ------------------ 0.8'

7. Limestone, dark gray-green, weathers gray, hard, arenaceous, massive; interbedded thin chert layers ------------------------- 6.0'

6. Limestone, gray; interbedded with chert layers 2 to 8" thick; chert is light to dark gray; near top chert disappears and concretions are present ------------------------- 76.3'

5. Dolomite, light gray, abundant dark gray chert ------------------------------------ 12.5'

4. Covered interval -------------------------- 8.4'

3. Sandstone, light gray, fine grained, calcareous near base, hard, massive; contains calcite stringers ------------------------- 44.5'

2. Limestone, light gray, fine grained, hard, massive; contains large dark gray chert nodules ---------------------------------- 71.6'

1. Dolomite, gray to buff, weathers light gray; very fine grained, sandy ------------- 5.0'

Total thickness -------- 802.1'

The above section was measured by Brunton compass by H. H. Krusekopf, R. Becker, and E. G. Lipp.

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. Blackwelder considered it as the upper part of D. D. Condit's (1916, p. 263) Embar formation of Permo-Triassic age. According to Blackwelder, the limits of the Dinwoody formation are defined by the Phosphoria formation below and the bright red shales and siltstones of the Chugwater formation above. N. D. Newell and B. Kummel (1942, p. 941-947) found that the characteristic red of the Chugwater formation is not a true stratigraphic plane, but crosses both lithologic and time lines. Therefore, Newell and Kummel redefined the Dinwoody as including only the lower silty portion of Blackwelder's original Dinwoody. In the Tendoy Mountains, the Dinwoody fitted Newell's and Kummel's definition, and was mapped accordingly.

The formation contains many pelecypods including *Claraia* sp. The most characteristic fossil is the brachiopod, *Lingula borealis*.

Dinwoody formation measured in W. ½,
Sec. 26, T. 13 S., R. 10 W.

33.	Limestone, gray, weathers reddish brown, argillaceous, thin bedded, sandy	4.7'
32.	Covered interval	37.4'
31.	Limestone, light gray, weathers dark gray, hard, massive	4.7'
30.	Covered interval	2.0'
29.	Limestone, light gray, weathers dark gray, argillaceous	1.0'
28.	Covered interval	14.0'
27.	Limestone, light gray, weathers dark gray, hard, dense	2.0'
26.	Covered interval; includes a thin limestone bed in the middle	9.3'
25.	Limestone	1.0'
24.	Covered interval	4.7'
23.	Limestone, gray, weathers buff; argillaceous, thin bedded	6.0'
22.	Covered interval	18.7'
21.	Limestone, gray, weathers dark gray, massive	1.0'
20.	Covered interval	14.0'
19.	Limestone, gray, weathers reddish, thin bedded	6.0'

18. Covered interval; includes 3' bed of shaly limestone ---------------------------------- 14.8'

17. Limestone, weathers chocolate brown, calcareous, fossiliferous, thin bedded; contains shale partings; forms a prominent ledge -- 63.9'

16. Covered interval ----------------------------- 25.7'

15. Limestone, gray-brown, weathers to chocolate brown, interbedded with shale partings; forms a ledge --------------------- 6.3'

14. Covered interval ----------------------------- 23.4'

13. Limestone, gray-brown, weathers chocolate brown; interbedded with shale partings; forms a ledge ------------------------------- 9.3'

12. Covered interval ----------------------------- 39.8'

11. Limestone, weathers chocolate brown, argillaceous ---------------------------------- 2.0'

10. Covered interval ----------------------------- 6.0'

9. Limestone, weathers chocolate brown, argillaceous ---------------------------------- 3.0'

8. Shale, mostly covered ------------------------ 7.0'

7. Limestone; two thin white limestone layers separated by a shale parting; shale weathers reddish brown -------------------------------- 2.0'

6. Shale; largely covered ----------------------- 7.0'

5.	Limestone, light colored, weathers reddish brown; thin bedded with shale partings -----	4.0'
4.	Shale, reddish brown, weathers chocolate brown; thin bedded --------------------------	44.1'
3.	Covered interval ----------------------------	10.0'
2.	Limestone, weathers reddish brown; thin bedded, calcareous; forms a ledge ----------	5.0'
1.	Shale, dark brown, largely covered ---------	153.7'
	Total thickness --------	553.0'

The above section was measured by Brunton compass by E. G. Lipp and R. Becker.

Woodside formation. The Woodside formation was named by Boutwell (1907, p. 446) for exposures in Woodside Gulch in the Park City District, Utah. It has been identified as far north as the Snake River and Teton Ranges of Idaho and Wyoming and in the Dillon and Melrose areas to the north in Montana. In the Montana usage, the lower tan beds here called the Dinwoody formation and the overlying limestone beds, here called the Thaynes formation, have been included in the Woodside. As a result of work in southwestern Montana by the writer and several associates in nearby areas in 1947, the three lithologic units were found to be distinct and similar lithologically to the formations south of the Snake River Plain and therefore it was decided to use the southern formational names provisionally, pending paleontological studies.

Woodside formation measured in W. ½, Sec. 26,
T. 12 S., R. 10 W.

19.	Covered interval ----------------------------	18.7'
18.	Shale, brown, weathers dark brown; sandy, calcareous, thin bedded --------------------	2.5'
17.	Covered interval; dark brown soil ----------	107.4'
16.	Covered interval; red soil -----------------	65.4'
15.	Sandstone, light gray, arenaceous, thin bedded --	1.5'
14.	Covered interval ----------------------------	7.9'
13.	Sandstone, gray to buff, weathers light gray; fine grained, calcareous, thin bedded ------	6.0'
12.	Covered interval ----------------------------	7.0'
11.	Sandstone, gray, weathers light gray; fine grained, thin bedded -----------------------	2.0'
10.	Covered interval ----------------------------	5.5'
9.	Sandstone, light gray, weathers to gray buff; well indurated, massive at base, thin bedded near top -----------------------	36.0'
8.	Covered interval ----------------------------	4.7'

7.	Sandstone, light gray, weathers brownish red and gray; well indurated, thin bedded to massive	9.3'
6.	Sandstone, light gray; friable, thin bedded	23.4'
5.	Covered interval	10.6'
4.	Limestone, light gray, weathers to brownish red in places, dark gray patches in places; very sandy, very thin bedded	14.0'
3.	Covered interval	11.7'
2.	Limestone, gray, weathers grayish buff; arenaceous, thin bedded at base, massive at top; forms a prominent ledge	9.3'
1.	Covered interval	11.0'
	Total thickness	353.9'

The above section was measured by Brunton compass by E. G. Lipp and R. Becker.

Thaynes formation. Boutwell (1907, p. 448-452) named the Thaynes formation for exposures in Thaynes Canyon in the Park City District, Utah. In the Tendoy Mountains, the section recognized as the Thaynes consists of a thick succession of light gray to buff, fine grained, calcareous sandstones and finely crystalline limestones. The limestones form prominent ledges throughout the area. Several of these beds contain numerous columnals of Pentacrinus sp. These and other fossils were identified by Dr. R. W. Imlay (field conference communication) as Triassic.

Thaynes formation measured in W. ½, Sec. 26, T. 13 S., R. 10 W.

17.	Covered interval; silty limestone with chert	84.4'
16.	Limestone, light gray; finely crystalline, pitted on weathered surfaces	4.5'
15.	Limestone, buff colored, silty, thin bedded; contains some sandy layers; mostly covered	68.8'
14.	Limestone, gray to buff; finely crystalline; largely covered	50.5'
13.	Siltstone, tan, calcareous, cherty	22.9'
12.	Limestone, dark gray, weathers to light gray; massive, fine grained; pitted on weathered surfaces	18.3'
11.	Siltstone, light gray to buff; calcareous; largely covered	18.3'
10.	Limestone, light gray; crystalline, thin bedded	18.3'
9.	Siltstone, tan; largely covered; abundant chert in float	18.3'

8.	Covered interval; gray limestone with chert in float ----------------------------------	22.9'
7.	Limestone, buff to gray; massive, crystalline; forms a prominent ledge -----------	27.5'
6.	Covered interval, calcareous tan siltstone and chert in float ------------------	27.5'
5.	Limestone, light gray to buff, some pinkish mottling, massive, coarsely crystalline; forms a prominent ledge capping a ridge; contains abundant <u>Pentacrinus</u> sp. columnals ---------------------------------	15.0'
4.	Covered interval --------------------------	314.2'
3.	Limestone, gray-brown, weathers gray, thick to thin bedded; forms a ledge -------	32.7'
2.	Covered interval --------------------------	26.8'
1.	Limestone, gray brown, weathers to chocolate brown; thick to thin bedded; very dense -------------------------------------	21.0'
	Total thickness -------	791.8'

The above section was measured by Brunton compass by S. R. Wallace, H. H. Krusekopf, E. G. Lipp, and R. Becker.

Jurassic system

<u>Sawtooth formation</u>. The Ellis formation (group) consists, from top to bottom, of the Sawtooth, the Rierdon, and the Swift formations (Cobban, 1945, p. 1264). The presence of the Swift formation in the Tendoy Mountains is doubtful, but the two lower formations were identified by Dr. R. W. Imlay on the occasion of a field conference in July, 1947.

The Sawtooth formation was named by W. A. Cobban (1945, p. 1274-1276) for exposures in Rierdon Gulch in the Sawtooth Range, Montana. The total thickness of the formation in the Tendoy Mountains is unknown as the top of the measured section was covered by Tertiary volcanics. The most conspicuous unit is a dark tan, white mottled, friable siltstone.

Sawtooth formation measured in S. ½, Sec. 22, T. 13 S., R. 10 W.

3.	Shale, light gray to buff, slabby and thin bedded, calcareous; not top of formation ?	105.5'
2.	Siltstone, buff, weathers with a speckled appearance - white spots	64.2'
1.	Covered interval	82.6'
	Measured thickness	252.3'

The above section was measured by Brunton compass by S. R. Wallace and H. H. Krusekopf.

Rierdon formation. The Rierdon formation was named by W. A. Cobban (1945, p. 1277-1280) for exposures in Rierdon Gulch in the Sawtooth Mountains, Montana. In the Tendoy Mountains, it consists of interbedded calcareous shales and oolitic limestones and is 116 feet thick.

Rierdon formation measured in W. ½, Sec. 10, T. 13 S., R. 10 W.

4.	Covered interval	78.0'
3.	Oolitic limestone, gray to buff, massive	10.0'
2.	Shale, light brown, calcareous	20.0'
1.	Oolitic limestone, gray to buff, massive	8.0'
	Total thickness	116.0'

The above section was measured by Brunton compass by S. R. Wallace and H. H. Krusekopf.

Cretaceous system

Kootenai formation. The Kootenai formation of Lower Cretaceous age, was named by C. A. Fisher (1909, p. 28-35) for exposures near Great Falls, Montana. In the Tendoy

Mountains it consists of a thick series of variegated red, yellow, and purple silty shales interbedded with "salt and pepper" sandstones and limestones. A gastropod limestone is a prominent marker bed in the lower part of the formation.

The basal unit of the measured section is 260 feet of gray shales underlying the lowest "salt and pepper" unit. These shales are poorly exposed and are here placed in the Kootenai formation, although they may belong to either the Morrison or Swift formations. Over 2,200 feet of Kootenai were measured but the upper part of the section was covered by the Tendoy thrust sheet and the total thickness is unknown.

Kootenai formation measured in E. $\frac{1}{2}$, Sec. 9, T. 13 S., R. 10 W.

Above bed 35 the section is covered by the Madison limestone of the Tendoy thrust sheet.

35.	Covered interval -------------------------	250.0'
34.	Sandstone; salt and pepper, massive; some beds contain subangular to rounded pebbles of black and brown chert ------------------	26.0'
33.	Covered interval -------------------------	26.0'

32.	Sandstone, rusty brown, very well indurated, salt and pepper	26.0'
31.	Covered interval	52.0'
30.	Sandstone, salt and pepper, massive	21.0'
29.	Shale, reddish	52.0'
28.	Sandstone, fine grained, salt and pepper	5.0'
27.	Shale, brownish red	42.0'
26.	Sandstone, salt and pepper	5.0'
25.	Shale, brownish red	29.0'
24.	Sandstone, salt and pepper, interbedded with several beds of dark brown weathering calcareous sandstones	10.0'
23.	Shale, variegated, red, brown, and purple	31.0'
22.	Sandstone, salt and pepper	5.0'
21.	Shale, red	33.0'
20.	Limestone, gray, weathers to dark brown, arenaceous	2.0'
19.	Sandstone, salt and pepper	28.0'
18.	Shale, red	21.0'
17.	Sandstone, salt and pepper	5.0'
16.	Shale, red	23.0'
15.	Shale, purple-gray; includes a two foot bed of reddish brown arenaceous limestone	10.0'
14.	Shale, red	57.0'

13.	Sandstone, gray to reddish gray; includes some interbedded sandy limestones ----------	26.0'
12.	Sandstone, salt and pepper ----------------	5.0'
11.	Shale, red ----------------------------------	10.0'
10.	Sandstone, medium grained, salt and pepper, thin bedded, weathers into slabby blocks ---	36.0'
9.	Shale, alternating red and brown ----------	73.0'
8.	Covered interval; includes a dark gray gastropod limestone and some gray shales not seen in measured section --------------	702.0'
7.	Shale, red ----------------------------------	21.0'
6.	Sandstone, light brown to gray, medium grained, friable; toward top coarser sandstone, salt and pepper with pebbles of black chert; thin bedded ------------------	36.0'
5.	Shale, variegated red, purple, and brown ---	42.0'
4.	Shale, light gray, hard, sandy ------------	52.0'
3.	Shale, red, calcareous; contains gastroliths ? ------------------------------------	109.0'
2.	Sandstone, salt and pepper with small limonite concretions, massive --------------	70.0'
1.	Shale, dark colored; poorly exposed -- Possible Morrison or Swift formations ? -------	260.0'

Measured thickness --- 2,201.0'

The above section was measured by Brunton compass by S. R. Wallace and H. H. Krusekopf.

Tertiary system

Red Rock conglomerate. A coarse, generally red conglomerate crops out in numerous places north, south, east, and west of Lima, especially in the Red Rock River valley and Red Rock Peak. It has been decided to call this tentatively the Red Rock conglomerate, but the most appropriate name must await more extensive mapping (A. J. Eardley, personal communication). The formation consists principally of sub-rounded pebbles and cobbles of the more resistant Paleozoic and Mesozoic limestones. Some well rounded cobbles and boulders of the Flathead, Kinnikinic and possibly of the Beltian quartzites are present. The matrix is calcareous sand and the cementing material contains some iron and weathers reddish. The exact thickness is unknown but it is estimated by A. J. Eardley (personal communication) to be about 2,000 feet thick in the Lima anticline. No fossils have yet been found in the beds and, therefore, its age can only be guessed. It post-dates the first major Laramide movements and is itself folded and faulted by later Laramide movements. It is therefore tentatively considered Paleocene in age.

Muddy Creek Basin beds. Muddy Creek Basin is filled by an unknown thickness of Tertiary rocks. The basal part of the section exposed consists of rhyolite flows overlain by a considerable thickness of light colored acid tuffs. Overlying these extrusives is a thick succession of poorly consolidated freshwater mudstones, siltstones, and limestones, interbedded with numerous thin bentonite beds. Gypsum fragments are common near the bentonite layers. Plant remains are locally abundant, but the poorly preserved specimens collected are undiagnostic (Dr. C. H. Arnold, University of Michigan). Beds of similar lithology are found in Nicholia Basin to the west, but there the succession includes some sandstones and conglomeratic beds.

Tertiary volcanics. Two small but significant patches of Tertiary volcanics lie on the upthrown horst block to the east of Muddy Creek Basin. The southernmost of these two patches consists of poorly exposed beds of water laid tuffs overlain by basalts. The other patch is a group of spatter cones made up of basaltic breccia. See. plate 2. These cones have been considerably modified by erosion but some of them still retain enough of their original shape to form closed drainage basins containing small lakes. The close spatial relationship

Plate 2. View showing some of the basaltic breccia in one of the spatter cones.

of the two exposures suggests that the basaltic flows are associated with the breccia. The preservation of the form of the cones indicates that they are no older than late Pliocene and may even be Quaternary in age.

Quaternary system

A mantle of Quaternary alluvium of unknown thickness covers the floor of the Red Rock Basin.[1] Alluvium is also found along the major drainage lines within the area. Two small landslides were recognized but these are old enough to be covered with vegetation. The smaller of these occupies a tributary valley on the south side of Little Water Canyon. The other one is just to the west of the group of spatter cones.

Environment of deposition

The thickness of the Paleozoic and Mesozoic sequence in the Tendoy Mountains is of geosynclinal proportions. Frederick S. Honkala, graduate student of the University of Michigan, mapped an area to the east of the Tendoy Mountains, including parts of the Snowcrest Range,

---

1. The term "Red Rock Basin" is here applied to that part of the valley of the Red Rock River lying between the Tendoy Mountains to the west and the Red Rock Mountains to the east.

the Gravelly Range, the Centennial Valley, and the Centennial Range, and found that the same formations in his area were considerably thinner (personal communication). Apparently, the Paleozoic and Mesozoic formations found in Honkala's area represent deposition in the marginal or shelf zone whereas those in the Tendoy Mountains represent deposition generally in the deepening geosynclinal zone. The thicknesses indicated in Table 1 seem large, but they are not out of order with the thicknesses given by C. P. Ross (1934, p. 940) and V. R. D. Kirkham (1927, p. 16-23) who have measured sections to the south and west of the Tendoy Mountains in Idaho.

STRUCTURE

Regional features

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, roughly parallel and trending generally northwestward. In Mid-Tertiary time a series of high angle normal faults, approximately parallel to the Laramide structures produced a horst and graben topography, and are partially responsible for the Muddy Creek Basin, the Tendoy Mountains, the Lemhi Basin, and the Red Rock Basin.

The Tendoy Mountains lie near the eastern margin of the Laramide thrust zone in this region. V. R. D. Kirkham (1927, p. 26-29) has mapped four major thrusts to the south in Idaho, and the Tendoy Mountains are approximately in line with the northward extension of the eastern edge of this zone. Another well defined thrust zone further to the east along the Rocky Mountain Front has been described by A. Bevan (1929, p. 427-456). Between these two well defined thrust zones is an area of ill-defined, but simpler features. The major topographic features of the area (Snowcrest Range, Gravelly

Range, Ruby Range, Tobacco Root Range, and Centennial Valley) exhibit diverse orientation and enough field work has not yet been done to define a structural pattern.

Laramide structures of the Tendoy Mountains

Folds. The part of the Tendoy Mountains mapped consists of a thick series of Paleozoic and Mesozoic sediments dipping from 20 to 30 degrees to the west. See geologic map, plate 9. These beds may represent the west flank of a north-south trending anticline asymmetrical to the east, but this cannot be determined from field evidence as the entire east limb of the structure is missing. The absence of the east limb is due to the dropping of the eastern block along the Red Rock fault (see page 41), and subsequent burial by later sediments. Crumpling of the Madison limestone near the mouth of Sheep Creek Canyon suggests that the Tendoy Mountains themselves may be a thrust sheet. See page 40. In this case, the east limb of the broken anticline would lie beneath the surface somewhere to the west.

Near the north end of the area the succession of westward dipping sediments is disturbed by a cross fold, the Little Water syncline. See plate 3. This syncline is both a structural and topographic depression and is

Plate 3. View looking northeast showing the steep northwest limb of the Little Water Syncline at the southwest end of the syncline.

named from Little Water Canyon which is eroded in the northeast end of the structure. The syncline trends northeast - southwest and is asymmetrical to the southeast. It pitches to the southwest and flares open as both limbs swing around to the general north - south trend. A small reversal of dip in the Cretaceous rocks on the southeast limb is imposed on the main synclinal dip. To the northwest, the dips steepen and the syncline pinches together and is broken by two small faults. Along both faults, the northwestern block has moved upward bringing the Dinwoody formation against the Thaynes formation. Toward the southwest these faults die out along bedding planes. The northeastern end of the syncline is truncated vertically by the Red Rock Fault.

Thrusts. Detailed mapping definitely established the presence of two thrusts in the area and gives some indication that a third thrust may be present. The most evident of these is the Tendoy thrust, so named for its exposure along the southwest flank of the Tendoy Mountains. The front of the thrust sheet consists entirely of Mississippian Madison limestone which has overridden formations varying in age from the Pennsylvanian Quadrant quartzite to the Lower Cretaceous Kootenai formation. The trace of the thrust plane is not exposed but its position can be closely located by the stratigraphy. Two masses of the thrust sheet composed of Madison limestone were mapped. See plate 9. At the south end of the area near the junction of Muddy Creek and Sheep Creek, a small klippe of Madison limestone rests on the Quadrant quartzite, and the Phosphoria and Dinwoody formations. The second mass is much larger and extends from the north end of the area southeast along the northwest side of Muddy Creek Basin for approximately three miles. Here the Madison limestone generally rests on the Kootenai formation of Lower Cretaceous age. At one place Madison limestone has overridden the Thaynes formation of Triassic age which was thrust over the Kootenai formation by an earlier thrust. See cross-section A-A', plate 10.

The southwestern edge of the larger mass marks the approximate position of the Muddy Creek fault (see page 41), which has broken the thrust plane. The thrust plane passes westward beneath the Tertiary sediments of Muddy Creek Basin. The thrust sheet (Madison limestone) but not the thrust plane is brought to the surface again on the southwest side of Muddy Creek Basin by two faults which bound that side of the basin. See cross-section A-A', plate 10, and plate 4.

Plate 4. View looking northwest across Muddy Creek Basin showing the approximate position of the Tendoy thrust, one of the faults that bound the southwest side of Muddy Creek Basin, and the basin beds. The basin beds dip toward the observer.

The Tendoy thrust was traced in the adjacent area on the south by Robert Becker and Edward Lipp (personal communication), graduate students of the University of Michigan. On the basis of a hasty reconnaissance in the vicinity of Medicine Lodge Pass, still further south, Robert Scholten, graduate student of the University of Michigan, believes a thrust to be present (personal communication). This presumably will tie in with the Medicine Lodge thrust described by V. R. D. Kirkham (1927, p. 26) on the Idaho side of the line.

Dr. A. J. Eardley (personal communication) mapped a thrust along the northwest end of the Lima anticline southeast of Lima. This may be part of the Tendoy thrust or the Medicine Lodge thrust. Further work will be necessary to determine the true relation between the Tendoy thrust and the Medicine Lodge thrust.

The other thrust noted in the area has brought the Thaynes formation over the Kootenai formation. The direction of thrusting was approximately the same as that of the Tendoy thrust; i.e., to the eastward. This thrusting preceded the Tendoy thrust, and the Tendoy thrust has overridden the earlier thrust and covered it in all but two places. The first of these is an elongate patch of the Thaynes formation that occupies a reentrant in the front of the Tendoy thrust sheet. Approximately a quarter of a mile west of here, a small patch of the Thaynes formation rests on the Kootenai formation. This is a klippe formed by the erosion of the earlier thrust sheet.

There is some indication that another thrust may be present in the area. Near the eastern end of Sheep Creek Canyon, the Madison limestone crops out in normal sequence. Only the upper part of the Madison limestone is exposed; the lower part of the limestone is covered by the Red Rock conglomerate. Where the Madison limestone is exposed, it is highly contorted into a series of tight and broken folds overturned to the east. See plate 5. This type of folding is similar to that observed in the Madison limestone in the Tendoy thrust sheet. The thrust if present lies below the surface in the area mapped and is covered by the Red Rock conglomerate. Further field work in adjacent areas may or may not definitely establish its presence.

Mid-Tertiary structures

High angle faults. Four high angle faults were mapped in the area. These faults are roughly parallel and strike northwest - southeast. Movement along these

Plate 5. View of the Madison limestone near the mouth of Sheep Creek Canyon. The folds are overturned to the east.

faults in Mid-Tertiary time broke the surface into a series of horsts and grabens. Continued movement and differential erosion have outlined the major topographic features of the area. The Tendoy Mountains are a horst block bounded on both sides by high angle faults. Muddy Creek Basin to the west of the Tendoy Mountains is a corresponding graben.

The northeast front of the Tendoy Mountains is marked by the Red Rock fault. See plate 6. The upthrown block is to the southwest and forms the steep mountain front. The fault cuts the Laramide structures composed of Mississippian, Pennsylvanian, Permian, Triassic, and Paleocene formations. The downthrown block is covered with a veneer of unknown thickness of Quaternary alluvium and the exact displacement is unknown. The throw is estimated to be at least 1,000 feet. Well defined triangular facets and a small fault scarp cutting the alluvium indicate recent movement along the fault.

The upthrown block described above is a horst. It is bounded on the southwest by a second high angle fault. This is the Muddy Creek fault which forms the northeast side of Muddy Creek Basin. The fault cuts the Laramide thrusts and the thrust planes pass to the westward be-

Plate 6. View taken from the Red Rock Basin looking west toward the northeast front of the Tendoy Mountains. The small scarp at the foot of the Mountains displaces alluvium and shows that this fault is still active.

low the Tertiary fill of Muddy Creek Basin. See cross-section A-A', plate 10. The displacement is unknown.

The southwest side of the Muddy Creek graben is bounded by two high angle faults. In both cases, the upthrown block is to the southwest. Both faults have brought the Tendoy thrust sheet (Madison limestone) to the surface. See plate 9 and plate 4. The displacement along these faults is unknown.

Age relationships

Thrusts. The structure and the stratigraphy indicate two periods of thrusting. The Thaynes formation forms the sole of the first thrust sheet. Where this thrust is exposed, the Thaynes formation has overridden the Kootenai formation.

The second thrust brought the Madison limestone over beds ranging in age from the Pennsylvanian (Quadrant quartzite) to the Lower Cretaceous (Kootenai formation). This is the Tendoy thrust. It has overridden the earlier thrust and covers it in all but two places in the area.

The relationship described above makes it difficult to determine the exact age of these two thrusts. No clastics are known to have formed as a result of the first thrust and the thrust itself is largely obscured. The Tendoy thrust may have supplied the source material of the Red Rock conglomerate.

The close spatial relation of the two thrusts suggests that they are closely related in age. Their relation to the Red Rock conglomerate is of critical importance.

Red Rock conglomerate. No fossils have been found in the Red Rock conglomerate and its exact age is unknown. Its lithology indicates that it is a product of a Laramide highland to the west. East of Dell it is overlain unconformably by the Sage Creek formation (E. Douglass, 1903, p. 145-146) of upper Eocene age. These two features suggest that the Red Rock conglomerate is lower Eocene or Paleocene in age.

The conglomerate alone reveals two phases of deformation. It rests unconformably on the early Laramide folds and therefore post-dates one period of folding. The conglomerate itself was deformed by a later period of Laramide folding. To which of these phases of deformation the Tendoy thrust belongs is not yet clear. The Tendoy thrust cuts the early Laramide folds and is therefore later than the early Laramide folding. However, the thrusting may have been closely associated with this period of deformation. In the Lima anticline, the Red Rock conglomerate is involved in the thrusting (A. J. Eardley, personal communication). Further field work is needed to establish the relation of this thrust to the Tendoy thrust. If these two thrusts tie together, then the Tendoy thrust is later than the conglomerate. On the other hand if these two thrusts do not connect the relation of the Tendoy thrust to the Red Rock conglomerate will still be unknown.

Muddy Creek Basin beds. The Muddy Creek Basin beds are placed in the Miocene. The Sage Creek formation which is exposed just east of Dell is upper Eocene in age and it has been suggested that it correlates with the Muddy Creek Basin beds. One afternoon was spent examining the Sage Creek formation. It was found to consist of a series of interbedded conglomerates, sandstones, and siltstones. Some rhyolite flows were noted but no bentonite beds were found. Fragmental vertebrate remains were numerous but plant remains were absent. The predominant colors were light gray and various shades of red. On the other hand, the Tertiary beds of Muddy Creek Basin are generally finer grained and the predominant colors are dull grays and browns. Plant remains were abundant but no vertebrate remains were found. Lithologically, therefore, the two deposits are not very similar. J. B. Umpleby (1913, p. 38) assigns the Tertiary basin beds of Montana to the Miocene and notes that they are lake beds with rhyolite at the base. J. T. Pardee (1911, p. 233) states that the Tertiary basin beds consist of tuffs, clays, sands, paper shales, and impure limestones with rhyolite flows at the base of the succession. He places these beds in the Miocene. But in view of the complexity of the numerous basin beds in Montana, these references and age assignments have little application to the Muddy Creek Basin beds. Bones of middle or late Miocene age were found in the Ruby Reservoir area and the deposits in which they occurred are similar to the Muddy Creek Basin beds (A. J. Eardley, personal communication).

High angle faults. Plate 6 illustrates recent movement along the Red Rock fault. Similar movements have probably taken place along the other high angle faults. Fixing the time when these faults came into existence is a little more difficult. All that can be said definitely is that considerable movement has taken place since the deposition of the Muddy Creek Basin beds. The basin beds have a fairly uniform dip of approximately

20 degrees to the east. The beds dip away from the faults on the southwest side of the basin and into the fault on the northeast side of the basin and since they are fine grained layered deposits, they have not accumulated against a fault scarp. Since the deposition of the basin beds, the movement along the Muddy Creek fault has been considerably greater than that along the two faults that bound the southwestern side of the basin. It is possible that some faulting occurred before the deposition of the basin beds, but it is not indicated by the field evidence.

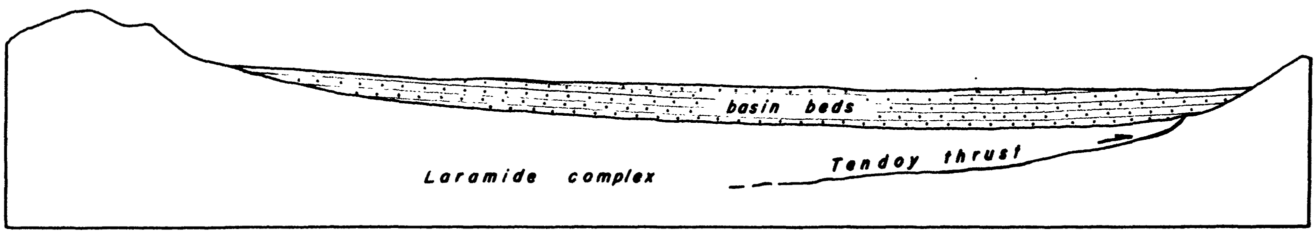
PHYSIOGRAPHY

Following the deposition of the Red Rock conglomerate and its deformation, a cycle of erosion resulted in valleys, evidently broad, and as far as known, deposits of upper Eocene, Oligocene, and Miocene accumulated successively. These basins have been attributed to faulting and warping as well as erosion, but not enough is known to date to consider this subject further with profit.

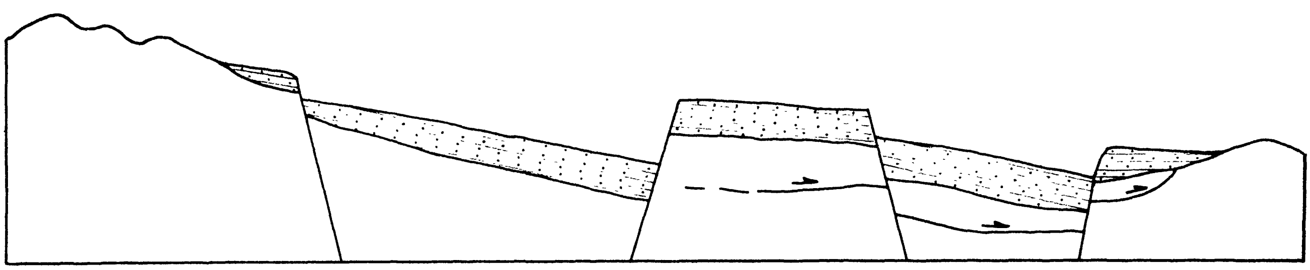
The exposed Tertiary fill in Muddy Creek Basin accumulated before faulting. The similar lithology of the basin beds of Nicholia Basin to the west suggests that the two basins were once continuous. See plate 7, 1.

Underlying the lake beds are tuffs and flows, and this relation suggests that volcanism may have played a part in forming the basins. The extrusive rocks may have formed barriers which blocked the drainage and ponded the streams.

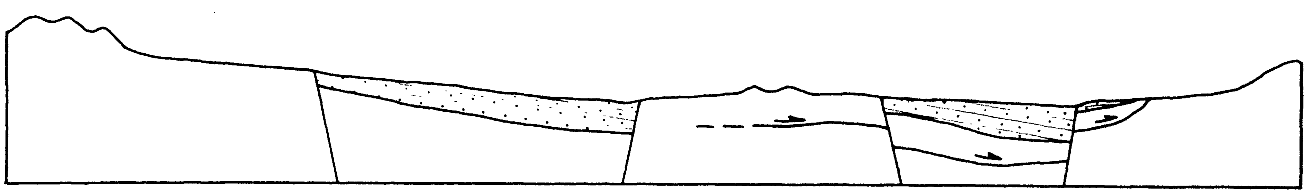
Following block faulting, erosion stripped the soft sediments from the uplifted blocks. See plates 7, 2 and 7, 3. Two small patches of Tertiary volcanics are present on the upthrown block that forms the Tendoy Mountains. One of these exposes a water laid tuff containing water



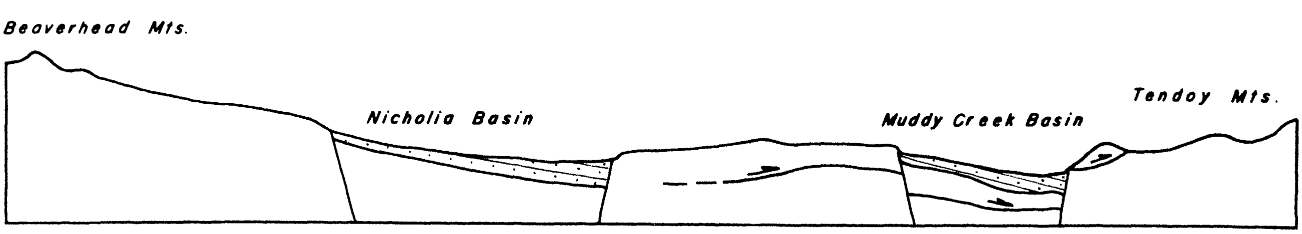
1) Miocene – accumulation of extrusives and fine clastics in broad basins.



2) Late Miocene – block faulting.



3) Late Pliocene – basin beds have been eroded from horst blocks; extensive pediments developed.



4) Present-differential erosion; development of fault line scarps.

Diagramatic sketches showing four stages in the development of the Mid-Tertiary deposits of Muddy Creek Basin and Nicholia Basin.

worn pebbles overlain by basalt. The tuff is similar to those found in the Muddy Creek Basin beds. This apparently represents an uneroded remnant of the basin beds that was covered by later basalt flows before the stripping of the basin beds from the upthrown block was completed. The basalt flows seem to have originated from the nearby cones. Some of these cones still have internal drainage. No basin beds were found in these cones. Therefore, they must post-date the basin beds.

The dating of erosion surfaces in the Northern Rocky Mountains and the relation of these surfaces to the Tertiary basins of Montana has been a controversial issue for some time. Various hypotheses with conflicting evidence are presented by W. W. Atwood (1916, p. 698-732), J. T. Pardee (1911, p. 229-244), J. B. Umpleby (1913, p. 21-30), V. R. D. Kirkham (1927, p. 11-13), E. Blackwelder (1912, p. 410-414), and J. L. Rich (1918, p. 89-90). No attempt is made to evaluate these different hypotheses.

The southwestern half of the horst block that forms the Tendoy Mountains is largely mantled by a heterogeneous float consisting of subrounded to rounded scattered fragments of the more resistant Paleozoic and Mesozoic formations. It is not known if similar gravels are present on the surface of the horst block that lies to the southwest of Muddy Creek Basin, but the surface of this block is nearly level and at approximately the same elevation as the high level gravels of the Tendoy block. These two features indicate the presence of a pediment. Evidently, erosion of the Mid-Tertiary block mountains continued through the Pliocene and by the end of Pliocene time the area was much reduced in relief and widespread pediments were developed.

Two dissected pediment surfaces developed on the soft Tertiary fill in Muddy Creek Basin show two interrupted cycles of erosion. The first of these cycles is represented by long flat topped spurs that project toward the center of the basin. See plate 8. The surfaces of these spurs slope gently toward Muddy Creek. On the northwest side of the basin these surfaces truncate the dipping basin beds. The lower pediment is much less dissected and generally forms the floor of the basin. This pediment is separated from the present flood plain by a small scarp.

Walter Kupsch and Robert Scholten (personal communication) found an analogous situation in Nicholia Basin. There, as in Muddy Creek Basin the vertical interval between the first and second pediments is much greater than

Plate 8. View looking south showing the two pediment surfaces in Muddy Creek Basin.

that between the second pediment and the present flood plain.

The drainage of Sheep Creek across the fault blocks is a problem of interest. The soft Cretaceous rocks of the Little Water syncline should have offered an easier course across the upthrown block than the hard Quadrant and Madison formations through which Sheep Creek has cut its present canyon. This suggests that the course of Sheep Creek pre-dates the high angle faulting and that Sheep Creek is an antecedent stream. The high level gravels also suggest that Sheep Creek Canyon is the site of an ancient drainage. The gravels lie on what is considered to be a late Pliocene pediment as far as can be determined to date. The surface is somewhat lower than the crest of the Tendoy Mountains which indicates that Sheep Creek followed its present course during late Pliocene time and occupied a valley through the Tendoy Mountains that existed before pedimentation. If no valley existed at that time it seems certain that Sheep Creek would have crossed the Tendoy Mountains through the Little Water syncline. Thus, it seems that Sheep Creek Canyon is the site of an ancient drainage and that Sheep Creek existed in its present position before block faulting and held to its course across the Tendoy horst block during the uplift.

Kupsch and Scholten (personal communication) also noted three stages of glaciation in the Beaverhead Mountains. Except where Sheep Creek cuts through the Quadrant quartzite, the valley is floored with Pleistocene and recent alluvium derived from the outwash plains of local glaciers in the Beaverhead Mountains.

SUMMARY OF EVENTS

Late Cretaceous	Laramide folding and (?) thrusting.
Early Paleocene	Erosion of the highlands and deposition of the Red Rock conglomerate.
Late Paleocene	Folding and thrusting (?) of Red Rock conglomerate and older rocks.
Upper Eocene	Reduction of the region to a surface of moderate relief; deposition of the Sage Creek formation.
Oligocene	Deformation of surface by warping and development of Tertiary basins by warping and/or erosion.
Miocene	Volcanism and filling of the Tertiary basins.
Late Miocene	Block faulting.
Pliocene	Pedimentation.
Late Pliocene or Pleistocene	Local volcanism.
Pleistocene and Recent	Development of present topography by three partial cycles of erosion.

BIBLIOGRAPHY

Atwood, W. W., (1916) The Physiographic conditions at Butte, Montana and Bingham Canyon, Utah when the copper ores in these districts was enriched, Econ. Geol., vol. 11, no. 8, p. 698-732.

Bevan, A., (1929) Rocky Mountain Front in Montana, Bull. G. S. A., vol. 40, p. 427-456.

Blackwelder, E., (1912) The old erosion surface in Idaho, a Criticism. Jour. Geol., vol. 20, p. 410-414.

Blackwelder, E. (1918) New geological formations in western Wyoming. Wash. Acad. Sci. Jour., vol. 8, p. 417-426.

Boutwell, J. M. (1907) Stratigraphy and structure of the Park City Mining District, Utah. Jour. Geol. vol. 15, pp. 434-458.

Branson, C. C. (1935) Carboniferous stratigraphy of Wyoming. Geol. Soc. Am. Proc. 1935, pp. 391-392.

Cobban, W. A. (1945) Marine Jurassic formations of Sweetgrass Arch, Montana. Bull. A.A.P.G., vol. 29, no. 9, p. 1262-1303.

Condit, D. D. (1916) Relations of the Embar and Chugwater formations in central Wyoming. U.S.G.S. P.P. 98, p. 263-270.

Condit, D. D. (1918) Relations of late Paleozoic and early Mesozoic formations of southwestern Montana and adjacent parts of Wyoming. U.S.G.S. P.P. 120-F, p. 110-206.

Darton, N. H. (1904) Comparison of the stratigraphy of the Black Hills, Bighorn Mountains, and Rocky Mountains, Front Range, Bull. G. S. A. vol. 15, p. 379-448.

Douglass, E. (1903) New vertebrates from the Montana Tertiary. Carnegie Museum Annals, vol. 2, p. 145-149.

Fisher, C. A. (1909) Geology of the Great Falls Coal Field, Montana. U.S.G.S. Bull. 356, 85 pages.

Kirkham, V. R. D. (1927) A Geologic reconnaissance of Clark and Jefferson and parts of Butte, Custer, Fremont, Lemhi, and Madison Counties, Idaho. Idaho Bur. of Mines & Geol., Pamphlet 19, 47 pages.

Kummel, B. (1942) See Newell, N. D.

Mansfield, G. P. (1912) See Richards, R. W.

Newell, N. D. and Kummel, B. (1942) Lower Eo-Triassic stratigraphy, western Wyoming and southeastern Idaho. Bull. G. S. A., vol. 53, p. 937-996.

Pardee, J. T. (1911) Coal in the Tertiary lake beds of southwestern Montana. U.S.G.S. Bull. 531, p. 229-244.

Peale, A. C. (1893) The Paleozoic section in the vicinity of Three Forks, Montana. U.S.G.S. Bull. 110, p. 1-56.

Rich, J. L. (1918) Dating of peneplain: an old erosion surface in Idaho, Montana, and Washington. — Is it Eocene? Abstract, Bull. G. S. A., vol. 29, p. 89-90.

Richards, R. W. and Mansfield, G. P. (1912) The Bannock overthrust; a major overthrust in southeastern Idaho and northeastern Utah. Jour. Geol., vol. 20, p. 681-709.

Ross, C. P. (1934) Correlation and Interpretation of Paleozoic stratigraphy in south central Idaho. Bull. G. S. A., vol. 45, part 2, Oct., p. 937-1000.

Scott, H. W. (1935) Some Carboniferous stratigraphy in Montana and northwestern Wyoming. Jour. Geol., vol. 43, no. 8, p. 1011-1032.

Umpleby, J. B. (1913) Geology and ore deposits of Lemhi County, Idaho. U.S.G.S. Bull. 528, 182 pages.

Weed, W. H. (1896) Yellowstone National Park; sedimentary rocks. U.S.G.S. Geol. Atlas, Yellowstone Nat. Park folio no. 30.

Plate 9

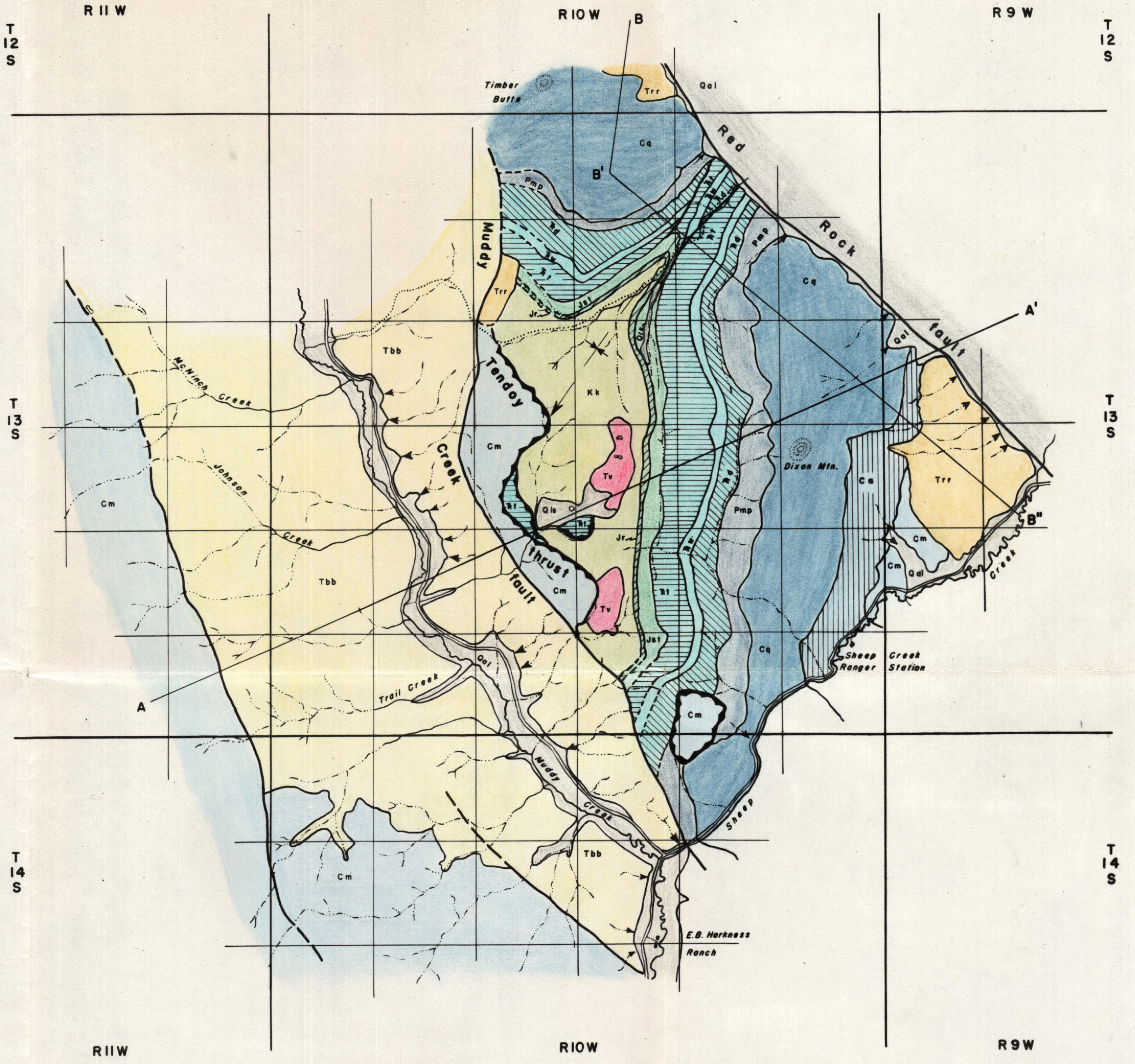
EXPLANATION

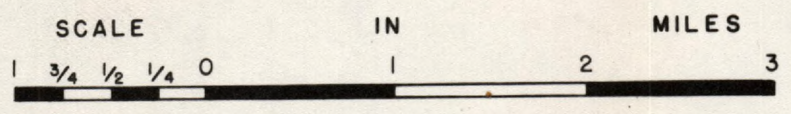
Sedimentary rocks

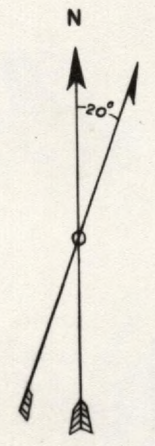
QUATERNARY	Qal	Alluvium
	Qls	Landslide
MIOCENE	Tbb	Muddy Creek basin beds
PALEOCENE	Trr	Red Rock conglomerate
CRETACEOUS	Kk	Kootenai formation
JURASSIC	Jr	Rierdon formation
	Jst	Sawtooth formation
TRIASSIC	Ꞧt	Thaynes formation
	Ꞧw	Woodside formation
	Ꞧd	Dinwoody formation
PERMIAN	Pmp	Phosphoria formation
CARBONIFEROUS	Cq	Quadrant quartzite
	Ca	Amsden formation
	Cm	Madison limestone

Igneous rocks

TERTIARY	Tv	basalt flows & breccia







Planimetric Map from aerial photographs

Control, U.S. Forest Service Map of

Beaverhead National Forest, 1947

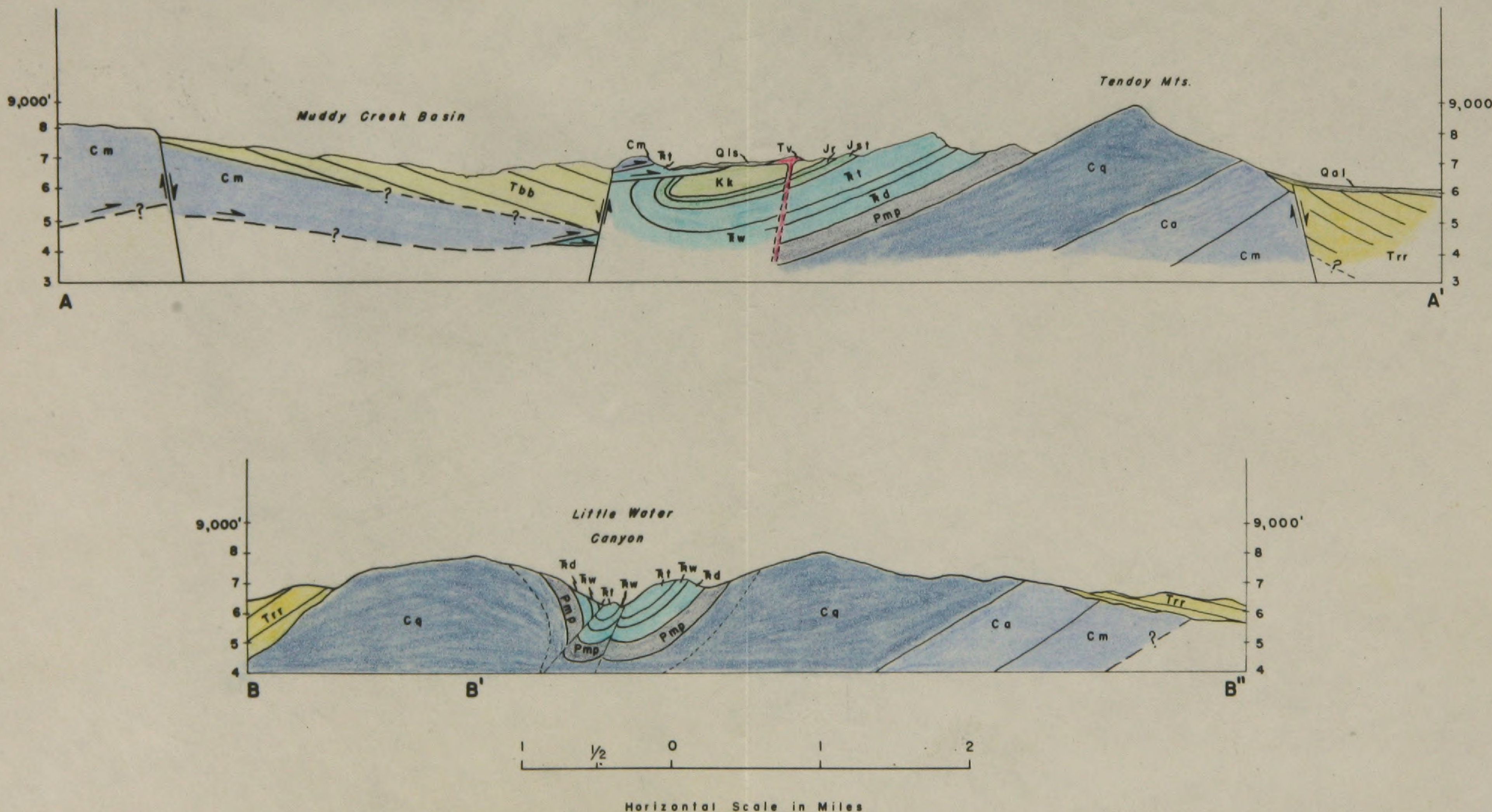
GEOLOGY OF PART OF THE

TENDOY MOUNTAINS, BEAVERHEAD COUNTY,

MONTANA

BY H. H. KRUSEKOPF & S. R. WALLACE

Plate 10



Cross-sections of Tendoy Mountains: Cm, Madison ls.; Ca, Amsden fm.; Cq, Quadrant qtzite.; Pmp, Phosphoria fm.; ҧd, Dinwoody fm.; ҧw, Woodside fm.; ҧt, Thaynes fm.; Jst, Sawtooth fm.; Jr, Rierdon fm.; Kk, Kootenai fm.; Trr, Red Rock congl.; Tbb, Muddy Creek Basin beds; Qls, landslide; Qal, alluvium.

H.H KRUSEKOPF & S.R. WALLACE

COLUMBIAN [illegible] CLASP [illegible]
PAT. 1,230,08[illegible] PAT. 1,[illegible],048
THE UNITED STATES ENVELOPE CO. SPRINGFIELD, MASS.
7[illegible] X 10½