THE GEOLOGY OF THE TENDOY-MEDICINE LODGE AREA,
BEAVERHEAD COUNTY, MONTANA

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ABSTRACT

The Tendoy-Medicine Lodge area is located in the southwestern part of Montana in Beaverhead County. The area, approximately 150 square miles in size, was studied and mapped during the Summer of 1948 by Dean L. Cummins and William T. Smith, graduate students at the University of Michigan. The rocks in the area range in age from Mississippian to Recent. They are severely faulted in the eastern part of the area, four normal faults and one reverse fault being mapped. The general structural trend is north-south, although two episodes of diversely oriented Laramide folds are represented. A granodioritic intrusion in the central and western part of the area has made for some interesting mineralization. Two prospects of commercial significance were studied.

Three well-defined erosion surfaces are evidenced in the area, the Black Rock surface at 7500-9000 feet, the Circle surface developed at 6000-7000 feet, and the present surface now being developed on modern river bottom lands. Pedimentation has been extensive in the basins.

CONTENTS

INTRODUCTION

Location and accessibility of the area

The Tendoy-Medicine Lodge area is located in the extreme southwestern part of Montana in Beaverhead County. The part of the area with which this thesis is concerned lies within Townships 12 and 13 S., Ranges 10 and 11 W. The mapped area is roughly bounded by Big Sheep Creek on the south, by U.S. Highway 91 on the east, by the northern boundary of T. 12 S. on the north, and by Medicine Lodge Creek on the west. The area approximates 150 square miles. It is readily accessible from Lima on the south via Big Sheep Creek road, Muddy Creek road, and Cabin Creek road. From Armstead, on U.S. 91 to the north, access is gained to the area by the Medicine Lodge road. Besides these roads which are comparatively good, there are also numerous foot and wagon trails, some of which are passable by motor vehicle in dry weather.

Description of the area

The area consists of two high north-south trending ridges or ranges, the Tendoy Mountains and an unnamed range. The Tendoy Mountains are flanked by the Red Rock basin on the east and the Muddy Creek basin on the west, and the unnamed range lies to the west of the Muddy Creek basin and to the east of the Medicine Lodge Creek basin. The local relief is approximately 3800 feet, and the gorge of Big Sheep Creek through the Tendoy Mountains is very precipitous. The lowest elevation in the area is 6300 feet above sea level near the mouth of Big Sheep Creek and the highest point is Ellis Peak which rises over 10,000 feet. The three basins are the sites of several large ranches and afford good hay meadows in places. The intervening uplands are excellent grazing lands for sheep and cattle. Wild game is plentiful. Badlands are locally developed in Muddy Creek basin and torrent gullies as much as 20 feet deep are common.

The area lies in the headwaters of the Missouri drainage system. It is drained by Big Sheep and Medicine Lodge creeks, both of which flow into the Red Rock River which, itself, flows subsequently into the Beaverhead River. The Continental Divide is located at the crest of the Beaverhead Mountains to the west and forms the Montana-Idaho border.

Previous work

Little detailed work had been done in this or surrounding areas, prior to the Summer of 1947. A reconnaissance map was made of the Tendoy Mountains and the area to the west and south as far as the state line by E. S. Perry and U. M. Sahinen during the Summer of 1946. Part of the area was mapped in detail by W. Lowell during the same season, but the results of his work are as yet not published. During the Summer of 1947, E. G. Lipp, R. W. Becker, H. H. Krusekopf, and S. R. Wallace, graduate students at the University of Michigan, mapped areas to the south of the area of this thesis. The area which was jointly mapped by Wallace and Krusekopf has been incorporated with some changes into the map which accompanies this report. The author and his associate recognized outcrops of Triassic beds that had been misidentified and consequently, a slightly erroneous picture of the structural relationships was postulated by Wallace and Krusekopf. At the suggestion of Prof. Eardley, the area which they mapped was included as reinterpreted in the author's map. It constitutes approximately the south-eastern quarter.

Purpose of the study

The work was undertaken with the purpose in mind to map in detail the area and to work out its geologic history. The report is written as a thesis by the author as a partial fulfillment of the requirements for the degree of Master of Science in Geology at the University of Michigan.

Acknowledgments

The field work for this report and its subsequent writing was done during the Summer of 1948 under the supervision of Dr. A. J. Eardley, Professor of Geology at the University of Michigan. Dr. Eardley also supervised the preparation of the accompanying geologic map of the thesis area. The writer is indebted to William T. Smith, graduate student at the University of Michigan, with whom he collaborated on the field work, and to Walter O. Kupsch, also a graduate student at the University, within whose larger Ph. D. area the area of this thesis was located.

STRATIGRAPHY

Stratigraphic column

The rocks exposed in the area range in age from the Madison limestone of Kinderhookian-Osagian (?) age to Recent. However, inasmuch as older rocks have been described in surrounding areas the writer will include a brief discussion of pre-Mississippian rocks in the report. Because of the difficulty in finding suitable locations to measure the various formations within the area, and because most of the units appearing in the stratigraphic column were approximated or measured in detail during the Summer of 1947 by Kupsch, Scholten, Wallace, Krusekopf, Lipp, and Becker, graduate students at the University of Michigan, the writer and his associate felt that there would be little of value in repeating this work. Consequently, the thicknesses obtained by the aforementioned students will be used and accredited accordingly.

According to C. P. Ross (1947, p. 1126) and Kupsch (personal communication) no Mesozoic rocks are found in the Beaverhead Mountains to the west of the Tendoy Mountains. Ross puts the line marking the westward limit of outcrop of Mesozoic sediments approximately along 113° W. longitude. He further states that the Paleozoic strata thicken to the west, and the Mesozoic rocks for a short distance to the east.

The following is the stratigraphic column for the general region:

Cambrian system

Flathead quartzite--The Flathead quartzite was originally described by A. C. Peale (1893, p. 20-21) for exposures in Flathead Pass in the northeast corner of the Three Forks quadrangle, Montana. Peale placed the formation in the Lower Cambrian, but it is now generally considered to be of Middle Cambrian age. It rests unconformably on pre-Cambrian granites and varies laterally in thickness and lithology. Kupsch and Scholten (Kupsch, 1948, p. 13) measured 900 feet of Flathead at Trail Creek in the Beaverhead Mountains. The base of the formation was not exposed, however, so the figure is a minimum thickness for that locality. They describe the formation as being a reddish to maroon quartzite, thinly bedded, and often cross-bedded. There are conglomerate beds which exhibit stretched pebbles. It is generally a cliff-former, but it is highly fractured in places. No fossils were found and thus the correlation of the aforementioned section with the Cambrian Flathead quartzite is only tentative. However, the white quartzite which overlies it has been fairly well established as Ordovician in age. Perry and Sahinen (1946) previously mapped this section in Trail Creek as Beltian, but Kupsch and Ross feel that the degree of metamorphism is insufficient to justify the correlation. (Kupsch, 1948, p. 14).

Ordovician system

Kinnikinic quartzite--The Kinnikinic quartzite was named by C. P. Ross (1934, p. 94) for exposures along

Kinnikinic Creek, at Clayton, Custer County, Idaho. Its age is assigned to the Upper Ordovician. Toss estimated 3000 feet of the Kinnikinic are present in the Lemhi Range in Idaho (1947, p. 1095). However, the formation thins rapidly eastward, as Kupsch (1948, p. 15) estimated only 800 feet in the vicinity of Nicholia Creek in the Beaverhead Mountains.

The formation is described as white to light gray and in places iron-stained. Its color and the absence of fine bedding make it easily distinguishable from the underlying Cambrian quartzite, upon which it lies conformably. In places, a conglomeratic layer has been found at the base.

Devonian system

Threeforks formation--The Threeforks formation was named by A. C. Peale (1893, p. 29) for outcrops at the junction of the three forks of the Missours River, near Three Forks, Montana. The formation is of Upper Devonian age.

Kupsch (1948, p. 18) has estimated that the thickness of the Threeforks is 800 feet, but suggests that this may not be a representative figure due to difficulty in determining accurate dip measurements. Another factor which may invalidate this figure is the difficulty encountered in picking the contact with the overlying Madison limestone. Also to be considered is the fact that the Threeforks erodes into wide belts of outcrop which overexaggerate the apparent thickness. Ross (1947, p. 1112) states that there is great lateral variation in thickness which he postulates as being due to differences in amount of material originally deposited.

The formation consists of yellow and gray calcareous shales with a purplish cherty shale in the lower part. It is a slope forming formation, between two hard beds, the resistant Kinnikinic quartzite underlying it unconformably, and the cherty Madison limestone overlying it conformably.

Mississippian system

Madison limestone--The Madison limestone was named by A. C. Peale (1893, p. 33-39) for exposures in the Madison Range, Montana. However, Sloss and Hamblin (1942, p. 313) state that no satisfactory type section is exposed there and describe a section at Logan, Montana, which they propose as the type locality. Long considered as a single formation, the Madison has in many localities been subdivided into the Lodge Pole and Mission Canyon formations. This division is based largely on lithologic grounds (Weller, et al, 1948, p. 138). Although both members were observed in the subject area, the writer did not attempt to differentiate them in mapping since at no place was their contact found. Rather, they were treated together as Madison and mapped as such.

The total thickness of the Madison is not known. Nowhere in the area was the base of the formation exposed. Kupsch and Scholten (1947) measured and described 980 feet of the series, but this by no means constitutes the total thickness. They estimated 3000 feet of Madison to be present in southwestern Montana which is in accord with the 3500 feet found in Idaho by Shenon (1928, p. 7).

The Madison is composed of a series of bluish gray limestones, thin bedded in the lower part and massive in the upper part. It is interbedded with thinner units of shale. It effervesces freely in dilute acid, indicating a low magnesia content. Much of the massive portion is marked by chert nodules and calcite veins. Some horizons are fossiliferous, although fossils are rare in the outcrops found in the thesis area. The writer did, however, find several cupcorals in a poor state of preservation.

The following is a partial section of the Madison limestone measured in sections 7, 8, 9, 17, T. 17 S., R. 10 W. by Kupsch and Scholten:

12. Limestone, medium to dark gray, thin bedded, bands of dark chert, cliff-forming.............350'

11. Limestone, dark gray, weathers differentially in light gray and tan, laminated in gray colors, bedding of intermediate thickness, scattered chert nodules, crinoid stems and large cupcorals, bryozoa, gastropods. The crinoids decrease, corals increase in quantity in higher parts of unit.....200'

10. Limestone, light to medium gray, massive, strongly jointed, almost entirely built up of fossils, mainly crinoids, calcite veins, chert layers................................ 60'

9. Limestone, medium gray, weathers tan and light gray to white, bedding of intermediate thickness, strongly jointed, calcite veins, chert layers, few fossils...................... 30'

8. Limestone, light gray, weathers white, massive, no chert, completely built up of crinoid stems. 30'

7. Limestone, light gray, laminations in gray colors, cliff-forming, calcite veins, chert, very fossiliferous, crinoid stems, corals, bryozoa, brachiopods............................ 50'

6. Limestone, gray, thin bedded, slope-forming, chert nodules, calcite veins................... 15'

5. Limestone, dark gray to black, fan-like laminations, breccia layers, regular chert beds, calcite veins, fossiliferous.............100'

4. Limestone, gray, weathering pink, laminations in brown and red colors, massive chert nodules, calcite veins, corals................. 30'

3. Limestone, dark gray, thin bedded, chert and calcite, fossiliferous......................... 25'

2. Shale, brown and sandstone, violet-pink........ 30'

1. Limestone, dark gray, breccia with sandstone fragments, rusty brown, few fossils, some lenses of recrystallized crinoid stems......... 60'

Measured thickness....980'

Pennsylvanian system

<u>Amsden formation</u>--The Amsden formation was named by N. H. Darton (1904, p. 398-401) for exposures along the Amsden Branch of the Tongue River, west of Dayton, Wyoming. The exact age of the Amsden has long been under controversy. The formation may span the Mississippian-Pennsylvanian boundary. The confusion appears due in part to the multiplicity of terms which have been employed for various units. Ruth Bachrach (1946) made a study of the problem and has resolved it by placing all the members of the Amsden below the Darwin sand into the Chester. This would generally conform to C. C. Branson's (1936, p. 391-392) Sacajewea formation, although this

term has not had general acceptance since it is not a mappable unit. Bachrach's studies were restricted to the Wyoming sections, thus the boundary she proposes is not generally applicable in the Montana area. The time division is based solely upon paleontological evidence and it cannot be determined in Montana until more extensive work has been carried out.

The Amsden formation consists of a series of interbedded limestones and calcareous shales with some calcareous sandstones in the upper part. The beds range in color from dark gray to light buff, and are thin bedded. Wallace (1948) reports gypsum fragments at some horizons. However, in an area farther to the south on the East Fork of Little Sheep Creek, Richard Benner and William Adam reported gypsum in mineable quantities (personal communication).

In the subject area the Amsden formed steep slopes, capped by the Quadrant quartzite, but the author was at no place able to delimit the upper or lower contacts accurately.

The following section was measured by Wallace and Krusekopf (1947) in NW $\frac{1}{4}$, Sec. 36, T. 13 S., R. 10 W.:

29.	Limestone, dark gray weathering to light gray, fine grained..............................	2'
28.	Sandstone, light tan, friable..................	6'
27.	Limestone, dark gray weathering to light gray, fine grained..............................	8'
26.	Covered interval..................................	58'
25.	Limestone, dark gray weathering to light gray, massive, dense.........................	10'

24. Covered interval.................................139'

23. Limestone, dark gray weathering to buff color, crystalline, well bedded; contains numerous thin bands of chert.................... 43'

22. Shale, gray; grades upward into brown shales; upper part of bed covered........................389'

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'

20. Sandstone, tan, weathers to rusty brown, massive, friable................................ 24'

19. Covered interval--covered by Quadrant quartzite talus................................269'

18. Limestone, gray, finely crystalline; contains numerous organic fragments............ 12'

17. Limestone, dark gray weathering to buff, argillaceous, thin bedded with some interbedded chert.................................. 38'

16. Limestone, gray brown weathering to buff, finely crystalline, fossiliferous.............. 62'

15. Shale, gray, thin bedded, calcareous; contains numerous pelecypods...................... 80'

14. Sandstone, light tan weathering to orange-buff, hard... 3'

13. Shale, gray calcareous, thin bedded............ 29'

12. Limestone, dark gray weathering to buff, crystalline; contains productids............... 21'

11. Gray shales interbedded with limestones; grades upwards into brownish and buff colored beds...................................106'

10. Limestone, argillaceous, gray; interbedded with shales, dark gray weathering to light gray, thin bedded, calcareous; some gypsum fragments.......................................245'

9. Limestone, medium gray, medium grained, highly fractured............................... 29'

8. Shale, dark gray weathering to light gray, calcareous, thin bedded; interbedded argillaceous limestones......................... 67'

7. Limestone, light to medium gray weathering to buff, finely crystalline, highly fractured; fractures filled with secondary calcite.................................... 14'

6. Shale, dark gray weathering to light gray, calcareous, thin bedded; interbedded argillaceous limestones....................... 43'

5. Limestone, gray, thin bedded, argillaceous..... 67'

4. Limestone, buff colored, thin bedded, silty.... 10'

3. Limestone, dark gray, fine grained, petroliferous.................................. 4'

2. Shale, gray weathering to light gray, thin bedded, calcareous; contains pelecypods........ 86'

1. Limestone, dark gray weathering to buff, dense, compact................................. 48'

Total thickness......2022'

Quadrant quartzite--The Quadrant was first named by A. C. Peale (1893, p. 32-43) from outcrops on the southwest side of Quadrant Mountain in the northwestern part of Yellowstone Park. Subsequently W. H. Weed (1896, p. 5), D. D. Condit (1918, p. 111), and H. W. Scott (1935, p. 1013) have used the name to include rock units of different ages and lithology. Some students have described fossils as young as middle Virgil in the Quadrant, or its equivalent in Wyoming, the Tensleep (Bachrach, 1946). However, the Pennsylvanian Subcommittee of the National Research Council Committee on Stratigraphy, (Moore, et al, 1944) calls the Quadrant middle Desmoinian in age, based on fusilinids, saying that no Missourian fossils have been recognized.

The term as used by the author included those beds lying between the Amsden and the Phosphoria formations, approximately equivalent to the Tensleep sandstone of Wyoming. It consists of a thick series of massive, light tan to white, quartzitic sandstones with some dolomite beds in the upper part. It is easily identifiable in the field by its large, dark talus slopes, the angular blocks of which are profusely covered with black lichens. Four of the highest peaks in the area are capped by the Quadrant--Ellis Peak, Dixon Mountain, Graphite Mountain, and Timber Butte. As far as could be ascertained by the author locally, the relationship of the Quadrant to the underlying Amsden is conformable, although Scott (1935, p. 1020) states that regionally in western Montana and northern Wyoming the Quadrant lies disconformably on the Amsden.

The following section was measured by Lipp, Becker, and Krusekopf (1947) in the 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, soft, white, easily weathered, forms rolling slope...........................131.0'

5. Sandstone (first exposure), dense, white to light gray, weathers to brownish tan, becomes light tan toward top..................1724.9'

4. Sandstone, friable, massive, dark tan, weathers to yellowish tan. Many black lichens covered talus slope near top..........913.6'

3. Sandstone, friable, massive, light tan, weathers to light gray, interbedded with 2 inch thin layers of more quartzitic and slightly dolomitic near the center. Also another member of quartzitic, slightly dolomitic sandstone near top..109.4'

2. Sandstone, quartzitic, very dense, gray to buff, weathers to tan, thinly bedded with thin 3 inch shaly sandstone layers........ 5.0'

1. Sandstone, white to buff, friable, mottled slightly reddish, fine well sorted sand, weathers to light gray, becomes more dense near top, massive, cross bedded................................... 43.8'

Total thickness......3319.1'

Permian system

Phosphoria formation--R. W. Richards and G. R. Mansfield (1912, p. 683-689) named the Phosphoria formation for exposures in Phosphoria Gulch near Meade Park, Idaho. In the subject area the formation consists of a diversified lithology. The series includes interbedded shales, limestones, dolomites, sandstones and siltstones. In places, the limestones and dolomites megascopically bear close similarity to the Madison limestone of the area. This resemblence occasioned one instance of misidentification on the part of Wallace and Krusekopf. In Sec. 35, T. 13 S., R. 10 W., and Sec. 2, T. 14 S., R. 10 W., they mapped as a klippe of their postulated Tendoy thrust a blue-gray limestone and dolomite lying between two yellow siltstones. They termed this Madison, but actually it was a member of the Phosphoria. A Brachiopod was found in this unit which was identified by Carl Moritz of the Phillips Petroleum Company as Bucksonia sp., a Permian index fossil (personal communication).

The phosphorite and phosphatic shale horizons which characterize the Permian in northwestern Wyoming were reported as absent from the section by Wallace (1948, p. 15), but Benner and Adam report finding phosphorite in a trench in Sec. 3, T. 15 S., R. 9 W. (personal communication). The Rex chert member of the type locality is not clearly represented as a unit, but most of the upper beds contain large chert nodules.

The following Phosphoria section was measured in Sec. 35, T. 13 S., R. 10 W., by Lipp, Becker, and Krusekopf (1947):

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

19. Dolomite and chert, gray, massive, fractured, hard, weathers gray with slight red-brown color, slight limonitic stains, also thin limestone beds interbedded. Forms a vertical, prominent cliff in one place but is partly covered in other places.................191.6'

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

17. Sandstone, mostly covered brownish sandstone; the sandstone weathers into small angular talus. Some chert present............. 66.0'

16. Limestone, massive, hard, gray, weathers light yellowish tan............................ 15.7'

15. Shale, light buff, mostly covered.............. 31.6'

14. Siltstone, red, very slightly limy, rather hard, forms small cliffs over the tan limestone; massive at top and bottom and thin bedded between.................. 45.1'

13. Limestone, yellowish tan, friable, fine grain, thinly bedded, also more or less massive in places...................... 10.0'

12. Dolomite, dense, medium dark gray, weathers light gray, chert is bluish, greenish and dark gray (concretions), some lime present, hard, also some chert lenses that resemble angular conglomerates................................ 8.4'

11. Sandstone, calcareous cement, fine grain, hard, light gray, weathers buff to medium dark gray, faint light gray or white color bands................................ 6.3'

10. Dolomite, contains a few chert concretions, sandy, light gray to white, weathers same, hackly weathered surface, massive but well fractured, horizontal joints, more chert lenses near the top............................ 92.6'

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

8. Chert, gray green............................ 0.8'

7. Limestone, hard, slightly sandy, dark gray-green, weathers gray, occasional thin chert layers, massive............................ 6.0'

6. Limestone with chert beds; limestone is gray, weathers same, chert is white to gray to medium dark, beds of chert 2 inches to 8 inches thick. Toward the top becomes less limy and the chert layers disappear and become concretions and are a little darker.................. 76.3'

5. Chert and dolomite; chert is medium dark gray, dolomite is light gray, more chert than dolomite.................................... 12.5'

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

3. Sandstone, more calcareous near base, fine grain, hard, massive, light gray, weathers same, few calcite stringers throughout......... 44.5'

2. Limestone, light gray, contains chert that is dark gray; the chert is in large concretions in the limestone. Limestone is very fine grained, hard, and massive..................... 71.6'

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

Total thickness.......802.8'

Triassic system

<u>Dinwoody formation</u>--E. Blackwelder (1918, p. 425) named the Dinwoody formation for exposures in the Canyon of Dinwoody Lakes in the Wind River Range, Wyoming. Blackwelder originally defined the limits of the formation as the top of the underlying Phosphoria formation and the bright red shales and siltstones of the Chugwater formation above. However, N. D. Newell and B. Kummel (1942, p. 941-947) found that the red of the Chugwater is not a true stratigraphic plane, but that it crosses both lithologic and time lines. Thus they redefined the Dinwoody as including only the lower silty portion of Blackwelder's original Dinwoody. The beds called Dinwoody in the thesis area are convient to map because they occur below a red member, and are called Dinwoody provisionally.

The following section was measured in the W. ½, Sec. 26, T. 13 S., R. 10 W., by Lipp and Becker (1947):

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'

Woodside formation--The Woodside formation was named by J. M. Boutwell (1907, p. 446) for exposures in Woodside Gulch, in the Park City District, Utah. The Montana usage of the term Woodside generally includes the entire Triassic section. However, Wallace (1948) provisionally divided the Triassic sediments into the Dinwoody, Woodside, and Thaynes formations. This division was made on lithologic grounds and paleontological work will be needed to establish it.

The Woodside formation consists of interbedded sandstones, limestones and shales, the color varying from red to brown to gray.

The following section was measured and described by Lipp and Becker (1947) in W. $\frac{1}{2}$, 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'

Thaynes formation--J. M. Boutwell (1907, p. 448-452) named the Thaynes formation for outcrops in Thaynes Canyon in the Park City District, Utah. The section exposed in the Tendoy Mountains consists of a thick succession of light gray to buff, fine-grained, calcareous sandstones and finely crystalline limestones, and is clearly mappable above the red Woodside formation. Its correlation with the type Thaynes is provisional. Paleontological work has not been done.

The following section of the Thaynes was measured and described by Wallace, Krusekopf, Liff, and Becker (1947) from exposures 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'

Jurassic system

Sawtooth formation--The Sawtooth formation was named by W. A. Cobban (1945, p. 1274-1276) for exposures in Rierdon Gulch in the Sawtooth Range, Montana. The Sawtooth constitutes the lowest formation of Cobban's Ellis group, the middle formation being the Rierdon, and the top, the Swift. Wallace (1948, p. 26) states that the presence of the Swift in the Little Water syncline was doubtful, but the writer was informed by Sloss that a thin section of the Swift as well as the overlying Morrison were found in a trench dug on the north flank of the syncline. Unfortunately, no description of these sections is available.

The total thickness of the Sawtooth in the Tendoy Mountains was not ascertained as the top of the measured section was covered by volcanics. The most conspicuous unit is a dark tan, white mottled, friable sandstone (Wallace, 1948, p. 26).

The following incomplete section was measured and described by Wallace and Krusedopf (1947) from exposures 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'

Rierdon formation--W. A. Cobban (1945, p. 1277-1280) named the Rierdon formation for exposures in Rierdon Gulch in the Sawtooth Range, Montana. In the Tendoy Mountains it consists of interbedded calcareous shales and oolitic limestones. (Wallace, 1948, p. 27).

The following section was measured by Wallace and Krusekopf in W. ½, Sec. 10, T. 13 S., R. 10 W.:

4. Covered interval.............................. 78'

3. Oolitic limestone, gray to buff, massive....... 10'

2. Shale, light brown, calcareous................. 20'

1. Oolitic limestone, gray to buff, massive....... 8'

Total thickness......116'

Cretaceous system

Kootenai formation--C. A. Fisher (1909, p. 28-35) named the Kootenai formation for exposures near Great Falls, Montana. Wallace (1948, p. 28) describes the Kootenai in the Tendoy area as consisting of a thick series of variegated red, yellow, and purple silty shales interbedded with "salt and pepper" sandstones and limestones. He makes mention of a prominent gastropod marker bed in the lower part of the formation. The exact base of the Kootenai is uncertain in the area since it is poorly exposed. The gray shales tentatively placed at the base may very possibly belong in the Morrison formation. The age of the Kootenai is considered to be Lower Cretaceous, and the Morrison to be uppermost Jurassic. No fossils were found by Wallace at this horizon, making a sharp distinction impossible.

Wallace and Krusekopf (1947) measured the following section of Kootenai in E. ½, Sec. 9, T. 13 S., R. 10 W. The writer is of the opinion that this section was measured entirely across the syncline, resulting in a double thickness of Kootenai (see Map, Plate 1). However, the section is included as measured to show the Kootenai lithology.

35. Covered interval.................................250'

34. Sandstone; salt and pepper, massive; some beds contain subangular to rounded pebbles of black and brown chert.............................. 26'

33. Covered interval................................ 26'

32. Sandstone, rusty brown, very well indurated, salt and pepper.............................. 26'

31. Covered interval................................ 52'

30. Sandstone, salt and pepper, massive............ 21'

29. Shale, reddish.................................. 52'

28. Sandstone, fine grained, salt and pepper....... 5'

27. Shale, brownish red............................. 42'

26. Sandstone, salt and pepper...................... 5'

25. Shale, brownish red............................. 29'

24. Sandstone, salt and pepper, interbedded with several beds of dark brown weathering calcareous sandstones............................. 10'

23. Shale, variegated, red, brown, and purple...... 31'

22.	Sandstone, salt and pepper....................	5'
21.	Shale, red....................................	33'
20.	Limestone, gray, weathers to dark brown, arenaceous..................................	2'
19.	Sandstone, salt and pepper....................	28'
18.	Shale, red....................................	21'
17.	Sandstone, salt and pepper....................	5'
16.	Shale, red....................................	23'
15.	Shale, purple-gray; includes a two foot bed of reddish brown arenaceous limestone.............	10'
14.	Shale, red....................................	57'
13.	Sandstone, gray to reddish gray; includes some interbedded sandy limestones..............	26'
12.	Sandstone, salt and pepper....................	5'
11.	Shale, red....................................	10'
10.	Sandstone, medium grained, salt and pepper, thin bedded, weathers into slabby blocks.......	36'
9.	Shale, alternating red and brown...............	73'
8.	Covered interval; includes a dark gray gastropod limestone and some gray shales not seen in measured section............................	702'
7.	Shale, red....................................	21'
6.	Sandstone, light brown to gray, medium grained, friable; toward top coarser sandstone, salt and pepper with pebbles of black chert; thin bedded..........................	36'
5.	Shale, variegated red, purple, and brown.......	42'
4.	Shale, light gray, hard, sandy.................	52'
3.	Shale, red, calcareous; contains gastroliths...	109'
2.	Sandstone, salt and pepper with small limonite concretions, massive...........................	70'
1.	Shale, dark colored; poorly exposed--possibly Morrison or Swift formations (?)...............	260'
	Measured thickness...	2201'

Tertiary system

Red Rock Conglomerate--A coarse conglomerate, generally red, occurs along the front of the Tendoy Mountains. It is also found on the east side of the valley in which Lima lies and forms part of low range of hills called the Red Rock Mountains. A conspicuous cliff of Red Rock is found just east of Dell on Highway 91. The name Red Rock has tentatively been given to this formation pending further study (Eardley, personal communication). Its age has not been definitely established because no fossils have been found in it to date. However, it is generally supposed to be Paleocene. It underlies the upper Eocene Sage Creek formation unconformably, and is younger than certain Upper Cretaceous beds in the region. It pre-dates the main Laramide thrusting , but post-dates the first Laramide movements. See later paragraphs under Structure.

The formation consists mainly of sub-rounded pebbles and cobbles of resistant Paleozoic and Mesozoic formations. Some Beltian rocks may also be present in the conglomeratic beds. Madison boulders are conspicuous and in many places seem to contribute as much as 75% of the material found in the conglomerate. It is to be noted, however, that there is great lateral diversity in the Red Rock formation. The matrix is generally calcareous and contains some iron which makes for red weathering. There are several massive sandstones interbedded with the conglomerate ranging in thickness from a few inches to several feet. These sandstone beds are generally friable and lighter in color than the conglomerates. The thickness of the Red Rock has not been determined but Prof. Eardley has estimated it to be at least 2000 feet thick in the Lima anticline. (Wallace, 1948, p. 31). The writer believes that this would constitute a minimum thickness because the exposures along the Tendoy Mountain front indicate that it is considerably thicker.

Basin beds--In the Muddy Creek basin, the Medicine Lodge Creek basin, and in intervening areas is found a thick series of continental sediments comprising what was formerly called the "Bozeman Lake beds" by Peale (1893, p. 32-43). W. P. Haynes (1916, p. 270-290) however, showed the basin beds to be sub-aerial fluviatile deposits, and maintained that, since they were not of lacustrine origin, the term "lake beds" was not proper. Furthermore, Atwood (1916, pp. 705, 706, and 712) showed that the "Bozeman Lake beds" in places were mainly glacial outwash deposits. It was formerly believed that the age of the basin beds was upper Miocene, or perhaps as young as early Pliocene, and such was stated by the University of Michigan graduate students who worked in the area during the Summer of 1947. However, it now seems more likely that they are the equivalent of Douglass' Sage Creek beds of upper Eocene age which are found in the adjacent Red Rock Hills on the east. The author has never seen these beds, but was informed by Prof. Eardley that the proximity and lithologic similarities between the Sage Creek beds and the basin beds found in the subject area make their correlation probable. In both are found bentonites and tuffs with wood fragments, and associated basalts and rhyolites (personal communication).

Kupsch describes similiar beds as occuring in the area which he studied in 1947. He applies the name Nicholia Creek basin beds to the formation, but the lithology which he describes conforms favorably to that of the basin beds in Muddy Creek and Medicine Lodge Creek basins. It is likely that all of the various basins in southwestern Montana were interconnecting prior to the Mid-Tertiary block faulting, and thus it might be expected that the deposits in two adjacent basins would be fairly similar in age.

A great variety of rocks comprise the basin beds, most of them being fairly well indurated. Among the various beds observed by the writer were included conglomerates, shales, sandstones, fresh-water limestones, bentonite, rhyolite tuffs, and siltstones. The total thickness of the deposit is unknown, although Kupsch (1948, p. 30) estimates a thickness in Nicholia Creek basin of at least 5000 feet, barring repetition of beds due to folding or faulting. It is reasonable to assume that approximately the same thickness would exist in the neighboring basins.

Although a considerable number of plant fragments have been found in the basin beds, none have proved diagnostic. However, several very good specimens were found by Kupsch, Smith, and the author in the Peterson coal mine in Section 33, T. 12 S., R. 12 W. in the Medicine Lodge Creek basin. Included among these fossils were several well preserved specimens of flowering plants which may prove of value in definitely dating the beds.

Tertiary (?) gravels--On the high spurs at the edge of the basins, at an elevation of about 7500 feet, there was found a veneer of unconsolidated gravels. The gravels, ranging from fine pebbles to boulders, consist of pre-Cambrian schists and quartzites as well as younger Paleozoic and Mesozoic rocks. That these gravels are till seems very doubtful. The gravels show no evidence of ice transportation, and the nearest source of mountain glaciers is the Beaverhead Mountains, some miles to the west. Rather, they are presumed to be pediment or channel gravels of a late Tertiary erosion surface. Their age cannot definitely stated, but they may be as young as Pleistocene (Eardley, personal communication).

Intrusive rocks--The western half of the area is intruded by an acid pluton of unknown dimensions. This rock is of a gneissic appearance due to lineation of the ferro-magnesian minerals. Megascopically, the intrusive appears to be a grano-diorite although petrographic study will be necessary for a correct determination. The intrusion caused some interesting contact metamorphism in several places in the area. In Sec. 7, T. 13 S., R. 11 W., the body is intruded into the Madison limestone. This contact is well exposed in the Sweeney mine in the NE $\frac{1}{4}$ of that section. The contact trends northeast and the mineralized vein dips 55° SW. The vein attains a maximum thickness of about 5 feet although this varies considerably. In some places as many as four thinner parallel veins were observed. The Madison has been recrystallized for a considerable distance from the contact. The mine was originally worked for lead ores, with galena and cerrusite present. At present it is being operated on a small scale. The vein also includes sphalerite and small quantities of silver. The vertical extent of the vein is about 100 feet, and its lateral extent could not be determined.

At the north end of McBride Creek, Sec. 22, T. 12 S., R. 11 W., is another mine working. Here the intrusive has a schistose appearance and carries a large amount of graphite. The source of the graphite is a matter of conjecture. This locality is near the contact with the Madison limestone, with the main trench about 100 yards from the contact. It is probable that the graphite was deposited either from hydrothermal solution, or by reduction of organic matter in the original limestone. Little could be learned about the prospect since the claim is only being held and not worked at the present time. The trench is shallow and yielded little information. It is possible that the rocks in the McBride Creek area have been cut by dikes, since a considerable amount of pegmatitic material was observed in the float.

The age of the granodioritic intrusion is a matter of considerable speculation. Ross (1928, p. 673-693) distinguishes three different groups of intrusives in this gerneral region, none of which seem to fit this particular case:

1. Idaho batholith with outliers--age is late Jurassic to early Cretaceous.

2. Boulder batholith with outliers--age is younger than the Idaho batholith but older than No. 3.

3. Tertiary granitic rock--is probably of Oligocene age.

(Kupsch, 1948, p. 42)

Kupsch describes a pluton along the Continental Divide which bears similarity to that found in this area. He dates the upper age limit of his intrusion by its relationship to extrusive flows in the area. Since these flows have generally been assigned to the Oligocene and Miocene, and since their relationship to the intrusion indicates that the flows are younger, the intrusive cannot fall into one of the categories proposed by Ross, but rather, it would conform to the pluton described by Umpleby (1913, p. 42) on the Idaho side of the Continental Divide. He assigns it to the late Cretaceous or early Tertiary.

The writer was not able to locate a relationship between the extrusives and the intrusives in his area, but on the suggestion of Kupsch it was decided to tentatively date the intrusives as Cretaceous-Tertiary. Future work may uncover relationships which will more accurately date the rocks.

<u>Volcanic rocks</u>--The extrusive rocks in the area consist of large scattered patches of thick basaltic flows, interbedded with thinner layers of rhyolites. These volcanics are mainly concentrated in Muddy Creek basin, although one tongue of basalts extends up over

the crest of the Tendoys, just north of Timber Butte. Associated with the flows are several large patches of volcanic breccia, some of which seem to indicate the presence of small spatter cones. Wallace (1948, p. 32) makes mention of spatter cones in the Little Water syncline area, stating that some of them have sufficiently retained their shape to form closed drainage basins containing small lakes.

The basalts are mainly dense and dark brown in color, although there is much local variation in color and texture. It is not uncommon to find vesicular basalts. The rhyolites and waterlaid tuffs are light colored and in some places contain phenocrysts. The maximum thickness of the extrusives is not known, but there are cliffs in the Sourdough Creek canyon which are over 300 feet high. These volcanics are generally upper Eocene and lower Oligocene in age.

Quaternary system

There is a deep mantle of alluvium of undetermined thickness in the Red Rock basin and along all the main stream courses in the area. This material extends only a short distance along each side of the stream so in some places it is not mappable. The large basins also exhibit terrace gravels of unknown thickness. In the Red Rock basin there are at least two distinct terraces, one about 40 feet higher than the other. Where exposed in cuts along the Highway 91 the gravels making up the terraces are well-rounded and show good sorting. They are only slightly indurated.

Wallace and Krusekopf mapped two small landslides in Little Water Canyon. There are numerous other landslides in the area but they are generally so small as to be unworthy of mapping.

STRUCTURE

Regional features

There have been three major periods of crustal deformation described in the region:

1. Crumpling and crushing of pre-Cambrian rocks toward the close of the Algonkian period, associated with regional metamorphism of low-grade intensity (Kupsch, 1948, p. 56).

2. Laramide movements in two phases, beginning in the Cretaceous and continuing into the early Tertiary. The early Laramide movements resulted in folding as far as known. The Later Laramide structures were the great thrust sheets. The early folds took both a northwest and northeast direction. The thrust faults trend northerly.

3. Mid-Tertiary block faulting, trending northwestward and producing horst and graben and tilted fault block topography.

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 eastward edge of this zone. The general structural pattern of the region is yet ill-defined. The major structural features (Beaverhead Mountains, Tendoy Mountains, Red Rock Mountains, Snowcrest Range, Gravelly Range, Tobacco Root Range, Madison Range, Centennial Valley) are diversely oriented. Future field work may serve to resolve the structural pattern. Still, sufficient is known to establish the geosynclinal and shelf zones, and the belt of thrusting.

Laramide structures

Folds--Folding in the area took place in two main episodes. Early Laramide folding resulted in NE-SW trending folds, as seen in the Little Water syncline, The Sawmill syncline to the south in the Lima Peaks area, and the Snowcrest uplift to the southeast in the Snowcrest Range. Later folding resulted in NW-SE trending axes. These folds make up the synclines and the southwestward dipping monoclines which form the main part of the Tendoy Mountains. The NE-SW folds pre-date the Red Rock conglomerate and the NW-SE folds may also pre-date the conglomerate. Following the deposition of the conglomerate the Beaverhead thrust occured, trending northerly and riding over the earlier Laramide features. To the north, just south of Armstead on Highway 91, the axis of the Tendoy syncline appears from under the thrust sheet (Eardley, personal communication).

Wallace (1948, p. 36) postulates that the part of the Tendoy Mountains south of Little Water canyon may represent the west flank of a north-south trending anticline of which the east flank was broken and downthrown by the Red Rock fault. However, Wallace misinterpreted the structure, believing that the sediments which make up the syncline in Little Water canyon flare to the north and south. The writer and his associate found that the structure was, in reality, almost a closed structural basin. The formations which Wallace believed to swing north actually swing back around and trend southward, paralleling the beds which make up the south flank of the syncline. Thus the anticline which Wallace postulated cannot exist.

Thrusts--The presence of one thrust was definitely established, another small thrust was postulated, and a third thrust which had been previously identified was proved non-existent.

The trace of the Beaverhead thrust (see Geologic map) was first picked up on the north flank of Timber Butte and was thence traced to the northern extent of the area. The same thrust reappears farther to the south in the area mapped by Adam and Benner. Future work may show that the thrust travels farther northward. At Timber Butte the Madison rides over the Quadrant quartzite. From the north as far as the fault was traced it was Madison over the Red Rock conglomerate. The thrust sheet is made up of the Madison limestone. The dip of the thrust sheet in Sec. 30, T. 12 S., R. 10 W. is 18° to the southwest. Dip readings were taken at several places along the thrust and they conform closely.

Another small reverse fault is portulated in the west flank of Little Water syncline (see cross section). This seems necessary to explain the horizontal displacement in the Mesozoic sediments. If no horizontal movement had occured it would seem that the west flank of the syncline would have been broken and downthrown by the East Muddy Creek fault.

During the Summer of 1947 Wallace and Krusekopf mapped a reverse fault along the west side of the Tendoy Mountains which they called the Tendoy thrust. This thrust was also mapped by Lipp and Becker in the area immediately to the south. The writer at first believed this fault existed and assumed that the thrust in his area was a continuation of the Tendoy thrust. However, upon investigation the writer and his associate found numerous columnals of the Triassic-Jurassic crinoid Pentacrinus sp. in the beds which Wallace and Krusekopf had identified as a Madison thrust sheet. Thus, the area in question was remapped as Thaynes, the sedimentary nature of the contact being established. Farther to the south in Sec. 35, T. 13 S., R. 10 W. they had mapped a klippe of the same thrust sheet. This klippe of Madison proved on investigation to be Phosphoria. Although the unit is quite unfossiliferous a brachiopod was found in this unit which was identified by Carl Moritz of the Phillips Petroleum Company as Bucksonia sp., a Permian index fossil (personal communication).

Mid-Tertiary structures

High angle faults--Four high angle faults were mapped in the area. The faults, in three instances, are the northward continuations of those mapped by Wallace and Krusedopf. They are all roughly parallel and strike in a northwesterly direction. The movement along these faults resulted in a graben, a horst, and a tilted block. Muddy Creek basin is a graben, the Tendoy Mountains a horst, and the Red Rock basin a tilted fault block.

The eastern-most fault, the Red Rock fault, truncates the Paleozoic and Mesozoic structures in the Tendoy Mountains, and with the downdropping of the basin block the mountain front was formed. The throw is estimated as 1000 feet (Wallace, 1948, p. 41). The basin has since received a thick fill of Quaternary alluvium. Recent movement along the fault is indicated by a small fault scarp, with triangular facets, cut in the alluvium at the Tendoy front. This scarp is best shown between Big and Little Sheep Creeks.

The upthrown block which forms the Tendoy Mountains is bounded on the southwest by another high angle fault, the East Muddy Creek fault. This fault, which forms the northeast side of the Muddy Creek basin, cuts across the Beaverhead thrust sheet and the broken sheet passes to the westward beneath the Tertiary sediments in the basin. The northward trace of the fault is lost at the contact of the Tertiary volcanics with the Madison in Sec. 8, T. 12 S., R. 10 W.

A third normal fault was found which cuts the Beaverhead thrust sheet along Sourdough Creek. The northeastern block was uplifted and the southwestern block was dropped. The fault was traced as far north as the tongue of intrusive rocks in Sec. 4, T. 12 S., R. 11 W. Future work may show the fault to continue farther north.

The fourth normal fault is the area, the West Muddy Creek fault, also bounds the southwest side of Muddy Creek basin, but it is displaced farther to the west than the associated fault farther to the south in the vicinity of the Lower Harkness Ranch, Sec. 15, T. 14 S., R. 10 W. Both of these faults bring the Beaverhead thrust sheet to the surface. Both are marked by fault-line scarps. The displacement along the faults is unknown.

Age relationships

Beaverhead thrust--The exact age of the thrust is not known. The youngest formation which it overrides is the Red Rock conglomerate. It is cut by the Mid-Tertiary normal faults and is overlapped by the basin beds. Since the thrust is younger than the Red Rock conglomerate (Paleocene?) and older than the basin beds (upper Eocene?) the thrust is deduced to have occured somewhere between late Paleocene and upper Eocene.

Red Rock conglomerate--Since no fossils have been found in the Red Rock conglomerate its exact age can only be guessed. That it was derived from a source-land which was vigorously uplifted is attested to by the coarseness of the material which makes up the conglomerate. It is overlain unconformably by the Sage Creek formation of upper Eocene age in the Red Rock Hills, east of Dell (Douglass, 1903, p. 145-146). This relationship, plus the fact that the source of the conglomerate was presumably a Laramide highland to the west, suggest that the Red Rock is lower Eocene or Paleocene in age.

<u>Basin beds</u>--The basin beds were first thought to be of Miocene age, but it now seems that they can be correlated with the Sage Creek beds. Their close proximity as well as their lithological similarity makes their correlation plausible. In both are found bentonites and tuffs with wood fragments, and associated basalts and rhyolites. Inasmuch as the upper Eocene dating of the Sage Creek beds is supported by paleontological evidence, the basin beds are also tentatively placed in the upper Eocene. Future work may establish or disprove this dating.

<u>High angle faults</u>--Fixing the time at which the normal faulting occured is difficult. That the Red Rock fault has experienced recent movement is evidenced by the fault scarp cut in the alluvium along the Tendoy front. However, all that can be inferred concerning the time of major displacement is that it took place following the deposition of the basin beds. In Muddy Creek basin the basin beds have a fairly uniform dip of 20° to the east (Wallace, 1948, p. 46). The lithology of the beds indicates that they were not deposited against a fault scarp, but, rather, their orientation suggests that they were tilted due to an unequal amount of displacement along the faults bounding the graben.

PHYSIOGRAPHY

The Tendoy-Medicine Lodge area is located in the Northern Rocky Mountain physiographic province. This province is characterized in southwestern Montana by a diverse structural pattern. The term "range" is not properly applied to the mountains since they exhibit little lineation. In the subject area, the relief in large part is attributable to the structure, the block fault structure controlling the topographic expression. The basins range in elevation from about 6200 feet to about 7000 feet according to the local base levels of erosion. The summit level, if such could be said to exist, ir roughly 9000 feet with a few residual peaks rising higher. These peaks are all held up by the resistent Quadrant quartzite.

Three erosion surfaces may be postulated within the area. These surfaces may possibly correlate with Blackwelder's surfaces in Wyoming. Only future detailed work can determine this. For the sake of convience the Wyoming names have been employed to designate the surfaces in the area. The oldest surface is the Black Rock surface, found from 7500 to 9000 feet. This is generally the summit surface. Younger than this is the Circle surface, generally a pediment, and best developed in the basins from 6000 to 7000 feet. This surface is well shown on the high pediments in Muddy Creek basin. The accordancy of the spurs is striking. The youngest surface comprises the river terraces of the Wisconsin and Recent and the modern river bottom lands. The age of the erosion levels is uncertain, but it does seem evident that the Circle surface post-dates the normal faulting. A good illustration of this is seen on the west side of Muddy Creek basin just south of Graphite Mountain where the prominent fault line scarp is suddenly interrupted by a reentrant of basin beds.

The area is drained by Big Sheep and Medicine Lodge Creeks. The latter is in a strike valley and has been rejuvenated at least once, as evidenced by terrace gravels. The former stream is an antecedent stream which is transverse to the Tendoy structure. If the channel had been developed on the present surface its easiest course of exit would have been through the soft Mesozoic sediments in Little Water canyon. Actually, the stream cuts through the main part of the Tendoys, not in a straight channel, but in a tight meandering course. Such a meander pattern could not have been developed on the present surface but must have been inherited from an old erosion surface which pre-dates the present topography.

The Red Rock basin has been heavily alluviated and at least two well separated terrace levels were noted.

SUMMARY OF EVENTS

Recent	Uplift and dissection. Glaciation and deposition of glacial outwash. Dissection of modern river bottom lands.
Early & Middle Pleistocene	Uplift and erosion of Circle surface pediment.
Pliocene	Erosion of Black Rock surface. Deposition of high level gravels.
Miocene	Block faulting.
Oligocene	Continued basin bed deposition and volcanism.
Upper Eocene & Lower Oligocene	Absarokan volcanism, volcanic damming, heavy volcanic dustfalls, local volcanism, creation of freshwater lakes, and extensive sedimentation in intermontane valleys.
Early & Middle Eocene	Long cycle of erosion to form intermontane valleys.
Late Paleocene or Early Eocene	Laramide thrusting. Compressional forces from southwest.
Paleocene	Erosion of highlands and deposition of Red Rock conglomerate.
Late Cretaceous	Major period of Laramide folding, producing NW-SE folds. Source of Red Rock conglomerate was elevated.
Early Cretaceous	Beginning of the Laramide orogeny. NE-SW folds produced.

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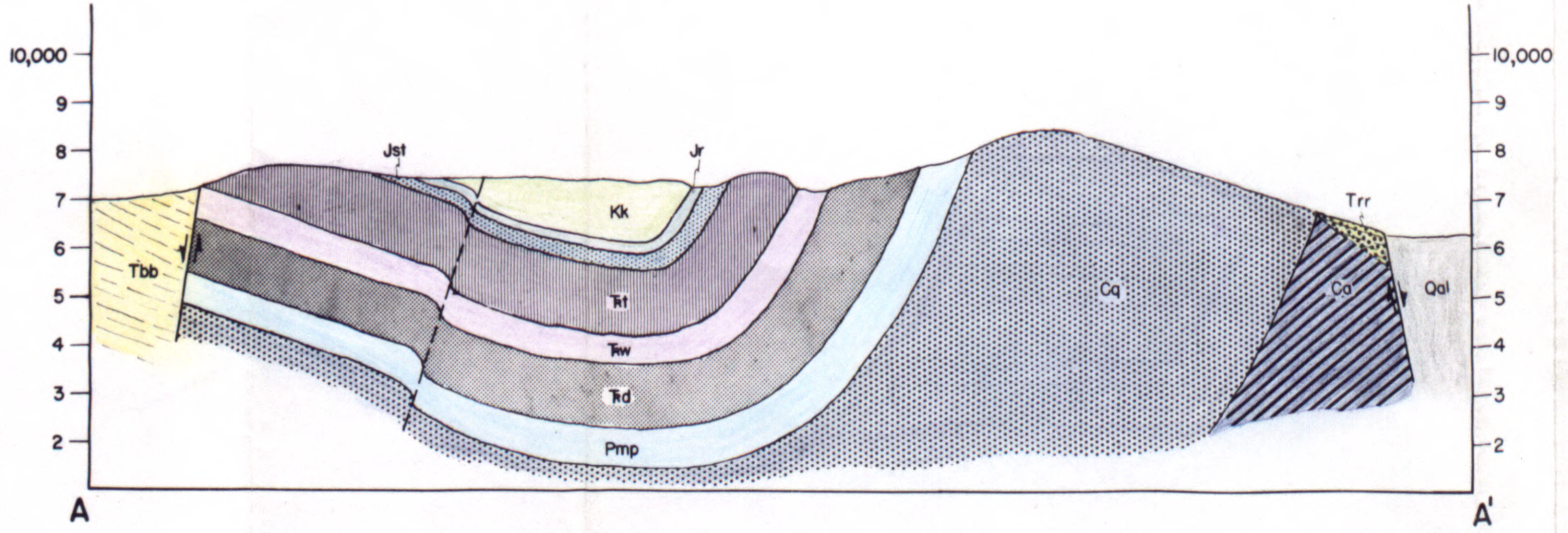
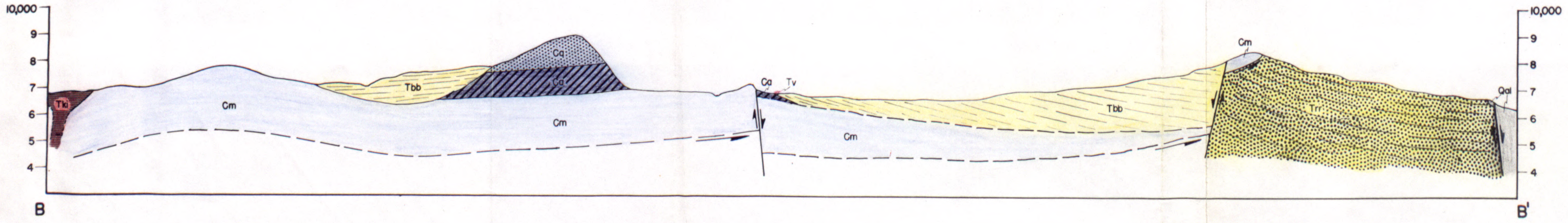
PLATE 2

STRUCTURAL CROSS SECTIONS

Profile and elevations approximated



Legend: Cm, Madison ls.; Ca, Amsden fm.; Cq, Quadrant qtzite.; Pmp, Phosphoria fm.; Ŧd, Dinwoody fm.; Ŧw, Woodside fm.; Ŧt, Thaynes fm.; Jst, Sawtooth fm.; Jr, Rierdon fm.; Kk, Kootenai fm.; Tki, Intrusive rock; Trr, Red Rock congl.; Tbb, Basin beds; Tv, Volcanic rocks; Qal; Alluvium.



1 ½ 0 1 2

SCALE IN MILES

D. L. CUMMINS & W. T. SMITH


PLATE I
GEOLOGY OF PART OF THE
TENDOY-MEDICINE LODGE AREA
BEAVERHEAD COUNTY, MONTANA
BY D. L. CUMMINS & W. T. SMITH
R 11 W
R 10 W
T 12 S
T 13 S
Ellis Peak
Graphite Mountain
Timber Butte
Dixon Mountain
Grassy Top
Muddy Hole Basin
Beaverhead Fault
Red Rock Fault
Muddy Fault
Thrust
EXPLANATION
SEDIMENTARY ROCKS
QUATERNARY
Qal Alluvium
Qls Landslide
Qt Terrace gravels
PLEISTOCENE
Tg High terrace gravels
UPPER EOCENE
Tbb Basin beds
PALEOCENE
Trr Red Rock conglomerate
CRETACEOUS
Kk Kootenai formation
JURASSIC
Jr Rierdon formation
Jst Sawtooth formation
TRIASSIC
Trt Thaynes formation
Trw Woodside formation
Trd Dinwoody formation
PERMIAN
Pmp Phosphoria formation
CARBONIFEROUS
Cq Quadrant quartzite
Ca Amsden formation
Cm Madison limestone
IGNEOUS ROCKS
UPPER EOCENE (?)
Tv Basalt flows and breccia
LARAMIDE
Tki Intrusive granite gneiss
SCALE IN MILES
1 3/4 1/2 1/4 0 1 2
Map compiled by radial line assembly of AAA aerial photographs, Series CXM, August, 1942, photograph numbers as shown on map. Control, U.S. Forest Service Map of Beaverhead National Forest, 1934.

Cummins, D.L.
Geology of the Tendoy-Medicine Area. Beaverhead County, Montana.
1948

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ILL - R. Lewis	JUN 21 1978	