THE GEOLOGY OF A PART OF THE TENDOY MOUNTAINS WEST OF LIMA, BEAVERHEAD COUNTY, MONTANA

by

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of the requirements for the degree
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ILLUSTRATIONS

ABSTRACT

The area studied is in the Tendoy Mountains of Beaverhead County, southwestern Montana. The mountains trend northwest-southeast and are approximately 40 miles in length.

The oldest formation exposed in the area of the report is the Madison, and the youngest is the Quaternary alluvium. No Mesozoic rocks are present, the nearest exposures being about a mile to the northwest. The Paleozoic rocks in the area are Madison, Amsden, Quadrant, and Phosphoria, and the Tertiary beds are the Red Rock conglomerate, and the Muddy Creek basin beds (Lower Miocene?).

Dips, in general, are to the southwest, and average about 30 degrees.

There are four faults in the area, three high angle faults and a thrust. The Tendoy thrust (late Cretaceous or early Paleocene?) moved from the southwest, its hor-

izontal displacement is unknown. The two southwestern high angle faults (late Miocene?) bound the graben of Muddy Creek basin. The latest high angle fault, the Red Rock fault (Pliocene?) at the mountain front, possibly bounds one side of a graben which forms Red Rock Basin. A small fault scarp indicates recent activity along this fault.

Several pediments along the mountain front show a high erosion surface to have existed before the Red Rock faulting. This is possibly Pliocene (?) in age and was dissected after the Red Rock basin was dropped.

INTRODUCTION

Object of the report

This report concerns the structure and stratigraphy of an area in the Tendoy Mountains of southwestern Montana. It is submitted in partial fulfillment for the degree of Master of Science at the University of Michigan.

Location of the area

The Tendoy and Beaverhead Mountains are part of the Bitterroot Range of western and southwestern Montana. The Tendoy Mountains lie 35 miles east of and are separated from the Beaverhead Mountains by the broad Nicholia Basin. The Idaho-Montana line is the crest of the Beaverhead Mountains. The Red Rock Basin and Red Rock Mountains lie to the east. (See plate I).

The area is located southwest of the town of Dell, Montana and about four miles west of Lima on

PLATE I

E. Raisz

INDEX MAP

the southwest side of U.S. Highway 91. Bordering the area on the northwest is Sheep Creek, and on the southeast, Little Sheep Creek. The northeastern boundary of the area is the Red Rock fault, about two miles southwest of Highway 91. The southwest boundary is an arbitrary line which gives the area a length of approximately 8 1/2 miles. It includes most of township 12 S, R 9 W, and parts of T 13 S, R 9 W, and T 14 S, R 10 W. The total area is approximately 52 square miles. (See plate I).

Accessibility of the area

The area is accessible by two good roads. The road bordering the northwest side of the area follows Sheep Creek Canyon along the entire northwestern border of the area and leaves Highway 91 about five miles northwest of Lima. From this road there are two small wagon trails which lead into the interior for a short distance. One, at Ranger Station, goes back about two miles into the higher country along the front of the range, and can be easily traversed by automobile. The other road heads southeast up Shearing Pen Gulch for about one mile and makes the western end of the area more easily accessible. (See plate 2 in envelope).

On the southeastern border of the area is the Little Sheep Creek road. From this road there is one wagon trail leading northwest up Straight Canyon for a distance of about a mile. Except for these roads, all travel in the interior must be done on foot.

Acknowledgements

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STRATIGRAPHY

Stratigraphic column

The stratigraphy on the following pages includes only the systems and formations that crop out in the area. Paleozoic and Tertiary sediments occur but the entire Mesozoic section is absent. The Mesozoic formations are found in the adjacent area to the northwest.

Good exposures for measuring the sections could not be found in the area so all measurements were made in the northern adjacent area. Krusekopf, Wallace, Lipp, and the writer collaborated in measuring these sections. No measurements, however, were made of the Madison formation, the Red Rock conglomerate and the Muddy Creek Basin Beds.

The contacts between formations were determined from knowledge of the analogous formations found in the Jackson Hole District of western Wyoming. The sections were measured with Brunton compasses and application of the height of eye principle.

The great thickness of some of the formations, particularly the Madison, Amsden, Quadrant, and Kootenai, show them to be geosynclinal facies. The sediments to the southwest are even thicker (Umpleby, 1917, p. 27)

The Madison is the oldest formation found in the area. In Nicholia Basin to the west Kupsch and Scholten report pre-Cambrian, Ordovician, and Devonian rocks. They also found intrusive igneous rocks and accompanying metamorphism. (Personal communication). The complete stratigraphic column for the region as assembled from the work of Kupsch, Scholten, Wallace, Krusekopf, Lipp, and the writer is given below.

Age	Formation	Thickness
Quaternary	Alluvium	Unknown
Miocene (?)	Muddy Creek B.B.	Unknown
Paleocene (?)	Red Rock congl.	2,000'
Lower Cretaceous	Kootenai fm.	2,200'
Jurassic	Rierdon fm.	116'
Jurassic	Sawtooth fm.	252'
Triassic	Thaynes fm.	791'
Triassic	Woodside fm.	353'
Triassic	Dinwoody fm.	553'
Permian	Phosphoria fm.	802'
Pennsylvanian	Quadrant fm.	3,319'
Pennsylvanian and Mississippian	Amsden fm.	2,022'
Mississippian	Madison fm.	2,000'
Devonian	Three Forks fm.	300'
Ordovician	Kinnikinic fm.	100'
Cambrian	Flathead quartzite (?)	300'

Mississippian system

Madison formation. The Madison formation was first described by A. C. Peale (1893, pp. 32—43) and named from the Madison Range of Montana. The type area is in the central Three Forks quadrangle of Montana.

No exposures of the Madison complete enough for good measurement were available in the area. To the southwest is a great area of Madison limestone which is the Tendoy thrust sheet. It is so badly crushed and broken that measurement was not attempted. Only a small part of the Upper Madison is exposed near the Madison-Amsden contact at the front of the Tendoy Range and the lower units are covered by the Red Rock conglomerate. At this latter exposure the dips vary from 38 to 40 degrees in a southwesterly direction. Two small outcrops also occur further to the northeast from under the Red Rock conglomerate. (See section on Red Rock conglomerate p. 21, and cross section B - B' plate 2 in envelope).

The Madison formation is largely limestone varying from dark to light gray. In places it is very massive, and interbedded with small shale partings. The limestone is dense with a decided petroliferous odor, and contains numerous thin calcite stringers.

Kupsch and Scholten measured 4,000 feet of a Madison section in an area 35 miles to the west and estimate the total thickness to be approximately 10,000 feet. This section, however, contains a great black series which they believe to be Madison and which does not occur in the writer's area. (Personal communication).

The Madison probably overlies the Devonian Three Forks formation conformably, but the contact is not exposed in the immediate area.

The Madison formation is extremely fossiliferous. Thirty distinct species and twenty-two different genera were found in the Madison about forty miles to the north. Chief among these were _Crania laevis_, crinoid columnal fragments, several species of _Productus_, and a number of species of _Spirifer_. (Shenon, 1931, p. 15).

Amsden formation. The Amsden formation was named by N. H. Darton (1904, pp. 394—401). Its type locality is along the Amsden branch of the Tongue River west of Dayton, Wyoming. According to H. R. Wanless (personal communication) and M. G. Wilmarth (1938, p. 2396) the Amsden formation is in part Upper Mississippian and in part Lower Pennsylvanian.

The section was measured by Henry Krusekopf and Stewart Wallace in the former's area. The section was started about 100 feet north of the Sheep Creek Ranger Station in the northwest quarter of section 36, T. 13 S., R. 10 W. The lower beds of the Amsden were well exposed, and the Madison-Amsden contact was easily ascertained. The upper beds, however, were poorly exposed and, in places, completely covered by talus of the overlying Quadrant formation. The Amsden-Quadrant contact was, therefore, difficult to determine and the thicknesses of the units could not be accurately measured.

The beds dip 32 degrees west and the total thickness is 2,022 feet. The formation was divided into 29 units composed mainly of gray limestones and interbedded calcareous gray and buff shales. Four beds of tan, argillaceous sandstone are present in the upper part of the formation (units 14, 20, 21, and 28). Four beds contain fossils which in some places are scattered about in great profusion. Pelecypods and productids were found by Krusekopf and Wallace, and the writer and Lipp found crinoid columnals in the Amsden of Lipp's area. The pelecypods were found in units 2 and 15, and the productids in unit 12. One bed (unit 3) was found to have a pronounced petroliferous odor.

The Amsden formation conformably overlies the Madison.

The measured section is as follows:

Amsden Formation measured in NW 1/4, Section 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, gray weathering to buff color, crystalline, well bedded, and containing numerous thin bands of dark chert	43.0'
22.	Shales, gray, grading upwards into brown. Upper part of bed is covered	389.0'

21.	Sandstone, light brown, thin bedded, calcareous. Bedding planes well developed. Thick and thin bedded. In places weathers to reddish purple ----------------------------	120.0'
20.	Sandstone, tan, weathering to rusty brown, massive, friable ---------------------	24.0'
19.	Covered interval - Tensleep talus -----------	269.0'
18.	Limestone, gray, finely crystalline, contains numerous organic fragments ------------	12.0'
17.	Limestone, dark gray weathering to buff, argillaceous, thin bedded, 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 quartzitic ----------------------	3.0'
13.	Shales, gray calcareous, thin bedded --------	29.0'
12.	Limestone, dark gray weathering to buff, crystalline and containing productids -------	21.0'
11.	Gray shales and limestones alternating and grading upward into brownish and buff colored beds ----------------------------	106.0'
10.	Argillaceous limestones and dark gray shales, weather light gray, thin bedded, calcareous, contains fragments of gypsum ----	245.0'
9.	Limestone, medium gray, medium grained, highly fractured ----------------------------	29.0'
8.	Shale, dark gray weathering to light gray, calcareous, thin bedded with some interbedded argillaceous limestones --	67.0'

7.	Limestone, light to medium gray, weathers to buff, finely crystalline, highly fractured, fractures filled with secondary calcite	14.0'
6.	Shale, dark gray weathering to light gray, calcareous, thin bedded, with some 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 odor	4.0'
2.	Shale, gray weathering to lighter gray, thin bedded, calcareous, contains pelecypods	86.0'
1.	Limestone, dark gray weathering to buff, dense, compact	48.0'
	Total thickness	2022.0'

Pennsylvanian system

Quadrant formation. The Quadrant formation was named by A. C. Peale (1893, pp. 32—43). The type section is on the southeast side of Quadrant Mountain in the northwestern part of Yellowstone National Park. The thickness of the type section, as measured by Peale, is 230 feet, but the Quadrant in the Tendoy Mountains is 3,319 feet. In an intermediate area, in the Snowcrest Range, Condit (1918, p. 111) measured approximately 1,000 feet. This shows the thinning of the geosynclinal facies into the shelf area to the east.

In eastern Montana and Wyoming the Tensleep formation is lithologically similar to the Quadrant. They are now considered to be the same formation and, as such, have been traced from east to west and have been seen to grade into one another. (Scott, 1935, p. 1019).

The Quadrant formation was measured in Hidden Pasture Canyon, half a mile southwest of the Sheep Creek Ranger Station, in the east half of section 35, T. 13 S., R. 10 W. The exposures in general were good, but in places the measurement was hindered by talus. The total measured thickness is 3,319 feet.

The average dip of the beds is 45 degrees in a westerly direction. Moving from east to west, however, the dip decreases.

The Quadrant formation is divided into twelve units and is characterized by dense, buff to tan sandstone which weathers to a darker reddish color. Another characteristic of the weathered surface is the great abundance of black lichens. Some of this sandstone is very quartzitic. Under favorable conditions, large talus slopes are formed which can be identified from great distances. Dolomite and limestone beds are also present, principally in the upper part of the formation. No fossils were found in the Quadrant. It conformably overlies the Amsden formation.

The measured section is as follows:

Quadrant formation measured in E. 1/2, section 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 before, otherwise similar to unit 8	8.8'
9.	Dolomite	15.5'
8.	Limestone, finely crystalline, dense, slightly pitted, gray to light tan, weathers white to tan	5.0'
7.	Dolomite, dense at base, white to light gray, chert near top, sandy	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

<u>Phosphoria formation</u>. The Phosphoria formation was first named by Richards and Mansfield (1912, pp. 683—689). The type locality is in Phosphoria Gulch, 2 1/2 miles northwest of Meade Park, Idaho. The formation is present in the Tendoy Mountains also, and was measured along a dry stream bed about one mile southwest of the Sheep Creek Ranger Station in section 35, T. 13 S., R. 10 W.

The measured dips were 40 degrees in the lower part of the formation and 37 degrees in the upper.

The formation is divided into 20 units with a total thickness of 802 feet. Part of the formation, however, was covered by vegetation and slope wash.

The lower Phosphoria-Quadrant contact was well exposed along the bottom of the creek bed in which the entire section was measured. Along the slopes on either side, however, few exposures could be seen. The upper Phosphoria-Dinwoody contact was likewise easily determined.

The Phosphoria formation is characterized by limestone and dolomite with an abundance of chert in the dolomite. The limestone varies in color from light gray to buff to light tan and the dolomite is characteristically gray, hard, and sandy. There are also three sandstone units present which are gray to brown in color and very hard and massive. Only one shale unit was seen but it is likely that some or all of the covered intervals consist wholly or in part of shale.

Three of the beds make good markers, the dense gray dolomite units which contain chert concretions (units 12 and 19) and a red siltstone member (unit 14). The dolomite beds form prominent ledges in many places because of the resistance offered by the chert to weathering. Unit 19 is 191.6 feet thick and is possibly the equivalent of the Rex Chert of western Wyoming. Unit 14, a red siltstone 45 feet thick, is very prominent because of its color and can easily be seen wherever it occurs in the area.

The section was measured by Edward Lipp and the writer. Both upper and lower contacts are conformable.

The measured section is as follows:

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

20. Limestone, tan to medium gray, weathers medium gray, very hard, fine grain, 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 grain, hard, and massive ----------	71.6'
1.	Dolomite, sandy, very fine grain, weathers light gray to gray-buff ------------	5.0'
	Total thickness --------	802.1'

Tertiary system

Red Rock conglomerate. The Red Rock conglomerate, found at the north end of the area, consists of large to small bluish pebbles of Madison (?) limestone and red-brown pebbles of Permian (?) sandstone. The pebbles and boulders are rounded to sub-angular and the materials of the conglomerate in general are poorly sorted.

Smooth, well rounded boulders of quartzite are also found in the conglomerate. Due to the lack of work previously done in the area and the short time available for field work, the source of the quartzite boulders is unknown. In the northeast corner of the area, the conglomerate with abundant quartzite pebbles forms high, steep, grass covered slopes, but the red conglomerate, with abundant limestone pebbles in the northeastern part forms lower slopes.

The cement is light gray to red-brown in color and slightly calcareous in the northeast corner of the area.

The conglomerate thins out against the Madison formation to the southwest and forms a sedimentary contact. In two places outcrops of Madison limestone were found at a considerable distance to the northeast in the conglomerate, which leads the author to believe that the conglomerate overlies the Madison unconformably. (See geologic map and cross-section B - B' plate 2 in pocket).

No sections of the conglomerate were measured since no good exposures were found. Judging from the dip and aerial exposure the thickness is estimated to be approximately 2,000 feet.

Muddy Creek basin beds. The Muddy Creek basin beds were originally called the "Bozeman Lake Beds" by Peale (1893, pp. 32—43). This has since been shown to be incorrect by W. P. Haynes (1916, pp. 270—290) who shows that the Muddy Creek basin beds are subaerial and fluviatile, and Miocene (?) in age. According to Atwood (1916, pp. 705, 706, and 712) the Bozeman Lake beds are mainly alluvial outwash deposits of Oligocene (?) and Pliocene (?) age but no paleontologic evidence for the age assignment is given.

In the basin country to the east of the Tendoy Mountains are found Upper Eocene, Oligocene, and Upper Miocene beds. According to Dr. Eardley (personal communication) the Muddy Creek basin beds are lithologically most similar to the Upper Miocene beds. No fossils, however, were found for accurate dating. The Muddy Creek basin beds are, therefore, tentatively considered to be Upper Miocene (?) in age. They are characterized by a red color and are conglomeratic. The pebbles and boulders are rather angular and the whole formation is so soft that, due to erosion, exposures for measurement are very poor. The conglomerate seems to have filled the Muddy Creek basin at the front of the Tendoy thrust front. The thickness is unknown since only the rolling hills and a few shallow gullies can be seen at the surface.

On the southwest side of Muddy Basin the beds lap up against the Madison thrust sheet and this condition exists for approximately one mile to the southeast up Shearing Pen Gulch from the Sheep Creek road. On the opposite side of Muddy Creek basin (northeast) the basin beds dip into the northeast Muddy Creek high angle fault. (See cross-section A - A' plate 2, in pocket). Along this fault angular fault breccia can be found. This fault forms the contact between the Phosphoria formation and the Basin beds. The fault dies out, however, before it reaches the thrust front and a short sedimentary contact exists up to the point where the Phosphoria comes in contact with the Madison. (See geologic map plate 2, in pocket). The basin beds die out at this point.

No measurements of the thickness of the basin beds were attempted. Some dip readings were taken, however, and the average dip was 20 degrees to the northeast. Since the basin beds dip into the Muddy Creek fault, the beds must have been deposited prior to the faulting.

STRUCTURAL GEOLOGY

General considerations

The sedimentary rocks of the Tendoy Mountains dip 30-35 degrees southwest and form, presumably, the northeast flank of a large syncline. However, since an overthrust sheet from the southwest covers much of the structure, its true nature cannot be determined. (See cross-section B - B' plate 2, in pocket).

The structural history can be divided into two general phases, the Laramide and the post-Laramide. During the Laramide phase great horizontal compression occurred, and resulted in folds and a thrust fault. During the post-Laramide phase several high-angle faults were formed. Between these two major stages extensive erosion occurred, particularly in Muddy Creek basin, and was an important factor in determining the present topography of the region.

Laramide structures

Folds. There are no folds in the area of the report. Undoubtedly, there are large folds in the general region whose trend is, in general, northwest-southeast. The trend of the compressional forces in the area is likewise northwest-southeast. All formations from the Madison through the Phosphoria were affected by the early Laramide orogeny. The Amsden and the Madison formations near the front of the range show evidence of great compression with small, minor, tight folds, some of which are overturned to the northeast.

Thrust faults. The Tendoy thrust is a great sheet of Madison limestone which has overridden the Triassic beds in the area. Its trend is nearly parallel to the strike of the beds. The thrust came from the southwest toward the northeast. The present thrust front extends from Sheep Creek in section 15, T. 14 S., R. 10 W. in an irregular line to section 33, T. 14 S., R. 9 W. on Little Sheep Creek. (See geologic map plate 2 in pocket).

A klippe of the Tendoy thrust was found approximately two miles to the northeast of the present thrust front on the northeast side of Muddy Creek Basin by Krusekopf and Wallace in the former's area. The klippe was found unconformably overlying the Quadrant formation. Krusekopf (1948, p. 40). Much of the thrust front has been eroded away and a part of it was dropped in the Muddy Basin graben. This latter block was eventually covered over by the Muddy Creek basin beds. (See cross-section A - A' plate 2, in pocket).

Early Tertiary history. The coarse and thick Red Rock conglomerate must have come from a highland that had just been vigorously elevated. The creation of this highland is considered the first stage of the Laramide period of orogeny. This orogeny began in late Cretaceous (?) and extended approximately through the Paleocene (?) epoch. The great horizontal compressions caused folding which created the highlands to the west in eastern Idaho, and in southwestern Montana. This large scale folding formed the important regional features of that time.

The formation of the highlands was followed by a period of vigorous erosion. At this time the Red Rock conglomerate was deposited in the Red Rock Basin to the northeast. Later compression caused folding which trends at an angle to the original folds. This later cross-folding is well shown by a small syncline in Little Water Canyon about six miles to the northwest. Wallace (1948, p. 36) has called it the Little Water syncline. The folding involves Cretaceous beds; therefore, it occurred at a later time than the original folding.

The more or less continual compressive forces of this epoch culminated in the late Cretaceous (?) or early Paleocene (?) in a great thrust fault, the Tendoy thrust.

Following a cycle of erosion in the Paleocene (?), the final phase of Laramide folding and faulting occurred. This latter phase is best shown to the south in the Lima anticline where the Red Rock conglomerate is folded and faulted. Eardley, who mapped the Lima anticline, estimates the age of the faulting to be late Paleocene (?) or early Eocene (?). (Personal communication). There is some evidence of folding of the Red Rock conglomerate at the north end of the area since one block seems to be dipping to the southwest. In the rest of the conglomerate the dip is to the northeast toward the high angle fault at the mountain front. The writer feels that these dips are due to the Red Rock fault which occurred at a later time and caused the whole block to be tilted to the northeast.

Following the last phase of activity of the Laramide orogeny, there was an extended period of erosion which produced broad basins in the region. During this erosional period, some of the basins were filled with sediments. One such basin was the Sage Creek basin to the northeast. The sediments filling this basin are called the Sage Creek beds and have been dated as being Upper Eocene by H. E. Wood (1934, pp. 253, 255, 277).

Volcanoes must have been active in the area during Upper Miocene time since volcanic tuffs were found interbedded with the Muddy Creek Basin beds by Krusekopf and Wallace (personal communication). These tuffs were found in the northern end of Muddy Creek basin.

Post-Laramide block faulting

Muddy Creek Basin faults. The block faulting in Muddy Creek basin produced a graben with a high angle fault on the southwest side of the basin, cutting the Tendoy thrust sheet, and another high angle fault on the northeast side of the basin. The basin was the downthrown block; its total vertical displacement is unknown. (See cross section A - A' plate 2, in pocket).

The southwestern fault cuts across Sheep Creek in section 15, T. 14 S., R. 10 W., and trends northwest-southeast. From Sheep Creek it can be traced southeast approximately 2 1/2 miles to where it apparently dies out in the Muddy Creek basin beds. (See geologic map plate 2, in pocket). The downthrown block is to the northeast, the upthrown block to the southwest.

Since this fault cuts the Tendoy thrust sheet it is obviously younger than the thrusting. Also, because it cuts the Muddy Creek basin beds it post-dates them and is, therefore, middle or late Miocene (?) in age.

The northeastern fault also trends northwest-southeast but does not parallel the southwestern fault.

It trends in such a direction that if both faults could be traced further to the southeast, they would intersect in section 24, T. 14 S., R. 9 W. (See geologic map plate 2, in pocket). The northeastern fault forms the contact between the Muddy Creek basin beds and the Phosphoria formation for a distance of about 2 1/2 miles southeast from Sheep Creek. Along this contact the Phosphoria and Muddy Creek basin beds can be seen dipping into each other. Near the point where the fault dies out to the southeast, a sedimentary contact continues in a southerly direction until it meets the thrust sheet. From this point southwestward, the contact is between the Madison thrust sheet and the Phosphoria formation.

Red Rock Basin fault. The Red Rock basin fault trends northwest-southeast along the front of the Tendoy range. It is a high angle, en échelon fault. The vertical displacement is unknown but the remnant of the scarp indicates a displacement of at least 200 feet. There are three main breaks which together extend from Sheep Creek to Little Sheep Creek, a distance of about seven miles. (See geologic map plate 2, in pocket).

From U. S. Highway 91 a recent small scarp is plainly visible. Also present is the erosional remnant of the older, higher scarp in the form of triangular facets.

The downthrown block is to the northeast, the upthrown block is to the southwest. On the upthrown block, the Red Rock conglomerate can be seen dipping to the northeast, into the fault. (See cross section A - A' plate 2, in pocket).

PHYSIOGRAPHY

Physical features

The Tendoy Mountains are located in the Northern Rocky Mountain physiographic province. They are made up of a horst and graben arrangement of peaks and basins. (See cross section A - A' plate 2, in pocket.) The highest elevations attained are approximately 9,000 feet, and the peaks extend about 3,000 feet above the valley floors. The dips are to the southwest and the slopes, which plunge gently to the southwest, approximate dip slopes.

Erosion surfaces

Following the last active phase of the Laramide orogeny there occurred a long cycle of erosion in Muddy Creek Basin. This proceeded in early or mid-Eocene (?) time while sediments of the Sage Creek beds (upper Eocene ?) were being deposited to the east.

After the deposition of the Upper Eocene (?) ash beds in the area to the east, Oligocene (?) beds were also laid down, and on these were deposited the beds presumably equivalent to the Muddy Creek basin beds of Lower Miocene (?) age. Also at this time volcanism was active in the area, and some volcanic ash was deposited in Muddy Creek Basin. No ash was found in the area, but Krusekopf and Wallace report the presence of small cinder cones as well as volcanic ash in the northern part of Muddy Creek Basin. (Personal communication). These were the last beds laid down before the renewed cycle of faulting began.

In late Miocene (?) time the beds were cut by high angle faults which formed a graben in Muddy Creek Basin. (See cross-section A - A' plate 2, in pocket). Due to the lowering of Muddy Creek Basin, vigorous erosion proceeded on the high surfaces on all sides of the graben. The softer Mesozoic beds were rapidly eroded away, and by Pliocene time the underlying Paleozoic rocks were exposed on all sides of the basin.

The exact dating of the old erosion surfaces of the Northern Rocky Mountain physiographic province is still a subject of considerable dispute. The writer can, therefore, only refer the reader to the following authorities: Blackwelder (1912), Umpleby (1912), Rich (1918), and Mansfield (1927). Pardee (1911), Umpleby (1913 and 1917), Atwood (1916), Kirkham (1927), and Ross (1931) treat the physiography of the region in a more general manner.

During the time of erosion in Muddy Creek Basin there existed a high erosion surface at the mountain front, sloping gently toward the northeast into Red Rock Basin. The drainage flowed northeast and emptied into the Red Rock River. This high pediment was broken at the mountain front by a fault, the Red Rock fault, which created a scarp of considerable magnitude. With the dropping of the valley floor, the drainage was rejuvenated and dissection of the scarp began. This dissection produced triangular facets which can still be seen at the present time.

As the streams cut back into the original high erosion surface, broad pediments were formed which are particularly prominent in Muddy Creek and Nicolia basins. After this cycle of erosion, glaciation took place in Nicolia basin and the surrounding mountains to the west.

Erosion is still at work at the mountain front and the presence of a fresh small fault scarp indicates that there has been recent activity along this fault. The latest displacement, however, could not have been more than 10 or 20 feet.

Glaciation

There is no evidence of glaciation in either Muddy Creek Basin or the Red Rock Basin to the northeast. The basin floors are blanketed entirely by Tertiary basin beds and Quaternary alluvium.

Fifteen miles to the southwest, however, in Nicolia Basin, Kupsch and Scholten report the presence of Bull Lake and Pinedale glacial till, originating from the glaciers in the Beaverhead Mountains. (Personal communication).

Drainage

The minor drainage in the area is consequent, heading in the highlands and flowing into the two principal streams of the district; Sheep Creek and Little Sheep Creek to the southeast. Nearly all of the minor streams are dry during most of the year but several are semi-permanent.

The master stream of the area is Sheep Creek, which heads in the Beaverhead Mountains and flows northeast, emptying into the Red Rock River near Dell. This stream is evidently an antecedent stream since it cuts across structures such as the Tendoy horst. If the stream came after the faulting it would probably have been blocked off by the fault and drained from a structural depression to the northwest, the Little Water Syncline. Further evidence pointing to its antecedent nature is the presence of high level gravels found on a high erosion surface which post-dates the faulting. This high erosion surface is well below the summit of the range and is believed to be Pliocene (?) in age. In view of the above evidence it is quite certain that Sheep Creek was present before faulting and maintained its course during the period of uplift.

Little Sheep Creek also heads in the Beaverhead Mountains and flows northeast, approximately paralleling Sheep Creek. It emerges from the Tendoy Mountains about four miles southwest of Lima and flows north into the Red Rock River.

Both Sheep Creek and Little Sheep Creek are utilized for irrigation by the farmers in the area. Hay is the principal crop and it is grown on the flood plains of Sheep Creek as well as on the alluvial flats of Red Rock Basin.

Climate and vegetation

The climate of southwestern Montana is arid to semi-arid. Precipitation is seasonal and slight during the summer, and the temperature ranges from 90 degrees during the day to near freezing at night.

Vegetation is sparse in the basins, and the principal plants are grass and sagebrush. Along the semi-permanent streams small groves of pine trees can be found. Trees are also commonly found on the northwestern slopes of the higher ridges. A sparse growth of grass covers all exposed slopes where there is enough soil to support growth.

The principal animal life of the area consists of deer, elk, rabbits, marmots, and ground squirrels. Cows and sheep are pastured in the area during the summer months. Among the bird life, sagehens are common as well as hawks and swallows, the latter building their nests in the steep Madison cliffs of the Sheep Creek canyon wall.

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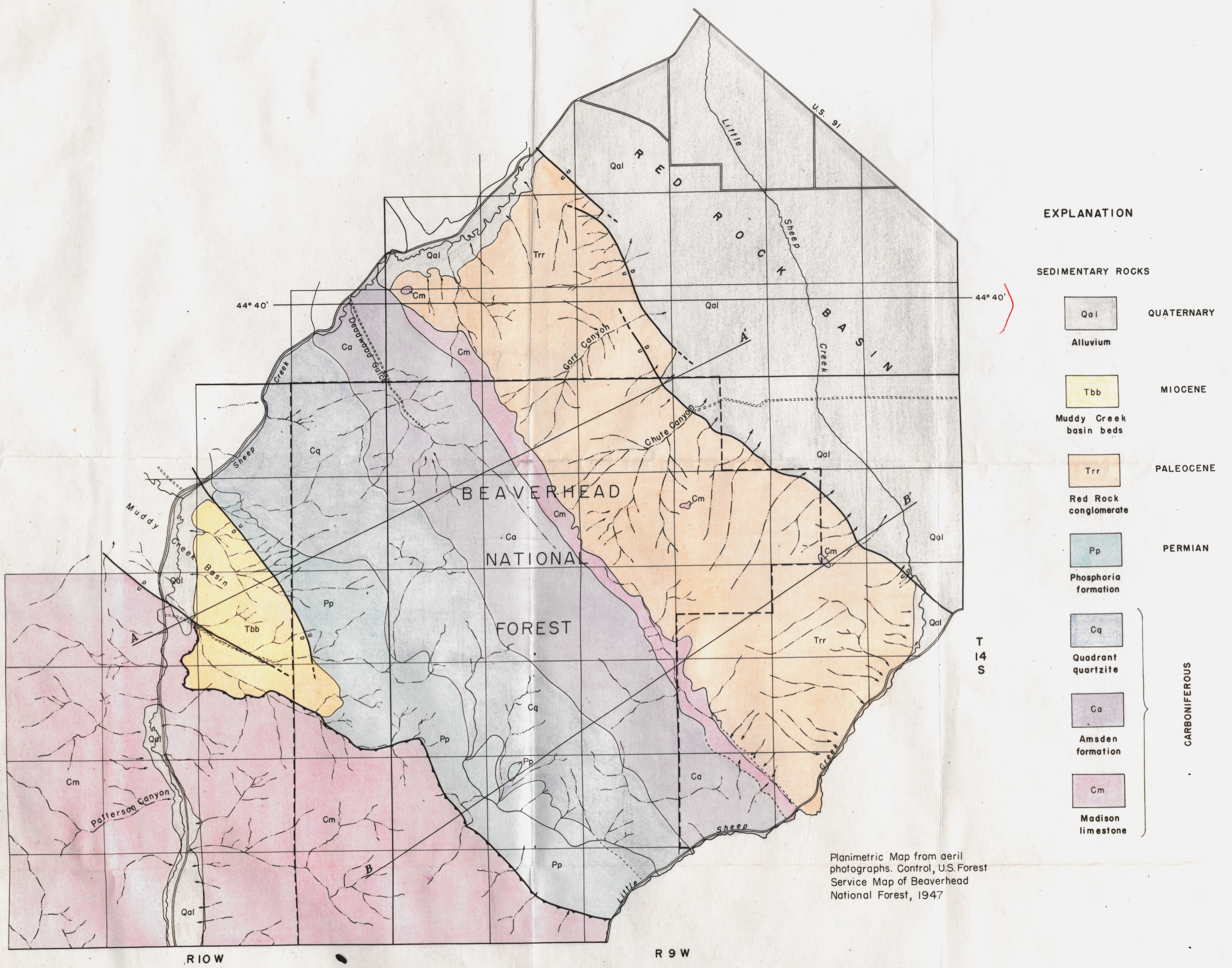
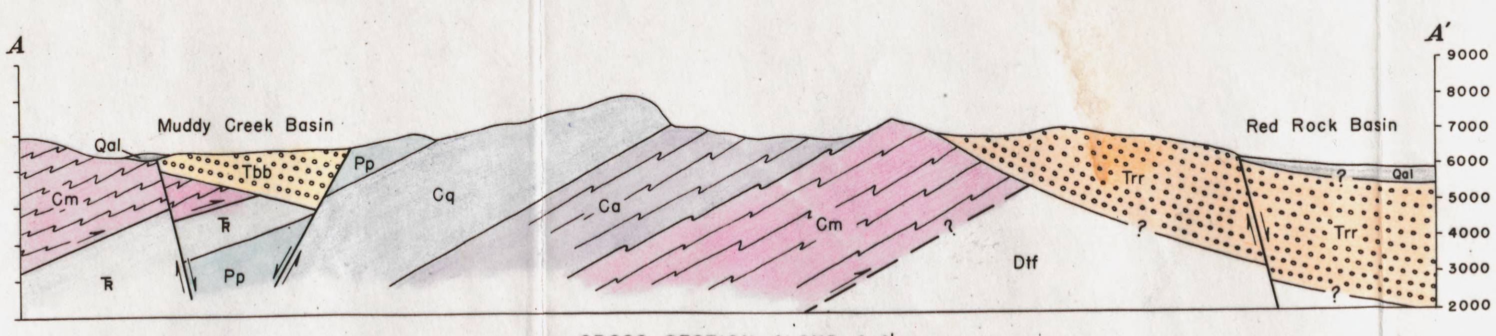


GEOLOGY OF PART OF THE
TENDOY MOUNTAINS, BEAVERHEAD COUNTY, MONTANA

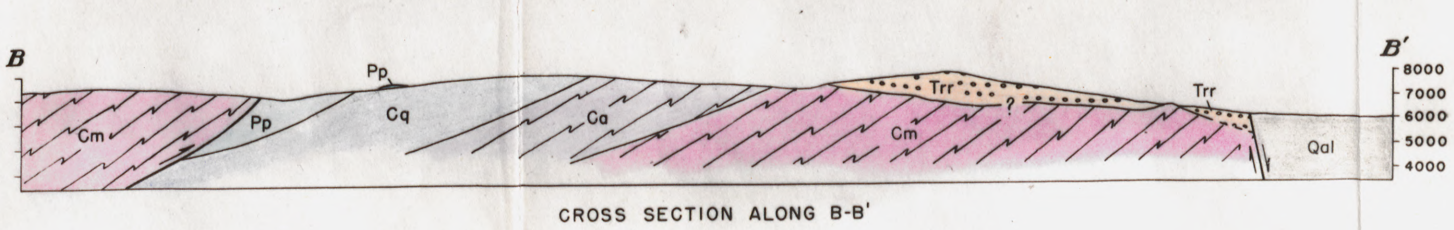
BY E.G.LIPP AND R.W.BECKER

MILES

1947



CROSS SECTION ALONG A-A'



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