GEOLOGY OF AN AREA EAST OF SHEEP CANYON, NEAR DELL, BEAVERHEAD COUNTY, MONTANA

E. G. LIPP

GEOLOGY OF AN AREA EAST OF SHEEP CANYON,

NEAR DELL, BEAVERHEAD COUNTY, MONTANA

E. G. Lipp

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

CONTENTS

PAGE

ILLUSTRATIONS

ABSTRACT

The Tendoy Mountains are in the southwestern part of Beaverhead County, Montana. The area discussed is in T. 13 S., T. 14 S., R. 9 W., R. 10 W. Only Mississippian, Pennsylvanian, and Permian rocks are present but Mesozoic rocks outcrop about two miles to the northwest. The Tertiary is represented by the Red Rock conglomerate (late Cretaceous or Paleocene) and the Muddy Basin beds (Lower Miocene). The Mississippian system is divided into two formations; the Amsden (Upper Mississippian) is 2,022 feet thick, whereas the underlying Madison limestone is about 10,000 feet thick. The Pennsylvanian section measured 3,319 feet and the Permian measured 802 feet in thickness. The total thickness for the Mesozoic section is 4,268 feet. No sections could be measured for the Red Rock conglomerate or the Muddy Basin beds; however it is supposed that their thicknesses are about 2,000 feet and 1,000 feet respectively. The total thickness for the formations that were measured in the area south of Dell is 18,380 feet.

The Tendoy Mountains are formed by uplifted Paleozoic and Mesozoic rocks that were folded into a large homocline in pre-Laramide time. This homocline trends northwest-southeast and the beds in the Tendoy Mountains dip generally southwest. In the Cretaceous the region of southwestern Montana was again subjected to compressional forces that produced the low angle Tendoy thrust of Laramide age. This thrust sheet forms the southwest side of Muddy Creek Basin.

The Tendoys were again disturbed by faulting in the late Miocene and Pliocene that produced high angle block faults. The structures formed at this time are of the post-Laramide orogeny. There are three high angle fault zones in the area; one bounds Muddy Creek Basin on its southwest side and another bounds the basin on its northeast side. The high angle fault on the southwest side of Muddy Creek Basin cuts the Tendoy thrust sheet. The remaining high angle fault zone separates the Tendoy Mountains from the Red Rock Basin. This fault is solely in the Red Rock conglomerate and is of a slightly later date (Pliocene) than the faults in Muddy Creek Basin (late Eocene). Muddy Creek Basin and the Red Rock Basin are both grabens.

The Muddy Basin beds lie unconformably against the Permian and the Madison limestone on the northeast and southwest sides of Muddy Creek Basin respectively.

In the early Pliocene an erosion surface was developed in both the Muddy Creek Basin and in Chute Canyon. The erosion surface in Muddy Creek Basin was developed after the high angle faulting had ceased, whereas the erosion surface in Chute Canyon has been cut by the high angle fault in that immediate area. This shows the faulting in Muddy Creek Basin to be of an earlier age than the fault that bounds the Red Rock Basin.

INTRODUCTION

Object of report

The purpose of the report is to describe the geology of an area in the Tendoy Mountains of southwestern Montana to determine its relations to the regional structure.

Location of area

The area studied covers 16 square miles and is located in the Northern Rocky Mountain province in Beaverhead County, Montana, T. 13 S., T. 14 S., R. 9 W., R. 10 W. It is in the Tendoy Mountains which are a part of the Beaverhead Range of southwestern Montana (see index map, plate 1). The area is about 38 miles south of Dillon, Montana. The northeast side of the area is a high angle fault scarp rising abruptly out of the Red Rock Basin. It can be seen from U. S. Highway 91 and lies about two miles off the road to the southwest.

The area is readily accessible by roads or trails. The entire northwestern side can be seen by driving up

Sheep Creek Canyon road from the fault scarp to the junction of Muddy and Sheep Creeks.

Acknowledgments

The writer is indebted to Robert W. Becker who worked in partnership with him on the mapping of the area and the preparation of the geologic map; to Stewart R. Wallace and Henry H. Krusekopf who provided helpful stratigraphic columns not available in the writer's area, and to Professor A. J. Eardley for his very helpful suggestions and guidance in local and regional structure, geologic history, and field procedures in mapping.

Methods

Aerial photographs were the basis for mapping in the field. Geologic contacts, faults, and formation dips were recorded on the photographs exactly as seen at the time of mapping. The photographs are from the United States Department of Agriculture, Agricultural Adjustment Agency, 145 Motor Avenue, Salt Lake City 1, Utah. They are numbered as follows:

8 - 21 - 42 -- CXM - 10B - 22--27
CXM - 10B - 49--52
9 - 1 - 42 -- CXM - 12B - 30--33

E. Raisz

INDEX MAP

The geologic map that accompanies this report includes both the writer's and the adjoining area to the southeast mapped by R. W. Becker. The writer's area comprises approximately the northwest half which is bounded on the west by Sheep Creek. See geologic map in pocket.

A radial line plot was first made from the photographs and then the section lines were located as well as possible on the plot. These were then transferred to the individual photographs where no section corners, fences, or roads exist to mark the positions. The geologic map (in pocket) was then drawn from the photographs, using a multiscope, at a scale of two inches to the mile. The method followed is that outlined by Eardley (1942, pp. 49—70).

STRATIGRAPHY

General statement

The following general stratigraphic column is complete for the formations found in the four areas in the Tendoy Mountains mapped by Wallace, Krusekopf, Becker, and the writer near Dell, Montana. Only the four systems found in the writer's area and their formations are discussed in detail; these include the Mississippian Madison and Amsden, the Pennsylvanian Quadrant, the Permian Phosphoria, and the late Cretaceous or early Tertiary Red Rock conglomerate and the Muddy Basin beds (lower Miocene).

The entire stratigraphic column could not be measured in one locality but, with the exception of some covered intervals, it was possible to obtain a fairly complete section which is discussed on the following pages.

The contacts between formations were determined mainly from information on stratigraphy and lithology learned at Camp Davis in the Jackson Hole area of

General stratigraphic column for the

Tendoy Mountains southwest of Dell, Montana

Age	Formation	Description	Thickness in feet
Lower Miocene	Muddy Basin Beds	Conglomerate, gray to light tan with reddish zones, light colored volcanic tuffs.	1,000 ± ?
Late Cretaceous or Paleocene (?)	Red Rock conglomerate	Conglomerate, red, yellow, matrix, blue ls. fragments. Conglomerate polished quartzite boulders with limy cement.	2,000 ± ?
Lower Cretaceous	Kootenay	Sandstones, salt and pepper, alternating with red, brown, and purple shales.	2,201
Lower Jurassic	Reardon	Limestone, gray to buff, oolitic, and shales, brown.	116
	Sawtooth	Shale, light gray to buff, siltstone, brown, interbedded with brown limestone.	252
Upper Triassic	Thaynes	Limestones, buff to tan, dark to light gray, siltstone, tan to gray. _Pentacrinus_ in one limestone unit.	792
Middle Triassic	Woodside	Mostly covered, brown shales, light gray sandstones and limestones.	354
Lower Triassic	Dinwoody	Mostly limestones, gray, gray brown, brownish red, with some shales, gray and reddish.	553

Age	Formation	Description	Thickness in feet
Permian	Phosphoria	Dolomite and chert, dolomite white to dark gray, chert bluish, greenish, and gray. Limestone, yellowish tan, siltstone, red, limestone and chert, gray to tan, chert light colored.	802
Pennsylvanian	Quadrant	Sandstone, white to buff, and tan quartzite, gray to buff. Limestone, gray.	3, 319
Upper Mississippian	Amsden	Limestone, light to dark gray, buff to tan sandstone, light tan to light brown shales.	2, 022
Mississippian	Madison	Limestones, bluish - no measured section.	10, 000 ± ?

Wyoming. The general stratigraphy was unknown to all of the group who mapped the four areas near Dell.

The sections were measured by using the height of eye and Brunton Compass set at the measured dip of the beds. The final thickness was found by multiplying the natural cosine of the dip times the measured thickness.

Mississippian system

Madison formation.— This formation was first described by A. C. Peale (1893, pp. 32—43) in the Madison Range in the central part of the Threeforks quadrangle, Montana. It is of Lower Mississippian age and is known in Montana, Wyoming, Idaho, and northern Utah. The type section consists (in descending order) of massive jaspery limestones, 575 feet; light bluish gray massive limestones, 350 feet; dark colored compact laminated limestones, 325 feet. It overlies the Devonian Threeforks shale, and underlies the Pennsylvanian Quadrant formation.

The Madison formation could not be measured in the writer's area or in its immediate vicinity. The only exposures were in zones of folding near the northeast or front part of the area. The beds were crushed and tightly folded and dips up to 60 degrees were measured along the Madison-Amsden contact. The contact is not clearly distinguishable and is thought to lie along a high steep ridge that trends northwest-southeast across the area. The general dip for the whole section is probably 38 to 40 degrees, and the thickness about 5,000 feet. However, due to folding and crushing, neither of these can be determined accurately.

The lower contact of the Madison, if conformable, would be with the Upper Devonian Three Forks formation. This is completely buried by the Red Rock conglomerate which blankets most of the Madison formation, except for the beds exposed along the high ridge. The conglomerate is in sedimentary contact over the Madison.

The Madison was measured by Robert Kupsch and Walter Scholten about ten miles to the southwest of the writer's area, in the Beaverhead Range, Montana. They measured 4,000 feet of Madison and estimated the total thickness to be 10,000 feet. They found a very thick section of black limestone that is not found in the writer's area; this black limestone is assumed to be of Madison age (personal communication).

Amsden formation.— N. H. Darton (1904, pp. 394—401) named the Amsden formation for the Amsden Branch of the Tongue River west of Dayton, Wyoming. The beds are red shales, white limestones, cherty and sandy limestones. The thickness ranges from 150 feet to 350 feet. It overlies the Little Horn limestone (name now replaced by the Madison limestone) without any apparent unconformity, and underlies the Tensleep sandstone.

Wilmarth (1938, p. 2396) states the age of the Amsden to be Pennsylvanian with some Mississippian locally. In Jackson Hole, Wyoming, the contact between the Mississippian and Pennsylvanian is considered to lie somewhere in the Amsden (H. R. Wanless, personal communication). However Scott (1935, p. 1032) positively states it to be Mississippian on stratigraphic and paleontologic evidence. (See also Scott, 1935, p. 1030, table VI).

The Amsden formation was measured in the NW 1/4, section 36, T. 13 S., R. 10 W., about 500 feet north from the Sheep Creek Ranger Station, Beaverhead County, Montana. The section, measured by Henry Krusekopf and Stewart Wallace, and in the former's area, is given below. The measuring started about 100 feet up from the road at the conformable Madison-Amsden contact. The complete section was measured on the northeast side of an exposed hill. The lower beds of the Amsden were better exposed than the upper ones. The contact between the Madison and Amsden was clear but the upper contact, between the Amsden and the Quadrant which overlies it conformably, was partly obscured by vegetation and Quadrant talus.

The section has a uniform dip throughout of 32 degrees west. The Amsden was divided into 29 units, with a total thickness of 2,022 feet. The units were in general well exposed but there were 466 feet of covered intervals, units 16, 24, and 26.

The Amsden is composed mostly of grayish limestone and shales with brown to orange sandstone beds scattered throughout the section. Where the section was measured the formation was not crushed or tightly folded as in the writer's area.

Fossils were found in three of the shale beds: pelecypods in beds 2 and 15, productids in bed 12.

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 shales. Upper part of bed is covered	389.0'
21.	Sandstone, light brown, thin bedded, calcareous. The bedding planes are very well developed but some of the beds are considerably thicker than others. In places weathers to reddish purple color	120.0'
20.	Sandstone, tan, weathering to rusty brown color, massive, friable	24.0'
19.	Covered interval - Tensleep talus	269.0'
18.	Limestone, gray, finely crystalline and containing numerous organic fragments	12.0'
17.	Limestone, dark gray, weathering to buff, argillaceous, thin bedded with some interbedded chert	38.0'
16.	Limestone, gray-brown weathering to buff, finely crystalline, fossiliferous	62.0'
15.	Shale, gray, thin bedded, calcareous, containing 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, weathering to light gray, thin bedded and calcareous, alternating. Contains some darker shale members with occasional 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 weathering to buff, finely crystalline, highly fractured with 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'

The Amsden formation conformably overlies the Madison limestone.

Pennsylvanian system

<u>Quadrant formation</u>.— The name Quadrant was first used in print by A. C. Peale (1893, pp. 32—43) after a field conference with I. P. Iddings and W. H. Weed, prior to 1893. Peale used the name for rock strata in southern Montana which he thought to be the same as the type section on Quadrant Mountain (Scott, 1935, p. 1013). The Quadrant formation was named not by Peale but by Iddings and Weed while working out the geology of the Gallatin Range (1883—93). The type section is on the southeast corner of Quadrant Mountain in the northwestern part of Yellowstone National Park (Iddings and Weed, 1899, p. 33).

In 1935 H. W. Scott revised the type section of the Quadrant and restricted the use of the name. Scott (1935, p. 1015) gives the following definition: "Under the heading 'The Quadrant Quartzite' the Quadrant formation was originally described as consisting of white, yellowish, and occasionally pink beds of quartzite, with intercalated beds of drab saccharoidal limestone. At the type locality the Quadrant lies between the top of the Amsden and the bottom of the Phosphoria formation."

The major consequence of the revision (Scott 1935, p. 1014) is that zone 13 in the type section, called "talus" belongs in the Amsden and not in the Quadrant. Scott also shows that the formation overlying the Quadrant may be either Permian or Jurassic, but the underlying formation is always the Amsden.

At the type locality the Quadrant is about 230 feet thick; other localities in Montana show the following thicknesses: 20 miles north of Cinnabar Mountain, 125 feet; Livingston, 140 feet; near Bozeman 88 feet; west of Eustis 160 feet; Lombard about 100 feet; and west of Taston less than 75 feet. In central Montana Reeves (1931, pp. 135—149) found that the formation is absent, but in the Snow Crest Range to the south, Condit (1918, p. 111) found the thickness to be as much as 1000 feet. The above data therefore show a thinning of the Quadrant north and east of the type locality and a great thickening to the west. Eardley (1947, p. 311) also confirms this.

Scott (1935, p. 1019) states that "The Quadrant quartzite is unquestionably a westward extension of the Tensleep sandstone. Geologists working westward from the type locality of the Tensleep invariably classify the quartzite in south central Montana as Tensleep; whereas those working northward and eastward from Quadrant Mountain identify the same zone in the same section as the Quadrant formation." Scott's revised type section (1935, p. 1017) shows a general similarity to the section in the writer's area. He (1935, pp. 1018—1019) states that "the eolian characteristics in the Big Horn Mountains gradually give way to the true marine characters, and at Quadrant Mountain at least 95 per cent of the formation represents marine deposited or reworked material. That a marine environment existed at the time of deposition of the Quadrant rocks is clearly indicated by excellent bedding, marine cross bedding, siliceous limestone, and marine fossils."

The Paleotectonic map of the Late Pennsylvanian (Eardley, 1947, p. 311, fig. 2) shows the 1000-foot line of depression running close to the Snow Crest Range area where Condit reports 1000 feet of Quadrant. This, plus the cross bedding found in unit 1, suggests the required marine environment. The overall general color conforms more to the Quadrant than to the Tensleep. It therefore seems advisable to call the rock formation lying under the Phosphoria (Permian) and over the Amsden (Mississippian) the Quadrant formation.

The Quadrant formation in the writer's area was measured in Hidden Pasture Creek, which is one half mile southwest of the Sheep Creek Ranger Station in the east half of section 36, T. 13 S., R. 10 W., Beaverhead County, Montana. The section exposed here was not ideal for measurement but it was the best that could be found in the vicinity of the writer's area. The formation was divided into 12 units which show a total of 3,319 feet of thickness. The underlying Amsden and overlying Phosphoria formations were both sufficiently exposed to show the contacts.

The beds have an average dip of 45 degrees, striking N. 80° W. The lower four units (1—4) were measured using 50° as the dip. However, somewhere in unit 4 the dip began to decrease and at the outcrop of unit 5 the measured dip showed a decrease of 10 or 40 degrees, striking N. 80° W. Units 5 to 12 were measured using 40 degrees as the average dip. The valley walls in most places show fairly good contacts, but the abundant Quadrant talus and vegetation could well have obscured thin soft beds. The Quadrant is easily distinguishable at any distance by the huge talus slopes, mostly covered by black lichens, produced by weathering.

The detailed section measured in the neighboring area 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	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 the 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 the top	1724.9'
4.	Sandstone, friable, massive, dark tan, weathers to yellowish tan. Many black lichens covered talus slopes near and toward the top. Partly covered?	913.6'
3.	Sandstone, friable, massive, light tan, weathers to light gray, interbedded with 2-inch thin layers more quartzitic and slightly dolomitic near the center. Also another member of quartzitic, slightly dolomitic sandstone near the 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.— The Phosphoria formation was named by Richards and Mansfield (1912, pp. 683—689). It consists mostly of phosphatic shales, with some thin limestone beds and the Rex Chert member at the top. The formation was named for Phosphoria Gulch, which joins Georgetown Canyon 2.5 miles northwest of Meade Park, Idaho. In the Bannock overthrust region of southeastern Idaho and northeastern Utah, the thickness of the formation ranges from 75 to 627 feet, and that of the Rex Chert member from very little to 450 feet. The Phosphoria is overlain by the Woodside shale (Triassic) and is underlain by the Wells formation (Pennsylvanian).

The Phosphoria formation was measured in a creek valley one mile southwest of the Sheep Creek Ranger Station, section 35, T. 13 S., R. 10 W., Beaverhead County, Montana.

The section was divided into 20 units with a total thickness of 802 feet, 108 feet of which were covered by talus and vegetation.

The dip varied only three degrees throughout the formation; units 1 to 12 were measured at 40 degrees striking north-south and flattening slightly until unit 13 was encountered dipping 37 degrees, and striking north-south; units 13 to 20 have an average dip of 37 degrees. The creek valley runs generally perpendicular to the strike so that the measuring could be done in the dry creek bed. The walls of the valley showed good outcrops in places that were not covered by vegetation and the underlying Quadrant quartzite talus. The latter rises topographically higher, due to folding and resistance to weathering.

Between the road and the lower Phosphoria-Quadrant contact there are approximately 600 feet of covered or partly covered Quadrant exposures. Below the base of the Phosphoria thirty feet of Quadrant may be seen and thus the contact between the two formations is well displayed.

The contact between the overlying Dinwoodie (Lower Triassic) and the Phosphoria is obscure, except in the creek bed. Also the Triassic section can be seen but is too well covered in most places to permit continuous measuring in the locality.

There are three good marker beds in the Phosphoria formation: a red sandstone, 45.1 feet thick (unit 14) near the middle of the formation; a dolomite bed with chert concretions 8.4 feet thick (unit 12); and near the top, a hard massive dolomitic limestone 191.6 feet thick (unit 19), possibly the equivalent of the Rex Chert member. The red sandstone is the most outstanding marker bed because of its color which makes it visible at long distances.

The detailed section measured in the neighboring area 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 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'

* Marker bed.

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 in color, 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 grained, 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 grained, hard, light gray, weathers buff to medium 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'

* Marker bed.

6.	Limestone with chert beds; limestone is gray, weathers same, chert is white 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 limy near base than near top, fine grained, hard, massive, light gray, weathers same, few calcite stringers throughout bed ----------------------------	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, gray buff ----------------------	5.0'
	Total thickness ------	802.1'

Triassic system

General statement.— The Triassic formations are not exposed in the writer's area. They are, however, suspected to be present in the subsurface. See cross-section (Plate 5). In the areas mapped by Wallace (1947, pp. 18—23) and Krusekopf (1947, pp. 21—26) three formations of the Triassic are exposed; these are the Dinwoody, Woodside, and Thaynes. The complete Triassic section was measured by the writer and Robert Becker in W 1/2 section 26, T. 13 S., R. 10 W., Beaverhead County, Montana. As shown on the cross section A - A' Plate 5 and the writer's sequence of events (page 45 of this report) the Triassic formations provided the surface over which the Tendoy thrust moved. It is suspected that the Madison limestone of the Tendoy thrust immediately overlies the Triassic below the beds of the Muddy Creek Basin and the area to the southeast; also, that the Permian and Triassic beds are in conformable contact in the same locality.

Dinwoody formation.— The Lower Triassic Dinwoody formation is composed of gray-brown to reddish limestones and shaly limestones, and gray to reddish shales. The 33 units together have a total thickness of 553 feet, 220 feet of which are covered.

Woodside formation.— The Middle Triassic Woodside formation conformably overlies the Dinwoody formation and underlies the Thaynes formation without unconformity. It is composed of brown shales that are mostly covered and light gray sandstones and limestones. The formation has been divided into 19 units, and together these total 354 feet in thickness, 250 feet of which are covered.

Thaynes formation.— The Upper Triassic Thaynes formation conformably overlies the Woodside formation, and underlies the Sawtooth formation of Lower Jurassic age. It is composed of buff to tan and dark to light gray limestones, and tan to gray siltstones. Unit 5 contains numerous Pentacrinus and its surface is covered with lichens; unit 16 is fossiliferous. The formation is composed of 17 units; their total thickness is 792 feet, 406 feet of which are covered.

Jurassic system

General statement.— The Jurassic system in the areas southwest of Dell is composed of two formations. The Sawtooth, of Lower Jurassic (Lower Ellis) age, and the Reardon, also of Lower Jurassic (Mid-Ellis) age, are the only representatives of the system in the area. There is a possibility that the Morrison formation, of Upper Jurassic age is present; if so, it is represented by unit 1 of the Kootenay formation. The Swift formation is not represented in the general area so far as the writer knows.

Sawtooth formation.— The Sawtooth formation is composed of three units. Units 1 and 2 are composed of light gray to buff shales, and brown siltstone, the latter interbedded with brown limestone. The third unit is completely covered. The total thickness of the formation is 252 feet. The Thaynes formation conformably underlies it and the Reardon formation conformably overlies it. The section was measured by Wallace and Krusekopf in the south half of section 22, T. 13 S., R. 10 W.

Reardon formation.— The Reardon formation is composed of four units of which two are gray to buff oolitic limestone units, one is a light brown shale unit, and one a covered interval. The Reardon formation is unconformably overlain by the Kootenay and conformably underlain by the Sawtooth. The total thickness is 116 feet, of which 78 feet are covered. It was measured by Wallace and Krusekopf in the west half of section 10, T. 13 S., R. 10 W.

Cretaceous system

Kootenay formation.— The Kootenay formation of Lower Cretaceous age lies unconformably over the Sawtooth and unconformably underlies the Tertiary Basin beds of

Muddy Creek Basin. There are 35 units in the formation. They consist of numerous salt and pepper sandstones alternating with red, brown, and purple shales. The total thickness is 2,201 feet, of which 1,030 feet are covered. Wallace and Krusekopf measured the section in the east half of section 9, T. 13 S., R. 10 W.

Cretaceous or Early Tertiary formation

Red Rock conglomerate.— The Red Rock conglomerate was deposited during the early part of the Laramide Revolution before the Eocene and following the folding that produced highlands to the west (plate 4, fig. 2). The exact age of the conglomerate is unknown and as yet no fossils have been found in it. However, as the sequence of events (page 45) was worked out, its most logical position seems to be following the first movement of diastrophism in the Laramide Revolution. The conglomerate is composed mainly of poorly sorted, blue limestone pebbles, rounded to subangular, probably of Madison age, with a friable red matrix of limy sandstone with lenses of friable, tan, limy sandstone, both possibly from the Phosphoria. In the only good exposure seen the blue limestone pebbles are found only in the red sandstone matrix but not in the tan sandstone which is found in layers and as small lenses within zones of pure red sandstone. In some areas it is well cemented and forms prominent cliffs and hills.

The two cross sections of Plate 5, A - A' and B - B', show the conglomerate as lying unconformably on top of the Madison. Cross section B - B' shows the Madison projecting through the conglomerate some distance to the northeast of the last exposure on the high ridge. The conglomerate therefore appears to have been deposited in a cup like depression in the Madison. The total thickness of the conglomerate may be as much as 2,000 $\pm$ feet but at the contact of the conglomerate and Madison in Chute Canyon the conglomerate completely wedges out. There were no exposures of enough magnitude to permit a measurement or even an estimate of the total thickness.

The conglomerate dips in two directions, approximately 26 degrees NE and 20 degrees SW. The reason for these two opposed dips is unknown to the writer; because of lack of exact knowledge it is difficult to make any direct statements concerning its history.

In the same area there is also a conglomerate composed of rounded, polished, quartzitic boulders. The cement is slightly limonitic and is grayish in color. At the head of Chute canyon, on the southeast side, this conglomerate is in sedimentary contact with the Madison. To the northwest, along the northeast side of the high ridge at the head of Chute canyon, and seemingly at a lower elevation, the Red Rock conglomerate is in sedimentary contact with the Madison. Here there is no sign of the quartzitic conglomerate. Whether or not this quartzitic conglomerate should be considered as a part of the Red Rock conglomerate is not known because much vegetation cover conceals any contact that may exist between the two. Their relationship must remain obscure until good contacts have been found by further investigation. The high hills back of the triangular facets to the southeast of Chute canyon appear to be composed of these hard quartzitic boulders near the tops of the hills and the Red Rock conglomerate is exposed only farther down the slopes of the hills.

Tertiary system

Muddy Basin Beds.— The Tertiary Basin beds in Muddy Creek Basin were probably deposited during the Lower Miocene. The beds consist of gray to light tan conglomerate with reddish zones and light colored volcanic tuffs. In places the red color is very prominent and can be traced as a distinct zone over short distances. The formation as a whole is poorly cemented and forms only low rolling hills in the southeastern part of the basin. In the northwestern or upper part of the basin light colored volcanic tuffs are exposed along the sides of the basin (see plate 2). Muddy Creek, at the present time is eroding these tuffs and the water is clouded by the suspended particles, hence the name Muddy Creek.

There are beds of shale in the formation that contain abundant plant remains. One of these beds outcrops on the northeastern side of the basin. Many plant leaves and stems were found but none sufficiently well preserved for identification. Bowen (1917, pp. 315—320) published the first account of Muddy Basin. He found Sequoia leaves in the shales exposed on the eastern side of the basin. Whether or not the shales mentioned by Bowen are the same as those described by the writer is not known.

PLATE 2

View looking approximately northwest up Muddy Creek Basin. Volcanic tuffs are seen as light colored deposits exposed on the southwest side of the basin.

The Basin beds lie unconformably against the Madison thrust block on the southwestern side of Muddy Creek Basin, whereas on the north side they lie unconformably against and over the Phosphoria. The Basin beds overlie the Phosphoria in a sedimentary contact where the fault dies out in the southeastern part of the basin (see geologic map, in pocket).

W. P. Haynes (1916, pp. 270—290) shows that the original name "Bozeman Lake Beds" of Peale (1893, pp. 32—43) is not correct. In the Threeforks region he found the beds to be subaerial and fluviatile deposits chiefly of Miocene and in places Oligocene age. The Bozeman beds there are chiefly conglomerates, sandstones, clays, and volcanics. Iddings and Weed (1892, pp. 1—4) found conglomerates, sandstones, clays, marls, and volcanic dust to make up the Bozeman Beds in Gallatin Valley. The Bozeman Beds were named for the town of Bozeman, Montana. The thickness exposed in the quadrangle is about 1200 feet.

W. W. Atwood (1916, p. 705) states that the Bozeman Beds around Butte, Montana, may be in part lacustrine but for the most part are great alluvial outwash deposits. He divides the formation into upper and lower divisions, the latter being of Oligocene age (page 706) and the upper of Pliocene age (page 712). On page 706 is a general outline for the physiographic events of the Butte area. His major events agree with the writer's sequence of events (page 45 of this report).

There is a very close similarity between the type of sediments found in Muddy Creek basin and those of the Bozeman Beds described in the papers cited. This fact, plus structural evidence (page 45 of this report) seems to place the Muddy Basin beds in the Miocene.

STRUCTURAL GEOLOGY

General statement

The structures of the Tendoy Mountains are the result of two disturbances; the first known as the Laramide orogeny, came in the late Cretaceous and was characterized by folding and thrusting; the second, in the mid-Tertiary, is characterized by high-angle block faults which cut the earlier Laramide structures.

As shown in Plate 4, fig. 1, the whole area of southwestern Montana and eastern Idaho was depressed during the Mesozoic and Paleozoic eras. By the close of Cretaceous time at least 18,000 feet of sediments had accumulated in the site of the present Tendoy Mountains.

The formations in the geosynclinal area, before disturbance began, are represented by Plate 4, fig. 1. The beds are thick and appear to be flat lying with a slight thinning to the east as the shelf area is approached. For the upper four Paleozoic systems, Lemish (1947, p. 8) shows only 4,668 feet of thickness as compared with approximately 16,000 feet in the writer's area.

Laramide orogeny

The first phase of the Laramide orogeny (Plate 4, fig. 2) was the folding and creation of highlands to the west, that is, the mountains of southwestern Montana and eastern Idaho. In the Tendoy Mountain region compressional forces folded the Mesozoic and Paleozoic rocks into a homocline that trends generally northwest-southeast. The general dip for all the beds in the Dell area is southwest. The next stage, represented in part by Plate 4, fig. 2, was the deposition of the Red Rock conglomerate (No. 3, page 45) in the Red Rock Basin to the northeast.

In the area mapped by Wallace (1947, pp. 36—37, plate 3) there is a minor syncline present, the axis of which is at an angle to the main trend of the homocline that produces the uplifted Mesozoic and Paleozoic rocks in the writer's area. Wallace and Krusekopf have called this structure the Little Water Syncline. This period is number 4 in the sequence of events on page 45 of this report.

The Amsden and Madison formations, wherever exposed in the writer's area, are badly crushed and tightly folded. As shown in the cross-section (A - A', Plate 5, in pocket) the upper Paleozoic strata lie conformably above one another and all have a more or less uniform dip in the same direction. However, the Phosphoria and Quadrant are not crushed or tightly folded as are the Amsden and Madison. This crushing suggests the possibility of overthrusting to some extent, the thrust plane lying somewhere in or below the Madison. (See northeast end of cross section). Overthrusting seems possible for the area because the Madison is thrust over the Triassic south of the Muddy Creek Basin (see cross-section, southwest side). The Madison there is crushed and folded in the same manner as the Amsden and Madison near the front of the writer's area.

During the period of erosion following the uplift of the western highland more compressional forces accumulated and the Madison formation broke and was thrust over the Triassic during the Paleocene. The limestone wherever exposed is crushed and tightly folded, showing evidence of drag on the overriding sheet. This low angle fault is here called the Tendoy thrust. The thrust moved from the southwest to the northeast, but at the present time the amount of horizontal displacement cannot be measured. On the cross section the Tertiary period of high angle block faulting is shown cutting the Tendoy thrust. Erosion has cut back the thrust sheet to its present site; however, the most northeasterly extent of the thrust sheet in the immediate area is marked by a "klippe" of Madison limestone lying unconformably over the Quadrant in the area immediately to the southwest (Krusekopf, 1947, p. 40).

Another period of erosion (No. 7, page 45) began after the Paleocene thrusting, and following this the Red Rock conglomerate was folded (No. 8, page 45). The Lima anticline is an excellent example of this folding. Folding of the conglomerate is apparent in the writer's area and this is shown by its dip in two opposite directions to the west of Chute Canyon. Only one direction is represented on the cross section. Between Garr and Chute Canyons the conglomerate dips 26 degrees to the northeast whereas northwest of Garr Canyon it dips from 17 to 25 degrees to the west. There is no apparent explanation for the two opposite dips.

Post-Laramide orogeny

Between the Laramide and post-Laramide orogenies there was a very long cycle of erosion that produced broad basins over southwestern Montana. The erosion of the Muddy Creek Basin started in the Eocene and proceeded to the close of the Oligocene. Muddy Creek Basin escaped deposition during Upper Eocene and Oligocene time but other basins in the area were filled with sediments. Of these the Sage Creek beds north of Dell are of Upper Eocene age.

Erosion ceased in Muddy Creek Basin in the Lower Miocene and the Muddy Creek Basin beds were then deposited (Plate 4, fig. 4).

Following this Early Miocene deposition, the second major diastrophism began. This time the forces were not compressive but tensional, producing high angle faults. Muddy Creek Basin became a graben. The high angle fault on the south of Muddy Creek Basin can be traced for 3.25 miles before it dies out in the Basin beds on both its east and west ends. The fault cuts across a part of the Tendoy thrust as shown on the geologic map (in pocket). A block of the Madison limestone has been dropped down on the north side of the fault and is covered by alluvium and Basin beds. The vertical displacement could not be measured but probably exceeds several hundred feet.

On the north of Muddy Creek Basin the high angle fault is traceable for 2.5 miles to the southeast of Sheep Creek road where it merges into an unconformable sedimentary contact with the Phosphoria and basin beds. The basin beds along the fault can be seen dipping ten to twenty degrees northeast into the fault, and in places flattening slightly at the fault, whereas the Phosphoria dips 26 degrees southwest into the fault. Where the fault dies out, the Basin beds unconformably overlie the Phosphoria in a sedimentary contact. The dip of the Basin beds is approximately equal to that of the Phosphoria and in the same direction.

Between the uplifted Paleozoics and the Red Rock Basin is the third high angle fault zone of the writer's area. This second major stage of high angle faulting began in the Pliocene after the first stage in Muddy Basin stopped in the Late Miocene. Three faults of the en échelon type cross the area. The faults broke only in the Red Rock conglomerate, the mountain side going up and the north, or Red Rock Basin, going down. The exact vertical displacement is unknown. However, judging from the height of the triangular facets (Plate 3), the maximum displacement was probably more than 500 feet. There is a discontinuous erosion surface in Chute Canyon that defines a stage of erosion probably of the same age as those surfaces found in the Muddy Creek Basin (see Physiography, page 51). Assuming this to be true, then the faulting of the Red Rock conglomerate must have been later than the high angle faulting in Muddy Basin in order to renew the erosion in that area. The erosion surfaces are as high as the uplifted block and this height agrees with the visible displacement of the fault scarp. This dropping down of the Red Rock Basin lowered the base level for Sheep Creek and rejuvenated the erosion of the basin beds in Muddy Creek basin.

Perfect examples of triangular facets may easily be seen from the highway between Lima and Dell (Plate 3). Above the alluvial fans there is a zone showing renewed movement along the fault. This is seen as a dark band immediately above the alluvial fans. The slope of this zone is much steeper than the slope of the triangular facets. See page 53 of Physiography.

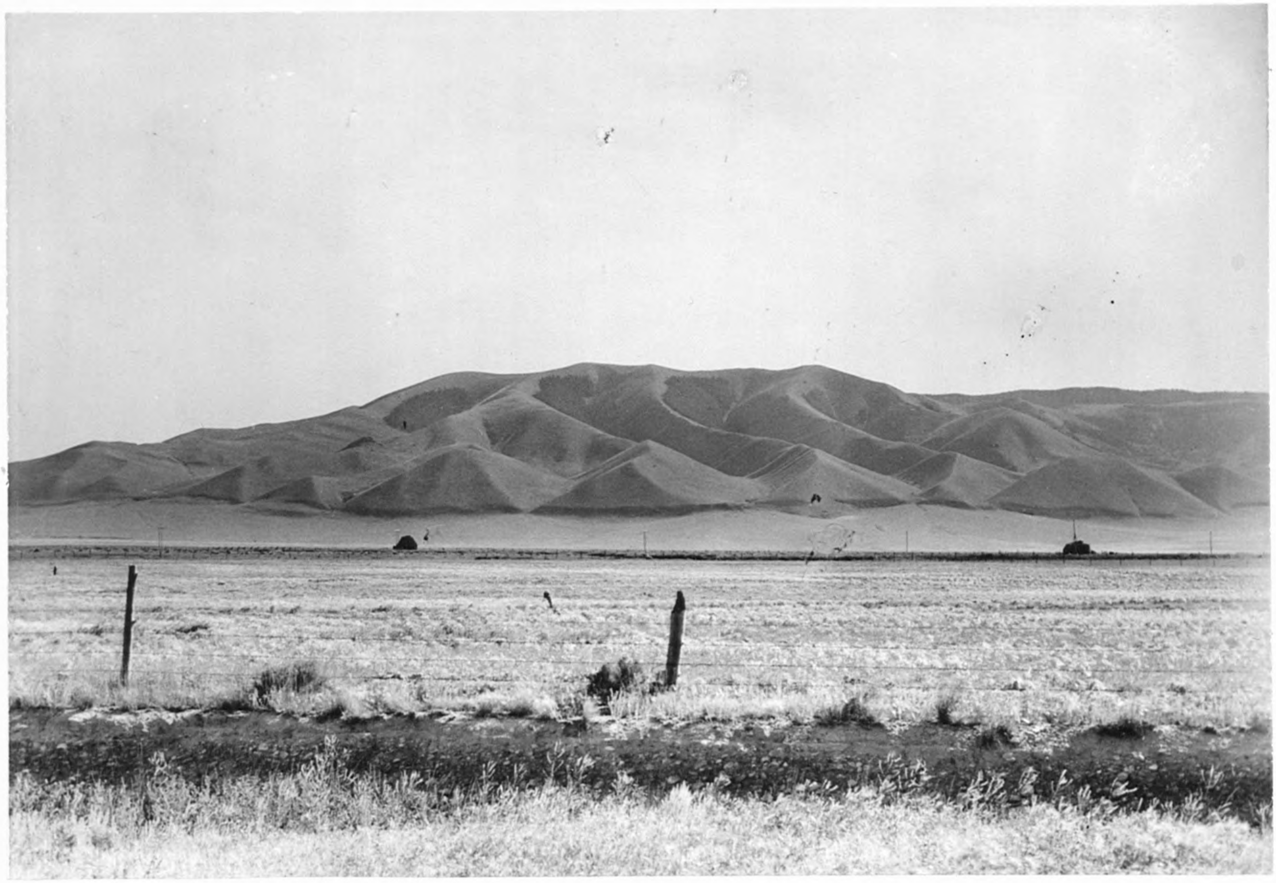


PLATE 3

Triangular facets on the front of the Tendoy Mountains rising abruptly from the flat Red Rock Basin; approximately two miles east of Dell, looking south. The dark gray band immediately above the alluvial fans is evidence for renewed movement along the fault in Recent times. Note the fairly flat high-level surface.

Sequence of Events for the General Area
of Dell, Montana

	17. Erosion of present day surface; movement along Red Rock fault	Recent
	16. Erosion cycle that resulted in broad pediments, glaciation in Nicholia Basin	Pliocene
Mid-Tertiary orogeny	15. Faulting along mountain front with rejuvenation of drainage	Pliocene
	14. Erosion of high erosion surfaces	Pliocene
	13. High angle faulting in Muddy Creek Basin	Late Miocene
	12. Deposition of Lower Miocene Beds in basins (Muddy Basin Beds)	Early Miocene
Erosion in Muddy Creek Basin	11. Deposition of Oligocene beds in basins	Oligocene
	10. Deposition of Sage Creek beds in basin and volcanism in area	Upper Eocene
	9. Long cycle of erosion producing broad basins	Early or Middle Eocene
Phases of Laramide orogeny	8. Folding and faulting of Red Rock conglomerate (Lima anticline)	Paleocene or Early Eocene
	7. Period of erosion	Paleocene
	6. Thrusting (Tendoy thrust)	Late Cretaceous or Early Paleocene
	5. Erosion	Late Cretaceous or Early Paleocene
	4. Cross-folding (cross-syncline) Little Water syncline	
	3. Deposition of the Red Rock conglomerate	
	2. Folding and creating of highlands to the west in closing stages of Cretaceous	
	1. Deposition of Paleozoic and Mesozoic formations in the geosyncline	

EXPLANATION OF PLATE 4

Sequence of events for the general area of Dell, Montana

The six figures represent the main events that resulted in the present structure in the area. The figures are not drawn to an exact scale; however the horizontal scale represents approximately 20 miles, and the vertical scale 10,000 feet.

Figure 1. (Unit 1 in sequence of events) Shows the slightly dipping, thick deposits of the upper Paleozoic and Mesozoic beds before the start of folding in the geosyncline of which this area is a part.

Figure 2. (Units 2 and 3 in sequence of events) Represents the folded Paleozoic and Mesozoic sediments before thrusting in the Early Laramide. This produced the rise of the highlands to the west, a regional feature in Idaho and southwestern Montana, and the deposition of the Red Rock conglomerate (Trr). The approximate plane where the Tendoy thrust will break is also shown.

Figure 3. (Unit 6 in sequence of events) Shows the Tendoy thrust in the Late Cretaceous or Early Paleocene. The much folded and crushed Madison (Cm) block is shown as it overrode the Paleozoic and Mesozoic rocks. A possible minor thrust plane is shown within the Madison, lying beneath the Red Rock conglomerate.

Figure 4. (Unit 12 in sequence of events) Shows the Lower Miocene basin beds filling both Muddy Creek basin and the upper basin (Nicholia basin) at the time of their deposition. There may be a possible connection between the beds in both basins.

Figure 5. (Units 13 and 14 in sequence of events) Represents the structure of the Late Miocene or Early Pliocene after the high angle faulting took place in Muddy Basin. Due to this faulting Muddy Basin is a graben. The high erosion surfaces of the Muddy Creek Basin and the Red Rock Basin are also shown sloping into their respective basins.

Figure 6. (Units 15 and 17 in sequence of events) Shows the structure after the last stage of major faulting in the represented area. This took place in the Pliocene as an en échelon fault pattern. The Red Rock Basin is now also a graben. The topography is represented essentially as it appears at the present time. Evidence for Recent movement along the fault bounding the Red Rock Basin is not shown.

PLATE 4

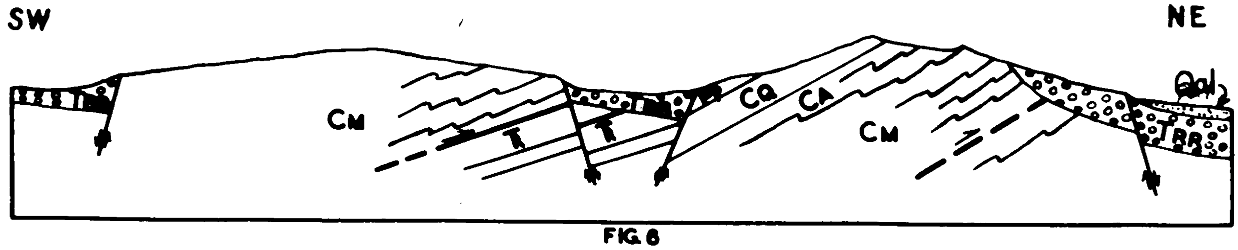


FIG. 6

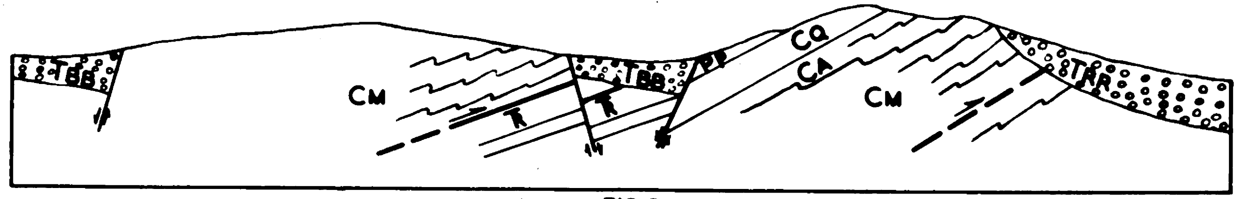


FIG. 5

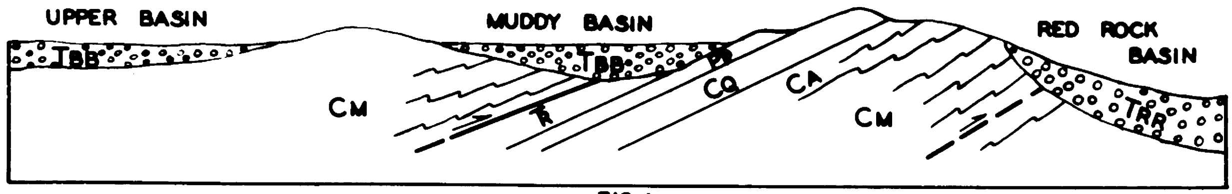


FIG. 4

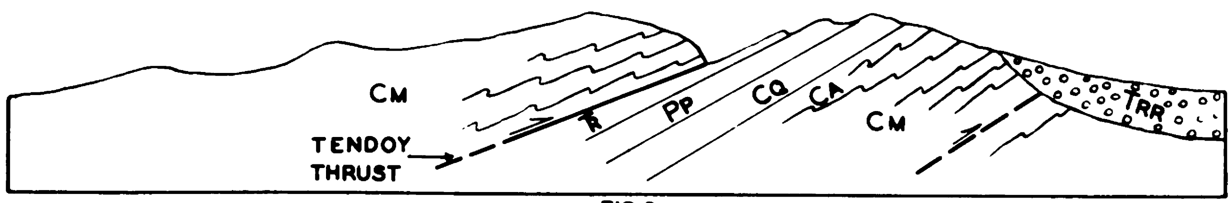


FIG. 3

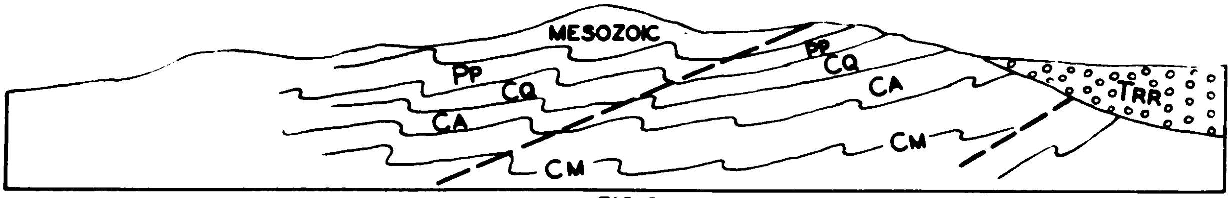


FIG. 2

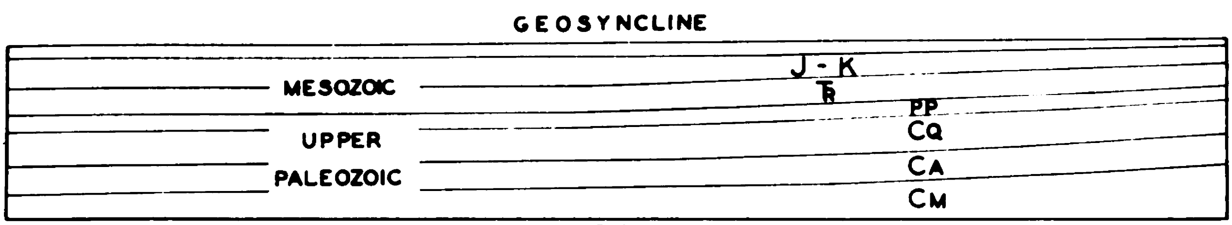


FIG. 1

PHYSIOGRAPHY

General statement

The Tendoy Mountains are located in the Northern Rocky Mountain province in southwestern Montana. The mountains extend slightly west of north from the Beaverhead Mountains near the Montana - Idaho border to the vicinity of Armstead in a band approximately five to six miles wide and 35 to 40 miles long.

Surrounding the Tendoy Mountains in Idaho and Montana are the Beaverhead and Lemhi Ranges to the west and the Centennial Range to the east. Both the Centennial and Beaverhead Ranges form part of the Continental Divide and the state border between Montana and Idaho in that region. The Red Rock Mountains, Snow Crest and Gravelly Ranges lie to the east and north of the Centennials; the Ruby Range and the Tobacco Root Mountains lie to the northeast.

Surrounding the area are also large valleys and basins, which lie between some of the various highlands named above; these are the Lemhi and Pahsimeroy Valleys to the west in Idaho, the Centennial Valley to the east, the Big Hole Basin to the northwest, and the large unnamed basin extending north of Dillon, all in Montana (see plate 1).

As shown by the following, the mountain chains in southwestern Montana are not regular. The northwest trending mountains are the Lemhi, Beaverhead, and Red Rock mountains. The Tobacco Root and Gravelly Ranges trend slightly east of north, the Ruby Range trends northeast, and the Centennial Range, east.

Minor drainage in the Tendoy Mountains is by consequent streams that head in the mountains and flow generally northwest or southeast. Muddy Creek is considered as a minor stream although it drains the greater part of Muddy Creek Basin; it flows southeast and more or less parallel to the structure.

The major streams in the area flow independently of the existing structure. Sheep Creek heads in the Beaverhead Mountains to the southwest and flows generally north across all existing structure and empties into the Red Rock River. It therefore must be an antecedent stream that occupied its present position before deformation commenced. If Sheep Creek was younger than the mid-Tertiary block faulting its course would most likely have been controlled by the horst-graben structure formed at that time. There are high level gravels on a post-faulting surface, well below the mountain crests in the area mapped immediately to the west by H. H. Krusekopf. It therefore seems probable that Sheep Creek was eroding its channel at the time of deposition and not draining by way of the Little Water Syncline a few miles to the northwest.

Climate and vegetation

Southwestern Montana is a semi-arid region, the rainfall is 10 to 20 inches annually (Goode, 1946, p. 46). The temperature is variable during the summer months, ranging from freezing at night to about 85 to 90 degrees Fahrenheit during the daytime. While the writer was in the field a strong breeze blew almost continuously during the daytime from a general easterly direction.

Vegetation is composed mostly of sagebrush, grass, and pine trees. The sagebrush is confined more generally to the stream valleys and grass covers the whole area. Pine trees seem to grow most abundantly in two places, the protected sides of watered valleys and canyons, and on almost every outcrop of the Quadrant formation with the exception of the talus slopes.

Erosion surfaces

Muddy Creek Basin.— During the early Pliocene there was much erosion in the Tendoy Mountains. The surfaces developed at this time are considered as high erosion surfaces (Plate 5, fig. 5). The Muddy Basin beds were eroded down to some extent and partly stripped of the underlying Paleozoic and Mesozoic beds. The preserved erosion surfaces that were developed upon the soft conglomeratic sediments appear as dissected flat-topped spurs. The most prominent spurs extend out into the basin from the northeastern side; however, one well preserved surface is found on a spur in Shearing Pen Gulch in the southeastern part of the basin. The surfaces in both places slope toward the central part of the bed of Muddy Creek. Where the present erosion surface is being cut into the spurs, the noses of the spurs have a variable slope, the maximum dip of which is not over 15 degrees.

Chute Canyon.— The erosion surface in this area was developed in the poorly cemented Red Rock conglomerate.

Remnants of this surface are present on top of dissected, flat-topped spurs above the present erosion level in the canyon. The canyon itself is a wide, shallow drainage area that was developed during an Early Pliocene period of active erosion. Chute Canyon is not a typical, steep-sided canyon except near its mouth. Above that point it spreads out into a broad, fan-shaped valley, having roughly the shape of a quarter-circle. The canyon ends at the fault front in a fairly narrow, flat floored outlet. Triangular facets are prominent along the fault front on both sides of the canyon, that is, to the northwest and southeast. The old surface that was downfaulted to form the Red Rock Basin is now covered with Quaternary alluvium of unknown thickness. Alluvial fans are present along the fault scarp for a short distance out into the Red Rock Basin. The general slope of the fans was found to average approximately 12 degrees. Two of the aerial photographs used in mapping the writer's area, CXM-12B-31, 32, show two sets of alluvial fans. The smaller, more recent fans are superimposed on the older and much larger fans.

The surface formed by the first fault movement in the Pliocene has been eroded back and thus the slope angle has been lessened. The present slope of the triangular facets is therefore not the true angle of the fault plane. Later movement along the fault front is suggested by two conditions: (1) The general slope of the triangular facets has been cut off above the contact of the facets and the alluvial fans. (2) New, smaller fans have been deposited on top of the older fans so as to form double fans. This is easily seen from the aerial photographs, especially No. CXM-12B-31.

Relationships between surfaces in Muddy Creek Basin and in Chute Canyon.— Assuming that the surfaces developed in Muddy Creek Basin and in Chute Canyon are of the same age (Early Pliocene) No. 14, page 45, then there must have been two periods of faulting. By the close of the erosion period Sheep Creek had probably eroded its channel to the base level determined by the elevation of the Red Rock Basin. Without a drastic change in the base level of Sheep Creek the present depth of erosion in Muddy Creek Basin could never have been attained. To account for this a later period of high angle faulting must be assumed. The erosion surfaces discussed in the two preceding sections provide the proof needed to establish two periods of faulting. The surfaces in Chute Canyon are located on the upthrown side of the fault. A projection of the surfaces extends out to the triangular facets and this coincides with the general plane formed by the crests of the spurs extending back of the facets. Therefore the surface is older than the fault.

In Muddy Creek Basin the erosion surface is a continuous one as it crosses the plane of the fault (Plate 4, fig. 5). Therefore the faulting in Muddy Creek Basin is older than the erosion surface. Assuming that there were two periods of faulting, then the rejuvenated erosion in Muddy Creek Basin is accounted for. The base level for Sheep Creek was lower when the Red Rock Basin was faulted down as a graben. Therefore Sheep Creek would again start to erode in a vertical direction, seeking the new base level. The base level for the drainage area of Sheep creek was therefore lowered and more vigorous downcutting began and Muddy creek began to carve out the soft basin beds over which it ran.

Various hypotheses have been developed in the past for the dating of old erosion surfaces in the general area of Idaho and western Montana. Each writer presents ideas that conflict with those of his predecessors. The writer makes no attempt here to evaluate these conflicting ideas; they are discussed in detail in the following references: Blackwelder 1912, Umpleby 1912, Rich 1918, Mansfield 1927.

Other writers have dealt with the more general physiography of the same region; they are: Pardee 1911, Umpleby 1913 and 1917, Kirkham 1927, Ross 1931, and Atwood 1916.

In the upper Basin, Kupsch and Scholten have mapped two glacial moraines and there is a possibility that a third one exists (personal communication).

REFERENCES CITED

Atwood, W. W. 1916 — The Physiographic conditions at Butte, Montana, and Bingham Canyon, Utah when copper ores were enriched. Econ. Geol. vol. 11, no. 8, pp. 698—740.

Blackwelder, Eliot. 1912 — The old erosion surface in Idaho; a criticism. Jour. Geol. vol. 20, pp. 410—414.

Bowen, C. F. 1917 — Phosphatic oil shale near Dell and Dillon, Beaverhead County, Montana. U.S.G.S. Bull. 661, pp. 315—320.

Condit, D. D. 1918 — Relations of Late Paleozoic and Early Mesozoic formations of southwestern Montana and adjacent parts of Wyoming. U.S.G.S. Prof. Paper 120-F, pp. 111—121.

Darton, N. H. 1904 — Comparison of the Stratigraphy of the Black Hills, Big Horn Mountains, and Rocky Mountain Front Range. Geol. Soc. Amer. Bull. 15, pp. 394—401.

Eardley, A. J. 1942 — Aerial Photographs; Their use and interpretation. Harper and Brothers, New York, 198 pp., 46 pls., 46 figs.

Eardley, A. J. 1947 — Paleozoic Cordilleran Geosyncline and related orogeny. Jour. Geol. vol. 55, No. 4, pp. 309—342.

Goode, Paul J. 1946 — Goode's School Atlas. Rand McNally and Co., 286 pp., illus.

Haynes, W. P. 1916 — The Lombard overthrust and related geological features. Jour. Geol. vol. 24, pp. 269—290.

Iddings, I. P. and Weed, W. H. 1892 — Livingston Atlas Sheet (Montana). U.S.G.S. Geol. Atlas, Livingston Folio (No. 1) 4 pp., maps, prel. edition.

---------- and ---------- 1896 — Livingston Folio (No. 1) Abstract, Jour. Geol. vol. 4, pp. 246—248.

---------- and ---------- 1899 — Descriptive Geology of the Gallatin Mountains. U.S.G.S. Monograph 32, pp. 1—59.

Kirkham, Virgil R. D. 1927 — A geological reconnaissance of Clark, Jefferson, and parts of Butte, Caster, Fremont, Lemhi, and Madison Counties, Idaho. Idaho Bur. of Mines and Geol., Pamphlet 19, 47 pp.

Krusekopf, Henry H. Jr. 1948 — Geology of the Tendoy Range, near Dell, Beaverhead County, Montana. University of Michigan, Master's thesis, 53 pp.

Lemish, John. 1947 — The Geology of the West Fork of the Madison River area, Montana. University of Michigan, Master's thesis, 40 pp.

Mansfield, G. R. 1927 — Geography, Geology, and Mineral Resources of part of southeastern Idaho. U.S. G.S. Prof. Paper 152, 453 pp.

Pardee, J. T. 1911 — Geology and mineralization of the upper St. Joe River basin, Idaho. U.S.G.S. Bull. 470, pp. 39—61, map.

Peale, A. C. 1893 — The Paleozoic section in the vicinity of Three Forks, Montana. U.S.G.S. Bull. 110, pp. 32—43.

Reeves, Frank. 1931 — Geology of the Big Snowy Mountains. U.S.G.S. Prof. Paper 165, pp. 135—149.

Rich, J. L. 1918 — An old erosion surface in Idaho; is it Eocene? Econ. Geol. vol. 13, pp. 120—136, 1 fig.

Richards, R. W. and Mansfield, G. R. 1912 — The Bannock overthrust, a major fault in southeastern Idaho and northeastern Utah. Jour. Geol. vol. 20, pp. 683—689.

Ross. C. P. 1931 — Correlation and interpretation of Paleozoic strata in south central Idaho. Geol. Soc. Amer. Bull. vol. 45, No. 2, pp. 937—1000, 2 figs.

Scott, Harold W. 1935 — Some Carboniferous stratigraphy in Montana and northwestern Wyoming. Jour. Geol. vol. 43, pp. 1011—1032.

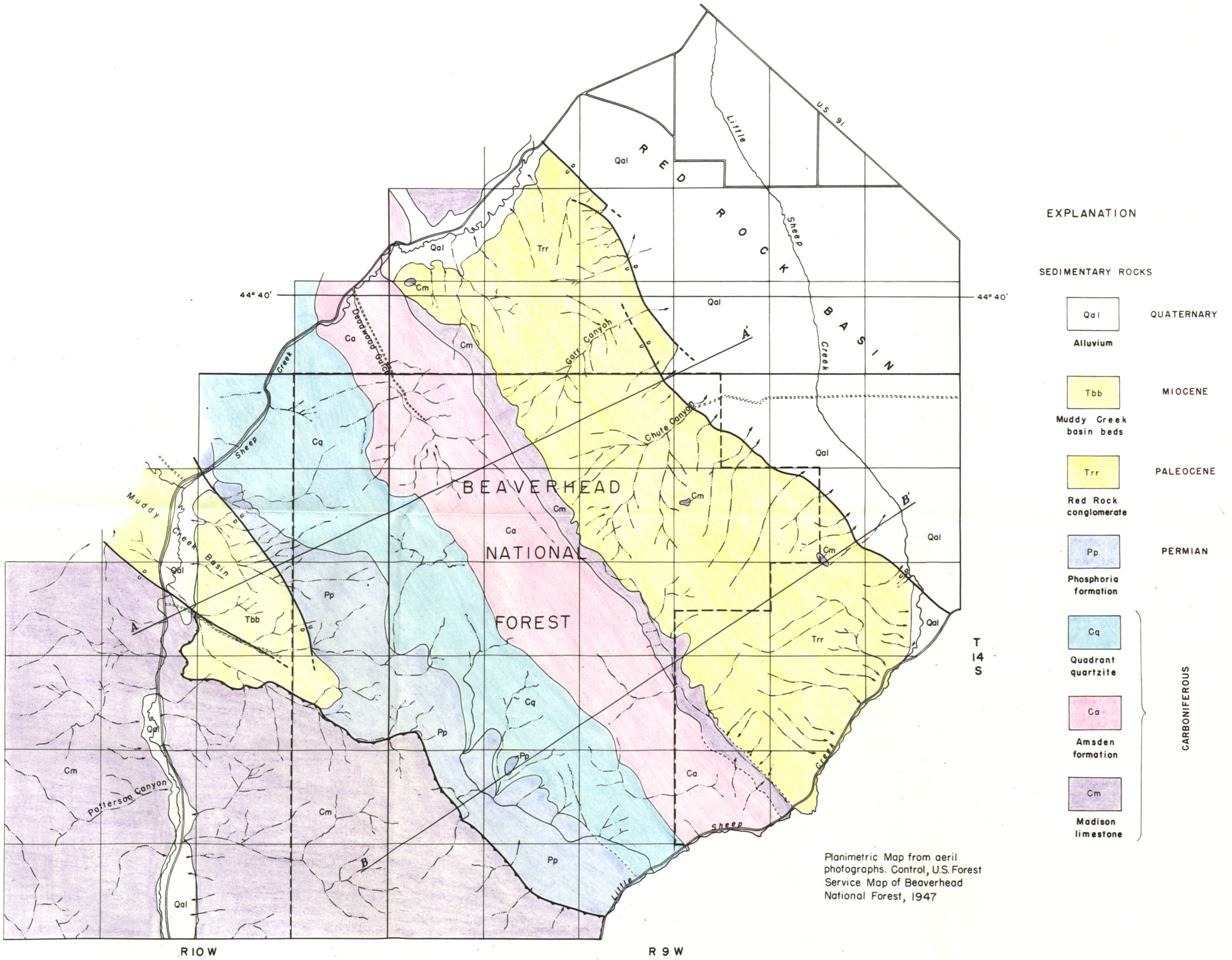
Umpleby, Joseph B. 1912 — An old erosion surface in Idaho, its age and value as a datum plane. Jour. Geol. vol. 20, pp. 139—147. (Abstract, Wash. Acad. Sci. Journal, vol. 2, pp. 109—110, 1912.)

---------- 1913 — Geology and Ore Deposits of Lemhi County, Idaho. U.S.G.S. Bull. 528, 182 pp.

---------- 1917 — Geology and Ore Deposits of Mackay Region, Idaho. U.S.G.S. Prof. Paper 97, 127 pp.

Wallace, Stewart R. 1948 — Geology of part of the Tendoy Mountains, Beaverhead County, Montana. University of Michigan, Master's thesis, 56 pp.

Wilmarth, N. Grace. 1938 — Lexicon of geologic names of the U. S. (including Alaska). U.S.G.S. Bull. 896, 2396 pp.

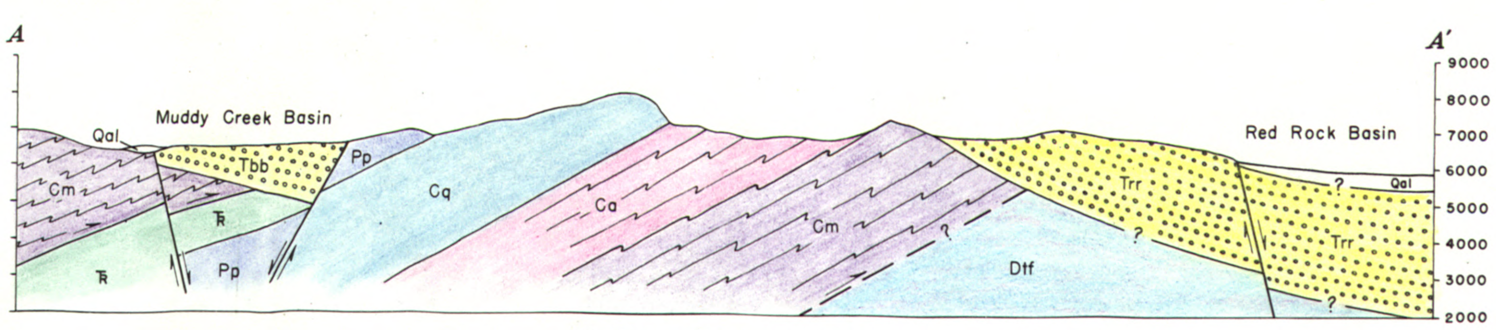


GEOLOGY OF PART OF THE
TENDOY MOUNTAINS, BEAVERHEAD COUNTY, MONTANA

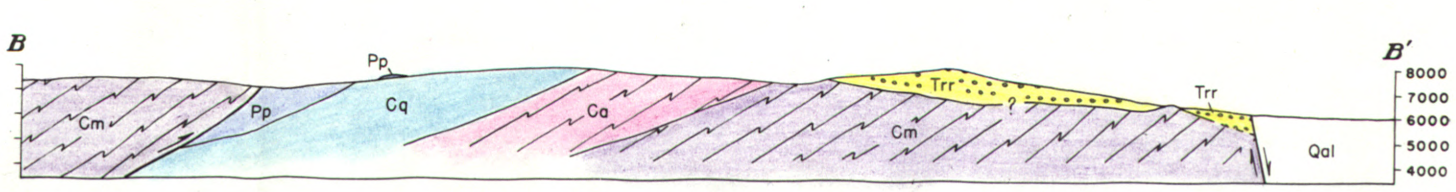
BY E.G. LIPP AND R.W. BECKER

1 0 1 2 3
MILES

1947



CROSS SECTION ALONG A-A'



CROSS SECTION ALONG B-B'