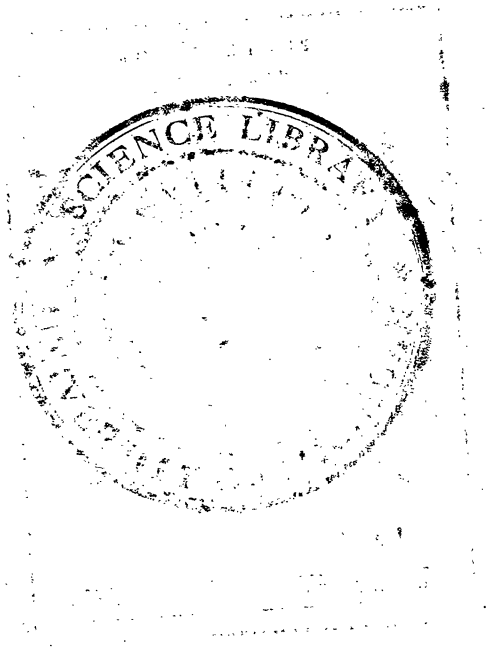
GEOLOGY OF THE TENDOY RANGE, NEAR DELL, BEAVERHEAD COUNTY, MONTANA

Henry H. Krusekopf, Jr.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GEOLOGY OF THE TENDOY RANGE, NEAR DELL, BEAVERHEAD COUNTY, MONTANA

Henry H. Krusekopf, Jr.

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

This report describes the geology of a portion of the Tendoy Range west of Dell, Montana. The region is in the Northern Rocky Mountain physiographic province and is characterized by steep sided valleys but flat or gently sloping mountain summits. Strata from Mississippian through the Recent are exposed in the area, but older strata are found a few miles west of the Tendoy Range. The Tertiary is represented by the Paleocene Red Rock conglomerate and the Miocene Muddy Creek basin beds. Volcanic activity in late Pliocene or early Pleistocene produced a breccia that covers a small area on the west side of the mountains.

Laramide folding produced the major structural features of the Tendoy Range. The Paleozoic and Mesozoic strata were tilted to the west and overridden on the western margin by the Tendoy thrust. In Miocene time the mass was cut by three normal faults, sharply dividing the basins and ranges. Subsequent erosion has produced the mountain range and valleys of the present.

INTRODUCTION

Location of the area

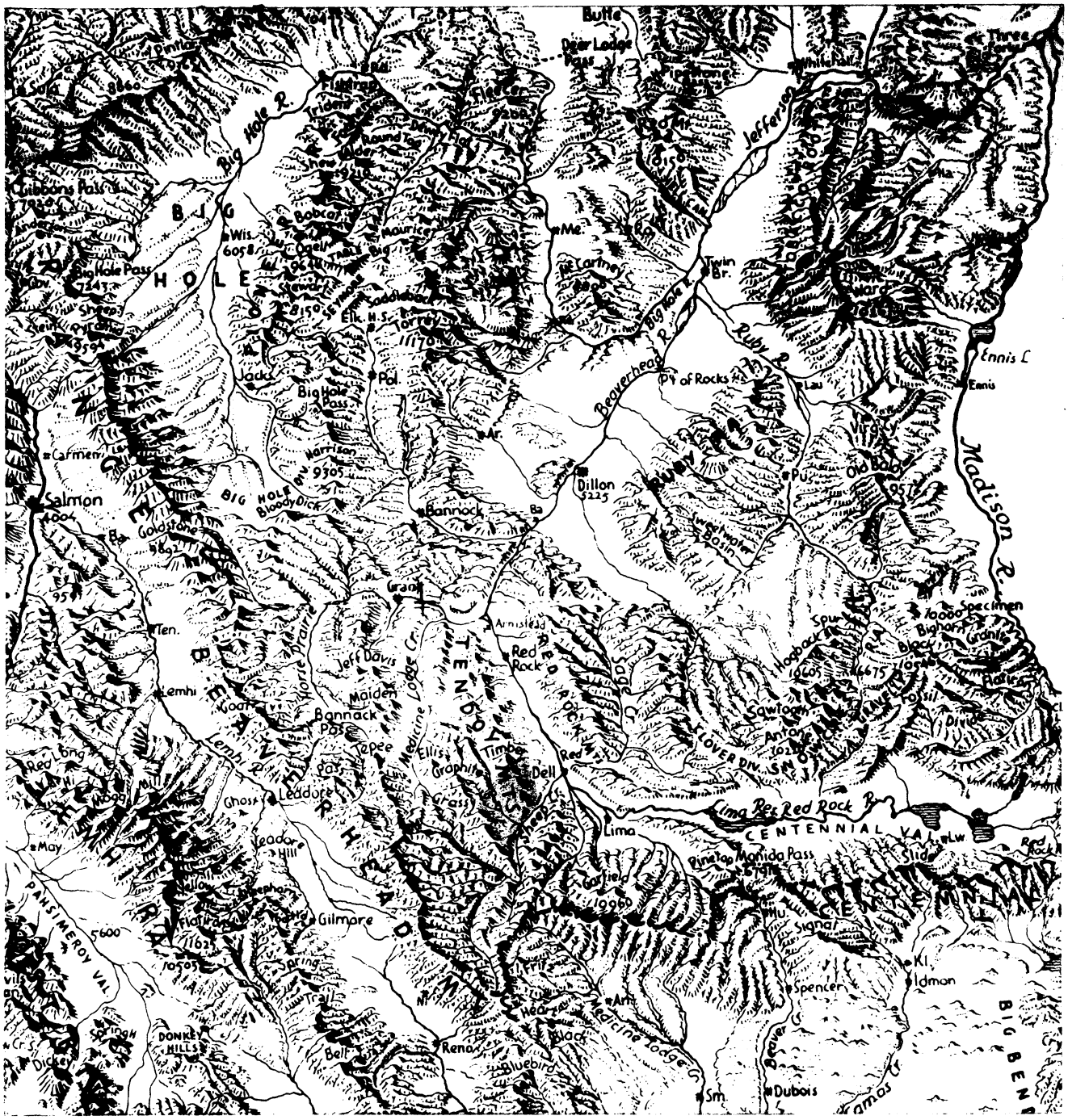
The Tendoy Range trends slightly west of north through the center of Beaverhead County, Montana. The area to be described lies in part of this range west of Dell, Montana. The Red Rock River valley lies on the east and the Muddy Creek basin on the west side of the area. The south side is bounded by Sheep Creek, which flows northeast across the range at right angles to the structural trends. A line across the range about six miles north of Sheep Creek delineates the northern extension of the area. See plate 1.

The area is reached by U.S. Highway 91 and the Oregon Short Line railroad, both routes extending north and south past the village of Dell. County roads along Sheep Creek and Muddy Creek allow easy access to any part of the area.

Purpose of study

The purpose of the study is to decipher the geology of the Tendoy Range. A secondary purpose in the study was to determine if Laramide structural trends already known in northwestern Wyoming and northeastern Idaho

PLATE 1



E. Raisz

INDEX MAP

could be identified in southwestern Montana. The present study marks the first attempt to correlate the geologic structures of the two areas across the broad Snake River lava plains. The report is submitted as a thesis in partial fulfillment of the requirements for the degree of Master of Science at the University of Michigan.

Acknowledgments

Field work for the report was done during three weeks in July and August, 1947. A base camp was established on Sheep Creek, one mile west of the junction of Muddy Creek with Sheep Creek. Dr. A. J. Eardley of the University of Michigan, supervised the field work and the writing of this report. Stewart Wallace, graduate student at the University of Michigan was the author's associate in the field. Edward Lipp and Robert Becker, graduate students at the University of Michigan, mapped an adjoining area just south of the subject area and measured part of the geologic section. Part of the geologic section was measured by Stewart Wallace and the writer.

Previous work

Oil shales were noted as early as 1917 by C. F. Bowen (1917, p. 315) in the Muddy Creek Basin. The

shales were described but not mapped. This is the only reference to work done in the Tendoy Range until 1946 when Perry and Sahinen (Blue-printed map personally furnished) made a geologic reconnaissance map of a portion of southwestern Montana. Winchell (1914), Shenon (1931) and Corry (1933) have described ore deposits near Dillon, Montana, 45 miles north of Dell. Pardee (1939, p. 354) mentions Tertiary faulting near Lima, Montana, 10 miles south of Dell. Outside of these general references to the area no geologic work has been done in the Tendoy Range. During the summer of 1947 two other mapping parties besides the author's were working in the Tendoy Range or adjacent areas. Personal communications from these parties aided in the preparation of this paper.

STRATIGRAPHY

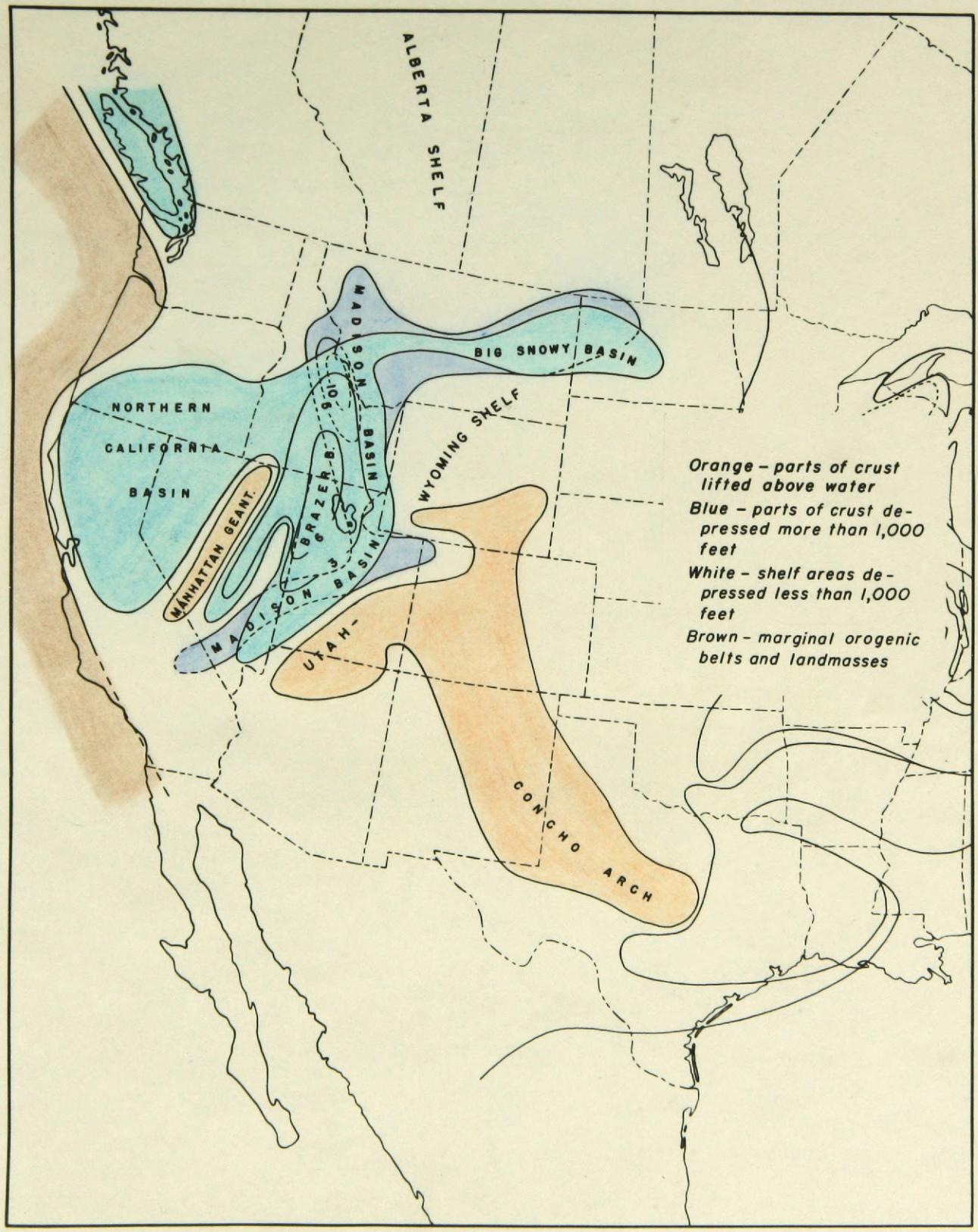
General outline

The rocks of the Tendoy Range consist mostly of consolidated sedimentary rocks. No intrusive igneous rocks are known in the area and extrusive igneous rocks occupy only a small area in the west central part of the mountains.

The sedimentary rocks range from Mississippian to Tertiary. Older rocks are exposed in the Beaverhead Range about 15 miles west and southwest of the area mapped. Marine invertebrate fossils were found in the Madison, Amsden, Phosphoria, Dinwoody, Thaynes, and Sawtooth formations. Plant fragments are numerous in some of the shales of the basin beds.

The sedimentary rocks of the region were laid down under progressively changing geographic conditions. The Paleozoic rocks were deposited in a subsiding geosyncline, the axis of which trended north-south and extended from southwestern Montana southward into western Utah. See Plate 2. This geosyncline started subsiding in early Paleozoic time (Eardley, unpublished data), and reached its greatest deepening in the Mississippian period when around 10,000 feet of strata were deposited. Geosynclinal

PLATE 2



after Eardley

TECTONIC MAP OF THE MISSISSIPPIAN

thicknesses of strata persisted into the Pennsylvanian and Permian periods but in southwest Montana did not reach the thicknesses found during the Mississippian period. Kirkham (1927, p. 19), Anderson and Wagner (1944, p. 7) and Umpleby (1917, p. 27-30), have reported similar thicknesses of Paleozoic rocks from central and eastern Idaho.

The Madison limestone thins rapidly both north and east of the Tendoy Range. Winchell (1914, p. 27) and Shenon (1931, p. 14) measured 1200 feet of Madison near Dillon, Montana, 45 miles north of Dell. Honkala (personal communication) measured 1,700 feet of Madison at the western end of the Centennial Valley, which thinned to 1,100 feet towards the eastern end of the Valley. The lithologic uniformity and absence of clastics in the Madison limestone in the geosynclinal area indicates an orderly and gradual subsidence with deposition.

The Mesozoic era was also a period of orderly deposition until the Cretaceous period. A coarse sandstone at the base of the Kootenai may indicate a slight tectonic disturbance at the start of the Cretaceous. To the north near Dillon, Montana Winchell (1914, p. 25) has described the Kootenai as containing a coarse conglomerate at its base. The major period of deformation

of the sediments, and the uplift of the Tendoy Range occurred at the close of the Cretaceous period. All Paleozoic and Mesozoic sediments were tilted about 30 - 35 degrees to the west at this time.

The Tertiary was a period of continental deposition, the Tendoy Range being alternately high and low. Coarse conglomerate and fine clastics attest to the changing geographic conditions, and unconformably overlie the older sediments. Volcanic material is abundant, and tuffs form a considerable thickness in the Tertiary sedimentary sequence.

The total thickness of the Carboniferous rocks is about 16,143 feet. The Triassic section measures 1,698 feet; the Jurassic section 368 feet; and the Cretaceous section at least 2,200 feet, although this is not a complete section. The following table summarizes the formations in the Tendoy Range:

Age	Formation	Thickness	Character
Quaternary	Alluvium	-------	Unconsolidated silt and gravel in valley bottoms

Age	Formation	Thickness	Character
Pleistocene or Pliocene	Volcanics	-------	Volcanic breccia and rhyolite
Miocene	Basin Beds	2,000'±	Volcanic tuffs, shales, sandstones, and limestones
Paleocene	Red Rock conglomerate	2,000'±	Massive conglomerate with limestone and quartzite pebbles and hematitic cement.
Lower Cretaceous	Kootenai	2,200'-	Red and gray shales and gray sandstones
Jurassic	Rierdon	116'	Oolitic limestones and light brown shales
	Sawtooth	252'	Light brown, calcareous siltstones and shales

Age	Formation	Thickness	Character
Triassic	Thaynes	792'	Gray limestones, silty limestones, and siltstones
	Woodside	354'	Gray sandstones and limestones and some shale
	Dinwoody	552'	Dark brown weathering shales, gray limestones
Permian	Phosphoria	802'	Gray, cherty, limestones and dolomites, buff sandstones and shales, with a red siltstone near top

Age	Formation	Thickness	Character
Pennsylvanian	Tensleep	3,319'	Massive brown quartzitic sandstone, with some dolomite towards top
	Amsden	2,022'	Gray to buff limestones, shales, and sandstones
Mississippian	Madison	8-10,000'	Massive gray limestone

Pre-Cambrian rocks

Very few exposures of pre-Cambrian rocks are found in the area, the closest exposure being at the northern end of Nicholia Basin (Kupsch and Scholten, personal communication). Here an undetermined thickness of gneiss and schist occurs.

Cambrian system

The Flathead quartzite is a dark red to brown dense quartzite, in places banded and crossbedded. An elongated pebble bed is also found. Complete sections are lacking so the thickness is undetermined. Outcrops are found along Tendoy Creek, about 15 miles west of the Tendoy Range. The Flathead was named by Peale (1893, p. 20) from exposures in Flathead Pass in the northeast corner of the Three Forks quadrangle, Montana, and is Middle Cambrian in age.

Ordovician system

The Kinnickinic quartzite is found in approximately the same localities as the Flathead, and apparently forms a minor anticlinal structure along Tendoy Creek. The formation consists of a white to pinkish, dense quartzite, which weathers to a yellow color. Outcrops are massive, and measure about 200 feet in thickness (Kupsch and Scholten, personal communication). The Kinnickinic formation was named by C. P. Ross (1934, p. 947) for the Kinnickinic creek near Clayton, Custer County, Idaho. It is Middle Ordovician in age.

Devonian system

The Three Forks formation was named by A. C. Peale (1893, p. 29) from exposures near the junction of three forks of the Missouri River in central Montana. The formation consists of alternating shales, thin limestones, and silty and sandy limestones and dolomites. A yellowish-gray color prevails throughout. The section measures about 150 feet and is found in the Nicholia Basin. It is Upper Devonian in age.

Mississippian system

The Madison limestone is Lower Mississippian in age and is very widespread in southwestern Montana. The formation was named by A. C. Peale (1893, p. 32) from exposures in the Madison Range of southwest Montana, and consists of the Lodgepole and Mission Canyon members. The Big Snowy group of Middle and Upper Mississippian age, as recognized by H. W. Scott (1935, p. 1023), is usually considered a part of the Madison formation. No attempt was made by the writer to differentiate the various members of the Madison limestone.

In the Tendoy Range the Madison is a light to dark bluish-gray, massive limestone, and crops out as prominent cliffs. Some beds of the formation are very fos-

siliferous, and contain cup corals, crinoid columnals, and bryozoa. A petroliferous odor on a fresh surface is characteristic. The Madison has been severely deformed, which has resulted in numerous tight folds and minor faults within the formation. The formation forms the sole of the Tendoy thrust and is the oldest formation exposed in the Tendoy Range.

Kupsch and Scholten (personal communication) have estimated the Madison to be 10,000 feet thick in the Nicholia Basin. The intricate folding in the formation and lack of continuous outcrop made measuring of the complete section impossible.

The Amsden formation is apparently conformable with the Madison, though outcrops are poor along the contact. An erosional unconformity is reported to separate the Madison and Three Forks formations, but the contact is not seen in the Tendoy Range. Kupsch and Scholten (personal communication) report that the Madison in the Nicholia Basin in places may rest directly on the Flathead quartzite. The possibility that this was a fault contact instead of an erosional contact was undetermined.

Plate 3. Laramide folding and faulting in the Madison limestone near the mouth of Sheep Creek. Overturning of folds is to the east.

Pennsylvanian system

Amsden formation. The Amsden formation consists of slightly over 2,000 feet of light gray limestones, shales, and sandstones. The formation was named by N. H. Darton (1904, p. 396) from exposures along the Amsden branch of the Tongue river, west of Dayton, Wyoming.

Good outcrops of the formation are seen along the east front of the Tendoy Range. Talus slides from the overlying Tensleep formation in places cover the upper beds of the Amsden. Several of the lower beds of the Amsden formation contain large productids and pelecypods.

Amsden Formation measured in NW¼, Section 36, T.13S., R.10W.

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 .

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.

The age of the formation is gradational from Mississippian to Pennsylvanian, since fossils of each age have been found in the lower and upper parts respectively (Darton, 1904, p. 396). Contacts with the overlying Tensleep quartzite are apparently conformable.

Tensleep formation

The Tensleep formation was defined by N. H. Darton (1904, p. 397) from a section he measured along Tensleep

Creek in Wyoming. The term Quadrant has been used extensively in southwest Montana by Winchell (1914, p. 26), Shenon (1931, p. 15), Corry (1933, p. 5), and Perry and Sahinen (1946) to denote the Upper Mississippian to lower Pennsylvanian beds of that region. This usage is in accordance with Weed's original definition of the Quadrant formation in 1896. The Pennsylvanian section as measured by the writer in the Tendoy Range has been divided into the Amsden and Tensleep formations, thereby making the name Quadrant inappropriate. The term Quadrant was used in the preparation of the enclosed map but its usage is considered incorrect by the author.

The Tensleep formation measures 3,319 feet in the Tendoy Range and forms a very prominent outcrop which caps several of the highest hills in the range. The lower 2,930 feet consists mainly of a dense quartzitic sandstone of a brown color. The formation is massive and consists of fine well-sorted quartz sand grains held tightly together by a silica cement. Frosting of the sand grains indicates that they have been well worked by a transporting agent. Long talus slopes, with the talus rocks covered by numerous black lichens are characteristic of the outcrops. The upper beds of the formation are dolomites and limestones with some cherty

beds. Outcrops of the dolomite are less rugged than the quartzitic sandstones. Rolling grassy slopes generally cover the dolomites.

Tensleep formation measured in E.½, Section 35, T.13S., R.10W.

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 bed 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 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, slightly friable, massive, dark tan, weathers to yellowish tan. Many black lichens on weathered surfaces, covered by long talus slopes near top	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, quartzite, 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'

The Tensleep formation conformably overlies the Amsden formation.

The formation is considered to be lower Pennsylvanian in age. No Tensleep fossils were seen by the author in the Tendoy Range, but Darton (1904, p. 397) and others have listed Tensleep fossils in other localities. The Tensleep is separated from the overlying Phosphoria formation by a minor unconformity.

Permian system

The Phosphoria formation consists primarily of cherty dolomites and limestones, with some shale and sandstone beds. A very prominent red siltstone bed is found about in the middle of the formation.

The Rex chert member and the phosphate beds usually found in the formation in northern Wyoming and eastern Idaho are lacking in the Tendoy Range. Phosphatic shales

also were not observed by the author in the Tendoy Range. However Bowen (1917, p. 317) has reported phosphatic oil shales in the Phosphoria of Muddy Creek Basin. Bowen's section in Muddy Creek Basin is too generalized to permit correlation with the section as measured by the author.

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

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 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 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 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 more dark ..... 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 the top, fine grain, hard, massive, light gray, weathers same, few calcite stringers throughout bed ..... 44.5'

2. Limestone, light gray, contains a 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, gray buff on fresh surface .... 5.0'

Total thickness ..... 802.1'

The Phosphoria unconformably overlies the Tensleep formation.

The Phosphoria was named by Richards and Mansfield (1912, p. 684) for Phosphoria Gulch, near Meade Park, Idaho. The formation is considered to be Middle Permian in age, and is separated from the overlying Dinwoody formation by a minor unconformity.

Triassic system

General statement. The Triassic section measures 1698 feet in the Tendoy Range, and in its lack of red beds differs from the Triassic section of Wyoming where red beds are common. Three formations are recognized in southwest Montana, the Dinwoody, Woodside, and Thaynes. Division of the various formations is difficult. More detailed work needs to be done on the section to definitely establish this division.

Dinwoody formation. The Dinwoody was named by Blackwelder (1918, p. 425) from exposures in the canyon of Dinwoody Lakes in the Wind River Range. The formation

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

33. Shaly limestone, gray, weathers a reddish brown, sandy, thinly bedded ..... 4.7'

32. Covered ..... 37.4'

31. Limestone, gray, weathers darker, hard, massive ..... 4.7'

30. Covered ..... 2.0'

29. Shaly limestone, gray, weathers dark gray ... 1.0'

28. Covered ..... 14.0'

27. Limestone, gray, weathers dark gray, dense, hard ..... 2.0'

26. Covered, a limestone bed in the middle ..... 9.3'

25. Limestone ..... 1.0'

24. Covered ..... 4.7'

23. Shaly limestone, thinly bedded, gray, weathers buff ..... 6.0'

22. Covered ..... 18.7'

21. Limestone, gray, weathers a dark gray, massive ..... 1.0'

20. Covered ..... 14.0'

19. Limestone, gray, weathers reddish, thinly bedded ..... 6.0'

18. Covered, with a 3-foot bed of limestone in the middle, shaly ..... 14.8'

17. Limestone, brownish red, weathers a red brown, thinly bedded, shaly, fossiliferous, some small shale partings present, forms a prominent ledge ..... 63.9'

16. Covered ..... 25.7'

15. Limestone, gray brown, weathers reddish, interbedded with shale partings, forms a ledge (same as #13) ..... 6.3'

14. Covered ..... 23.4'

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

12. Covered ..... 39.8'

11. Shaly limestone, reddish on both surfaces, massive (same as #9) ..... 2.0'

10. Covered ..... 6.0'

9. Shaly limestone, reddish on both surfaces, massive ..... 3.0'

8. Shale, covered slope interval (same as #6) . 7.0'

7. Limestone, 1-foot white beds interbedded with thin shale partings, weathers reddish (same as #5) ..... 2.0'

6. Shale, covered slope interval ..... 7.0'

5. Limestone, 1-foot white beds interbedded with thin shale partings, weathers reddish ..... 4.0'

4. Calcareous shale, brownish-red, thinly bedded, weathers red and tan ..... 44.1'

3. Covered ..... 10.0'

2. Shaly limestone, gray, weathers reddish, slightly conglomeratic, thin bedded, cliff former ..... 5.0'

1. Shale, dark brown, mostly covered ..... 153.7'

Total thickness 553.5

The Dinwoody unconformably overlies the Phosphoria formation.

consists of 427 feet of interbedded shales and silty limestones that weather to a brown or chocolate brown color. Outcrops are generally inconspicuous, because the shales weather readily to a brown soil. The contact with the overlying Woodside formation is conformable. The Dinwoody is Lower Triassic in age.

Woodside formation. The Woodside formation is composed chiefly of thin bedded sandstones of a gray to buff color. Some limestones near the base and some red shales toward the top of the formation are also present. The sandstones are poorly sorted with shale partings, giving the thin beds. Conformably overlying the Woodside formation is the Thaynes formation, indicating a continuous period of deposition throughout the Lower Triassic. The Woodside is Lower Triassic in age and was named by J. M. Boutwell (1907, p. 446).

Woodside formation measured in W.½, Section 26, T.13S., R.10W.

19. Covered	18.7'
18. Shale, brown, weathers dark brown, sandy, calcareous, thinly bedded	2.5'

17. Covered interval - dark brown soil ..... 107.4'

16. Covered interval of red soil ..... 65.4'

15. Shaly sandstone, light gray on both surfaces, thinly bedded ..... 1.5'

14. Covered ..... 7.9'

13. Sandstone, gray to buff, weathers light gray, fine grain, thinly bedded, calcareous cement ..... 6.0'

12. Covered ..... 7.0'

11. Sandstone, gray, fine grain, weathers light gray, thinly bedded ..... 2.0'

10. Covered ..... 5.5'

9. Sandstone, light gray, weathers to a gray buff, well indurated, massive at base, thinly bedded near the top ..... 36.0'

8. Covered ..... 4.7'

7. Sandstone, light gray, weathers brownish-red and gray, well indurated, alternated thinly bedded and massive ..... 9.3'

6. Sandstone, light gray on both surfaces, poorly indurated, thinly bedded ..... 23.4'

5. Covered ..... 10.6'

4. Limestone, light gray, weathers to brownish red in places, very sandy, very thinly bedded, dark gray patches in places; there is a 1-foot covered interval 6 inches below the top ..... 14.0'

3. Covered ..... 11.7'

2. Limestone, gray, weathers grayish buff, sandy, thinly bedded limestone at base, becomes massive toward the top. Forms a prominent ledge ..... 9.3'

1. Covered ..... 11.0'

Total thickness 353.9

The Woodside conformably overlies the Dinwoody formation.

Thaynes formation. The Thaynes formation takes its name after Thaynes Canyon in the Park City District, Utah. The section in the Tendoy Range is similar to the original section described by Boutwell (1907, p. 448) and consists of gray to pinkish buff limestones and calcareous siltstones. Some of the upper beds contain chert but outcrops are very poor. The lower part of the formation, which consists of massive limestones, forms prominent ridges in the Tendoy Range. The limestones are usually covered with an orange lichen. Fossils are generally rare, but one limestone bed has numerous Pentacrinus. The formation is considered to be Lower Triassic in age.

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

17. Limestone, tan, thin bedded, silty and some chert, mostly covered ..... 84.4'

16. Limestone, light gray, finely crystalline, weathers with rough surface, fossiliferous . 4.5'

15. Silty limestone, buff colored, thin bedded, some sandy layers present, mostly covered .. 68.8'

14. Limestone, gray to buff colored, finely crystalline, mostly covered ..... 50.5'

13. Siltstone, tan, calcareous and some chert ... 22.9'

12. Limestone, dark gray weathering to light gray, massive, fine grained, weathers with pitted surface ..... 18.3'

11. Siltstone, light gray to buff colored, calcareous, mostly covered ..... 18.3'

10. Limestone, light gray, crystalline, thin bedded ..... 18.3'

9. Covered, abundant tan calcareous siltstone and chert float ..... 18.3'

8. Covered interval with some gray limestone and chert float ..... 22.9'

7. Limestone, buff to gray, massive, thin bedded, crystalline, hard, forming a very prominent ridge ..... 27.5'

6. Covered interval but some calcareous tan siltstone and some chert in float, thin bedded ..... 27.5'

5. Limestone, light gray to buff, weathers same, some pink mottling, massive, coarsely crystalline, resistant, as a prominent ledge former, numerous Pentacrinus and numerous lichens ..... 15.0'

4. Covered ..... 314.2'

3. Limestone, gray brown, weathers gray, thick to thinly bedded, forms a prominent ledge with thin covered intervals .... 32.7'

2. Covered ..... 26.8'

1. Limestone, gray-brown, weathers to chocolate brown, thick and thinly bedded, very dense ..... 21.0'

Total thickness ..... 791.9'

The Thaynes conformably overlies the Woodside formation.

Jurassic system

General statement. The Jurassic system is the last marine sedimentary series in the Tendoy Range. Sediments include shale and siltstone which make up the Sawtooth formation and an oolitic limestone which forms the Rierdon formation. Collectively these two formations have been called the Ellis group. These formations are of late Jurassic age, and possibly are separated from the Triassic by an unconformity, though the contact of the Triassic and Jurassic is difficult to see. Condit (1918, p. 120) and Bevan (1929, p. 444) have reported a prolonged period of erosion and peneplanation prior to late Jurassic time over most of southwest Montana. This peneplane is not readily apparent in the Tendoy Range.

Sawtooth formation. The Sawtooth formation consists of shales and siltstones of a gray to light brown color that weather readily and are usually found as low

rounded hogbacks that lap onto the Thaynes formation. The upper shale bed contains pelecypods. The formation derives its name from the Sawtooth range in western Montana in which it is well developed. W. A. Cobban (1945, p. 1270) named the Sawtooth formation and considers it to be Middle Jurassic in age.

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

Shale, light gray to buff color, slabby and thin bedded, calcareous, not necessarily top of bed	105.5'
Siltstone, brown, with some interbedded brown limestone separated by silty partings, slightly crystalline, highly fractured though somewhat more massive near base, calcareous, weathers with a speckled appearance	64.2'
Covered interval	82.6'
Total thickness	252.3'

The Sawtooth unconformably overlies the Thaynes formation.

Rierdon formation. Conformably overlying the Sawtooth formation is the Rierdon formation, which consists of two oolitic limestone beds separated by a calcareous shale. The top bed of the formation is probably a shale but outcrops are indistinct. The Rierdon was named by W. A. Cobban (1945, p. 1277) and forms the middle member of the Ellis group. The Swift formation, the top member

of the Ellis group is missing in the Tendoy Range. The Rierdon is Upper Jurassic in age.

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

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

The Rierdon conformably overlies the Sawtooth formation.

Cretaceous system

The Kootenai formation is the only Cretaceous formation in the Tendoy Range. The formation was named by J. W. Dawson (1885, p. 531) from a tribe of Indians that hunted in Montana, northern Idaho, and southern Alberta. The formation is found over most of Montana and southern Alberta.

The Kootenai consists mainly of gray sandstones and red shales. The lowermost beds in the Tendoy Range are dark shales and sandstones, which possibly may represent the Morrison or Swift formations. A gastropod limestone about 2 feet thick in the lower part of the formation

makes a prominent marker bed. 2,201 feet of the Kootenai were measured in the Tendoy Range, but this is not necessarily the complete thickness of the formation. The Tendoy thrust cuts out all younger Cretaceous beds if such were present.

The predominance of red beds in the formation indicates conditions at the time of deposition were apparently unfavorable to organic life, as few fossils were found. G. M. Dawson (1885, p. 162B) has listed fossil flora from the Kootenai and placed the formation as lowermost Cretaceous in age. The sediments are of continental origin and unconformably overlie the Rierdon formation.

Kootenai formation measured in E.½, Section 9, T.13S., R.10W.

35.	Covered. Beyond this point the section is covered by Madison limestone which is part of an overthrust sheet	250.0'
34.	Sandstone, salt and pepper appearance, massive, some beds contain subangular to rounded pebbles of black and brown chert ..	26.0'
33.	Covered	26.0'
32.	Sandstone, rusty brown, very well indurated, salt and pepper	26.0'
31.	Covered	52.0'
30.	Sandstone, salt and pepper, massive	21.0'

29.	Shale, reddish color	52.0'
28.	Sandstone, fine grained salt and pepper	5.0'
27.	Shale, brownish red	42.0'
26.	Sandstone, salt and pepper	5.0'
25.	Shale, brownish red	29.0'
24.	Sandstone, salt and pepper, interbedded with several beds of dark brown weathering calcareous sandstones	10.0'
23.	Shale, variegated red, brown, and purple	31.0'
22.	Sandstone, salt and pepper	5.0'
21.	Shale, red	33.0'
20.	Limestone, gray weathering to dark brown, arenaceous	2.0'
19.	Sandstone, salt and pepper	28.0'
18.	Shale, red	21.0'
17.	Sandstone, salt and pepper	5.0'
16.	Shale, red	23.0'
15.	Shale, purple-gray. This member includes a two foot bed of reddish-brown arenaceous limestone	10.0'
14.	Shale, red	57.0'
13.	Sandstone, gray to reddish color with some interbedded calcareous layers	26.0'
12.	Sandstone, salt and pepper	5.0'
11.	Shale, red	10.0'
10.	Sandstone, thin bedded medium grained, salt and pepper	36.0'
9.	Shale, alternating red and brown	73.0'

8. Covered; includes a dark gray gastropod limestone about six feet thick and gray shales not seen in measured section ..... 702.0'

7. Shale, red ..... 21.0'

6. Sandstone, light brown to gray, medium grained, friable. Towards top coarser salt and pepper sandstone, generally thin bedded, and with pebbles of black chert ... 36.0'

5. Shale, variegated red, purple, and brown ... 42.0'

4. Shale, light gray, hard, sandy ..... 52.0'

3. Shale, red, calcareous and containing gastroliths ? ..... 109.0'

2. Sandstone, coarse salt and pepper with limonite concretions, massive ..... 70.0'

1. Shale, dark colored, poorly exposed. Possible Morrison or Swift formation ? .... 260.0'

Total thickness ..... 2201.0'

The Kootenai unconformably overlies the Rierdon formation.

Tertiary system

General statement. Tertiary formations range from coarse conglomerates to fine silts, and represent varying sedimentary environments. No measuring of the Tertiary section was done in the Tendoy Range.

Red Rock conglomerate. The Red Rock conglomerate is rather widespread in the Tendoy Range. In the upper

Little Water Canyon on the west side of the mountain the conglomerate is found at about 8,000 feet elevation where it dips 25° W. It is a remnant of a mass elevated by the Muddy Creek fault. Near the mouth of Sheep Creek the conglomerate is apparently part of a small anticlinal structure, paralleling the east front of the mountains. Just south of Lima, Montana the conglomerate forms the Red Conglomerate Peaks, which attain elevations of 9,000 feet. Some beds contain well rounded quartzitic pebbles, but other beds contain coarse angular fragments of Madison limestone and quartzite boulders. These later beds are poorly sorted and poorly cemented with a hematitic cement.

The formation derives its name from the Red Conglomerate Peaks and the Red Rock River (Hardley, unpublished data), and has been estimated to be about 2,000 feet in thickness south of Lima, Montana.

The age and sequence of the beds is somewhat controversial. More detailed work is needed to determine the stratigraphic relations of the conglomerate and its sequence in the structural development of the Range. Some structural relations of the conglomerate are known. East of the Tendoy Range in the Sage Creek Basin the Sage Creek formation of Upper Eocene age unconformably

overlies the Red Rock conglomerate (Eardley, personal communication). Near the mouth of Sheep Creek the Red Rock conglomerate overlies the tilted beds of the early Laramide complex. The conglomerate, therefore, was deposited in the Paleocene and folded and eroded prior to Upper Eocene. No fossils have been found in the conglomerate. Only erosional remnants of the conglomerate are found in the area north of Sheep Creek, but further south near Lima great thicknesses of the formation remain. The formation is of continental origin.

Muddy Creek basin beds. The Muddy Creek basin beds consist mainly of volcanic tuffs overlain by a series of shales and some thin limestone and sandstone beds. No measured section is available but the beds are probably correlative with the Bozeman Lake Beds recognized over most of southwest Montana by different writers. No correlation work has been done between the various localities. A. C. Peale (1893, p. 40) first used the name Bozeman Lake Beds for all of the mid-Tertiary deposits around Bozeman, Montana. Other workers have reported similar deposits over much of southwest Montana that contain Oligocene to Pliocene fossils. The formation is undoubtedly locally variable, but the Muddy Creek basin beds are similar to sediments found

a few miles east of the Tendoy Range. The Muddy Creek beds more nearly resemble the Upper Miocene Ruby Reservoir beds than the Sage Creek formation of Upper Eocene age (Eardley, personal communication). For this reason the Muddy Creek basin beds are considered to be Miocene in age. The only fossils found in the Muddy Creek basin beds were non-diagnostic plant fragments.

The sediments are principally fine textured clastics, and were probably deposited in a large shallow fresh water lake. Sometime after deposition, probably in Pliocene time, the beds were cut by high angle faults, and the basin block was tilted 15° to the east. The presence of tuffs in the lower beds indicates volcanic activity somewhere in the region, but the origin is unknown.

Quaternary system

Deposits of Quaternary age cover all basin floors, and consist chiefly of fine gravels, sands, and silts deposited by streams on the lowland areas when the streams were nearer base level. Sediments are unconsolidated and generally lack bedding planes. Next to the mountains the intermittent streams that drain into the basin have built up alluvial fans that grade outward into the basin deposits.

Igneous rocks

On the west side of the Tendoy Range are two small areas of volcanic rock, the only igneous rock in the subject area. The rocks are mainly coarse breccias of a rhyolitic composition. Minor amounts of a basaltic rock have been found, but the main rock type is a dark red volcanic ash or vesicular rhyolite rock. The volcanics are supposedly in place although no feeders for the volcanoes can be seen. Two undrained depressions within the volcanic outcrop tends to indicate the recent origin of the volcanics.

No fossils were found with the volcanic material so the precise age of the extrusion is dependent on areal relations with other sediments. The volcanics cut the Cretaceous Kootenai formation, and at one place apparently cut through a tuff bed. This latter bed may be an erosional remnant of the Muddy Creek basin beds, but no correlation is available. Another indication that the volcanics are younger than the basin beds is the complete absence of basin beds in or around the undrained depressions. Erosion has not completely dissected the outcrop. The volcanic rocks are therefore considered to be late Pliocene or Pleistocene in age. The volcanics are much younger than any tuffs known in the Tendoy Range.

Plate 4. Volcanic breccia in the exposure of volcanics about 1½ miles west of Dixon Mountain.

STRUCTURE

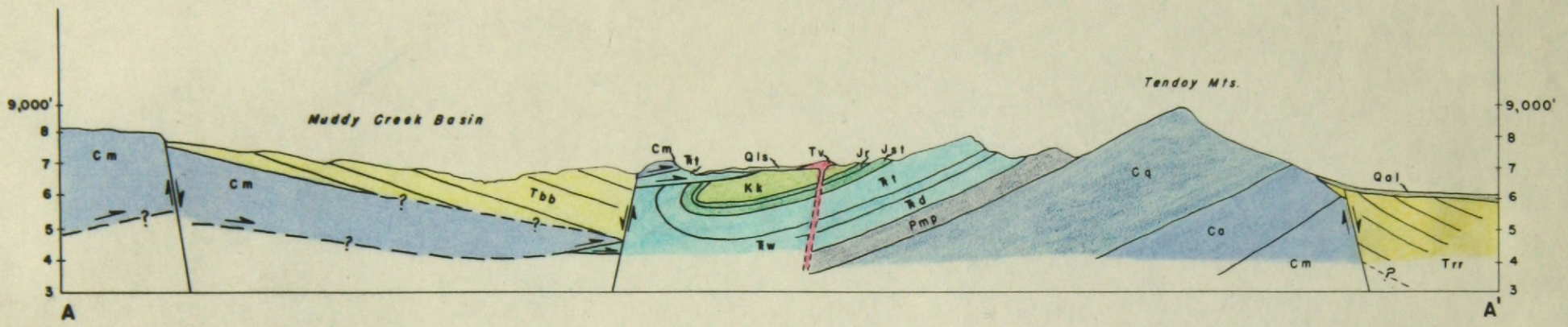
General features

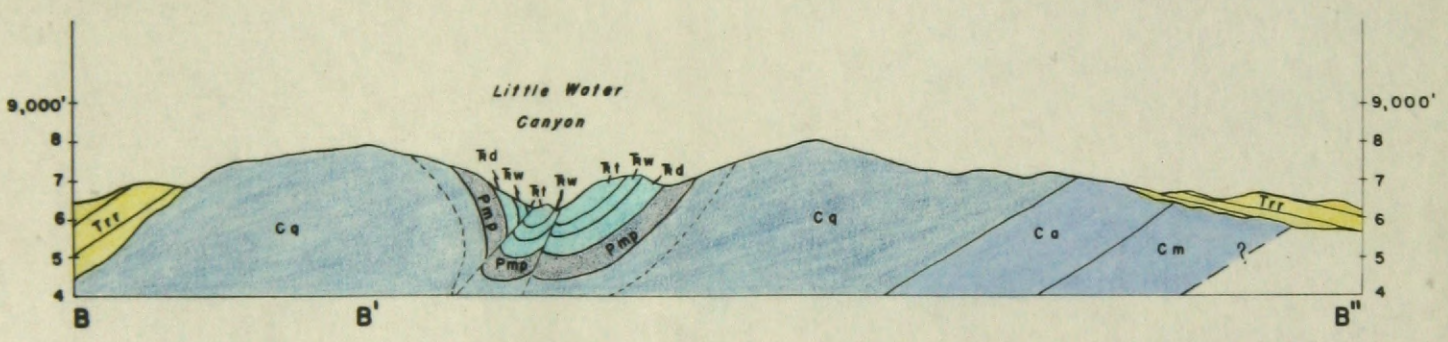
In the Tendoy Range a variety of structural features have been produced by several periods of orogeny. The Paleozoic and Mesozoic strata were folded and thrust faulted at the end of the Mesozoic, and the Red Rock conglomerate was deposited unconformably on the older strata. The conglomerate itself was then folded and later cut by high angle faults in mid-Tertiary time. The structural features of the area will be considered in chronological order.

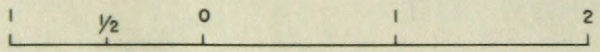
Laramide structures

The first of the late Cretaceous crustal disturbances resulted in folding of all Paleozoic and Mesozoic strata into northwest-southeast trending folds. All Mesozoic and older strata in the Tendoy Range dip about 30 - 35° to the west, and both the east and west sides of the inclined beds have been cut off by high angle faults of mid-Tertiary age. Other Laramide folding is represented by numerous, small, tight folds and minor faults in the Madison limestone.

Plate 10







Horizontal Scale in Miles

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

H.H KRUSEKOPF & S.R. WALLACE

Near the northeast corner of the area the Little Water Canyon syncline trends approximately northeast and at right angles to the other structures of the Range. The syncline starts near the eastern margin of the area and plunges towards the west. At its eastern extremity this syncline is broken by two normal faults, of small displacement, which probably pass into bedding plane faults towards the west. See Plate 9. Beds on the north wing of the fault dip about 70° to the north.

Thrust faulting followed late Cretaceous folding, but whether thrusting was pre-Red Rock conglomerate or post-conglomerate is uncertain. In the northwest part of the mapped area the relation of the Red Rock conglomerate and Tendoy thrust would indicate that the conglomerate overlies the thrust. However, near Lima, Montana, Eardley (personal communication) has mapped a thrust in the Red Rock conglomerate and believes it is a part of the Tendoy thrust. Additional mapping needs to be done to establish the conglomerate - thrust relationship.

The Tendoy thrust sheet is made up of Madison limestone which is found resting on the Kootenai formation. Towards the south end of the area the thrust transects older beds and may be found in contact with the Tensleep

Plate 5. North wing of Little Water Canyon syncline. Triassic beds in foreground are almost vertical. View looking north.

sandstone. Immediately below the Madison limestone at one place the Thaynes formation is in contact with the Kootenai formation as a result of an imbricate thrust from the main thrust. See Plate 10. The Tendoy thrust sheet is discontinuous at several points where erosion has cut through and left klippes of Madison limestone. From these klippes the fault front has been reconstructed. Thrusting was towards the east or slightly northeast, and places the Madison limestone over the folded Paleozoic and Mesozoic strata. The thrust trace is not readily apparent either north or south of the mapped area and additional work would be needed to verify the trace. The Madison limestone dips about 80° to the west, and is cut off sharply on the western side by mid-Tertiary high angle faulting.

A second phase of Laramide folding is recorded by the Red Rock conglomerate. Broad open folds are most characteristic of this phase of deformation and are best seen in the conglomerate outcrops near Lima, Montana. The effect of this folding on the Mesozoic and Paleozoic sediments is unknown.

The age of the major folding and thrust faulting in the Tendoy Range has been placed as Laramide. The chief evidence to support this age is that all Cretaceous and

older sediments are deformed with about equal intensity. This places deformation at least to Middle Cretaceous time. The latest date for the orogeny is determined by the Red Rock conglomerate. The conglomerate is considered to be Paleocene in age and was folded and eroded prior to deposition of the Sage Creek formation of Upper Eocene age. Laramide deformation probably extended from Middle Cretaceous to Middle Eocene with deformation active in three or four separate phases.

Fossil evidence has not been found in any Tertiary formations of the Tendoy Range to support their age. However from the evidence afforded by the sediments and by the character of the structural features a hypothetical sequence of events has been pieced together and ages tentatively assigned to the major structural features.

Tertiary structures

High angle faulting was most characteristic of the Tertiary structural development. Three distinct faults which cut across all sedimentary beds may be seen in the Tendoy Range. The Red Rock fault, the Muddy Creek fault and another fault on the west side of Muddy Creek (See plate 9) have sharply outlined the basins and ranges. These faults follow the general trend of Laramide struc-

tures. The east Muddy Creek fault extends from about two miles south of Sheep Creek, north, past the northern limits of the area. On the western side of Muddy Creek the structure consists of two faults. The lower or eastern fault extends from about two miles south of Sheep Creek to about one-half mile north of Sheep Creek. The upper fault overlaps the lower fault and is about 600 yards west of the lower fault. The upper fault forms the recent scarps in the Madison limestone and extends from about one mile south of Sheep Creek for an undetermined distance to the north. See Plate 9. The Red Rock fault is traceable to the south at least to Lima (Pardee, 1939, p. 354) and to the north the trace is undetermined past Little Water Canyon.

High angle faulting has sharply outlined the basins and range in the Tendoy Range. The Range was blocked out by the Red Rock fault and the Muddy Creek fault, and raised as a horst block. Muddy Creek Basin was outlined by the Muddy Creek fault and a fault on the west side of the Creek, and the Basin was lowered as a graben. Vertical displacement was greatest along the Muddy Creek fault, which tilted the basin beds about 15° to the east. Evidence of recent movement along the Red Rock fault is afforded by the triangular facets in the Red Rock conglomerate. See Plate 6.

Plate 6. Triangular facets along Red Rock fault scarp.

Normal faulting in the Tendoy Range did not take place until after deposition of the Muddy Creek basin beds. The uniformly fine-textured clastics of the basin beds indicate relief in the mountain masses was too low for the mountains to contribute coarse clastics to the beds, or the mountain was covered by the basin beds. In either case, uplift of the Range was post-basin beds, and probably of Late Miocene age.

PHYSIOGRAPHY

Physical features

The Tendoy Range is located in the Northern Rocky Mountain physiographic province. The Range forms a ridge about four miles wide and extends from the Beaverhead Range near the Montana-Idaho border generally northwest for a distance of 30 miles. Some peaks in the range attain heights of 9,000 feet, and rise about 3,000 feet above the valley floor. Many parts of the range exhibit flat or gently sloping summits, from which slopes descend sharply down to valley bottoms.

The ranges of southwestern Montana do not show a uniform trend. The Madison Range to the east and the

Beaverhead and Lemhi Ranges to the west all trend generally north. East of the Tendoy Range the Tobacco Root, Ruby, Snowcrest, and Gravely Ranges all trend northeast while the Centennial Range trends east. See plate 1.

The minor drainage of the area is largely by consequent streams. The streams head in the mountains and flow generally east or west into the basins. Muddy Creek flows south parallel to structural trends, and drains Muddy Creek basin. Sheep Creek, the master stream of the area, heads in the Beaverhead mountains to the southwest, and flows directly across the Tendoy Range to the Red Rock River in the eastern basin. Sheep Creek is an antecedent stream, and occupied its present position through the Tendoy Range prior to mid-Tertiary block faulting. When the horst block of the Tendoy Range was uplifted the stream maintained its course. If Sheep Creek had originated after mid-Tertiary block faulting, the Creek would have been deflected by the horst block and waters would probably have found an outlet through the structural depression of Little Water Canyon. Further evidence that Sheep Creek was flowing in its present channel prior to high angle faulting is afforded by the high level gravels (see page 46). The gravels are on a post-faulting surface well below the crest of the range. At the time of

of deposition of these gravels Sheep Creek was eroding its present channel instead of developing in the Little Water syncline.

Climate and vegetation

Southwestern Montana has an arid or semi-arid climate. The average annual rainfall is about 12 inches (U. S. Weather Station, Dillon, Montana), which falls mostly in the spring. Temperatures in the summer range from 90° during the day to near freezing at night.

The Tendoy mountain region has a vegetation adapted to the semi-arid climate. Most of the area is covered by grass and sagebrush but the higher slopes and the north slopes of stream valleys are usually covered by small pine trees. Basins and lower stream courses usually have a profuse growth of sagebrush which in places reaches a height of ten feet. The Red Rock River Basin is entirely under cultivation, with hay as the main crop. Waters from Sheep Creek and the Red Rock River are used for irrigation. A few ranches where hay is grown are found along Sheep Creek.

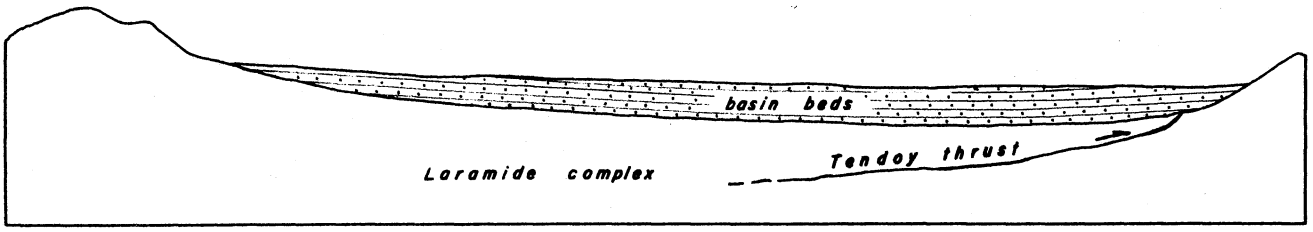
Animal wild life consists of deer, elk, antelope, brown bears, marmots, rabbits, and numerous chipmunks and mice. Birds, especially swallows that nest in the

Madison limestone cliffs, are numerous. Several large sheep and cattle herds are grazed in the Tendoy Range each summer.

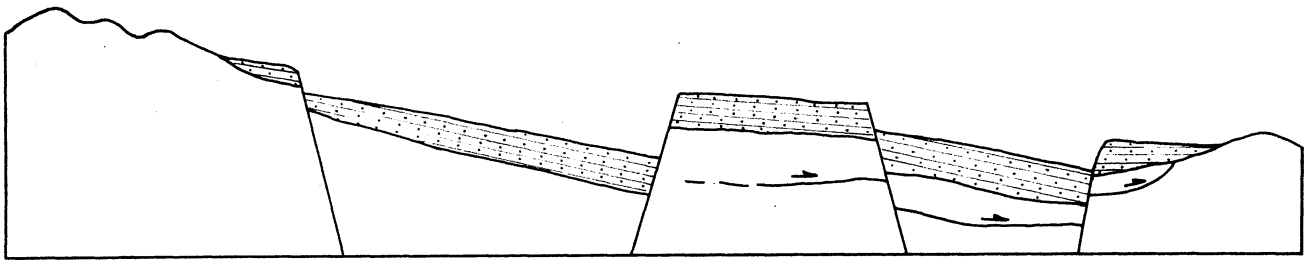
Erosion surfaces

About one mile north of the junction of Muddy Creek with Sheep Creek is a high, fairly flat-topped hill. Capping the hill are gravels composed of water-rounded boulders of Flathead and Kinnickinic quartzite. This surface is at an elevation of about 7,500 feet, and about 1000 feet above the present valley floors. It is cut across the tilted Mesozoic sediments. A similar hill of about the same elevation was located one and one-half miles south of Timber Butte. Erosion has dissected the surface so that only rounded, boulder-strewn hills remain.

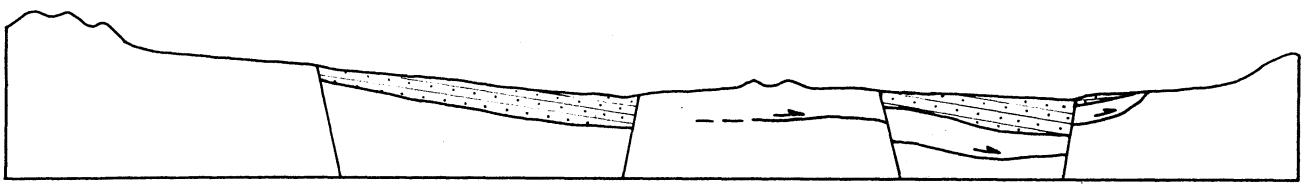
This high surface may possibly be the same as a surface seen on the uplifted horst block west of Muddy Creek and also the surface on the Red Rock Mountains east of Dell, Montana. The surface west of Muddy Creek was cut across the Madison limestone, and the Red Rock Mountain surface is cut across the Red Rock conglomerate. Evidence is not available to establish this correlation.



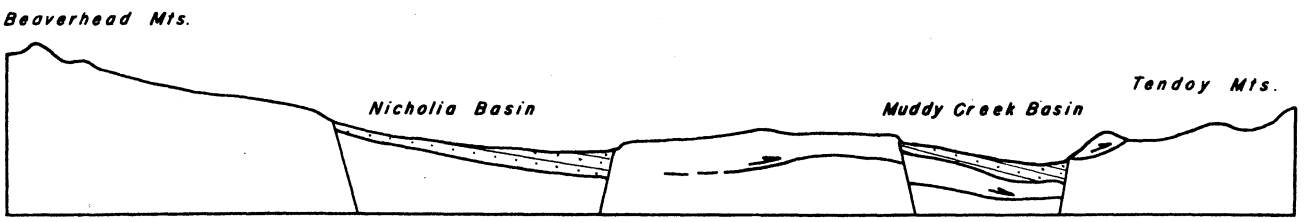
1) Miocene – accumulation of extrusives and fine clastics in broad basins.



2) Late Miocene – block faulting.



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



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

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

The surface on the east side of Muddy Creek was part of the erosion cycle that followed high angle faulting. The Tendoy Range horst block was uplifted and the basin beds eroded off the highland area before development of the surface. The surface has been tentatively placed as middle or late Pliocene in age.

A well defined pediment surface is seen on the east side of Muddy Creek about one mile north of the junction of Trail Creek with Muddy Creek. These pediments slope down almost to Muddy Creek, and are cut across the Muddy Creek basin beds. The pediment surface is at a lower elevation than the high erosion surface and was developed at a later date than the higher surface. The pediments have been placed in early Pleistocene period.

Glaciation

No evidence of glaciation was seen in the Tendoy Range. However in the Nicholia Creek basin, 15 miles southwest of the area, moraines of Bull Lake and Pinedale age may be seen. These glaciers originated in the Beaverhead Range and moved out into the Nicholia Basin a short distance, leaving several prominent lateral and terminal moraines. This glacial activity failed to result in the accumulation of outwash gravels in the lower Sheep Creek basin. No known glaciation took place in the Red Rock River valley.

Plate 8. Early Pleistocene pediment surface on the Muddy Creek basin beds, one mile north of the junction of Trail Creek with Muddy Creek. View is to the south.

TENTATIVE SUMMARY OF EVENTS

Present	Erosion of present day surface Movement along Red Rock fault producing modern fault scarplets
Pleistocene	Glaciation in Nicholia Basin Erosion and development of pediment surfaces Regional uplift or renewed faulting along Red Rock fault
Pliocene or Pleistocene	Volcanism in Tendoy Range producing volcanic breccias
Pliocene	Erosion of high erosion surface
Late Miocene	High angle faulting
Miocene	Deposition of Muddy Creek basin beds and Ruby Reservoir beds in broad shallow basins Volcanic activity in nearby areas
Oligocene	Erosion to near base level
Upper Eocene	Deposition of Sage Creek formation accompanied by volcanism
Early and Middle Eocene	Erosion with formation of wide, intermontane basins
Late Paleocene or Early Eocene	Folding and thrusting (?) of Red Rock conglomerate

TENTATIVE SUMMARY OF EVENTS (CONTINUED)

Paleocene	Deposition of Red Rock conglomerate
Late Cretaceous and early Paleocene	Folding and thrust faulting (?) of Mesozoic and Paleozoic strata
Paleozoic and Mesozoic to Middle Cretaceous	Fairly uniform sedimentation going on throughout area with only minor fluctuations between land and sea. Geosyncline developing by early Mississippian and persisting through Lower Triassic

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EXPLANATION

Sedimentary rocks

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

Igneous rocks

TERTIARY	Tv	basalt flows & breccia

SCALE IN MILES

1 3/4 1/2 1/4 0 1 2 3

N

20°

Planimetric Map from aerial photographs

Control, U.S. Forest Service Map of

Beaverhead National Forest, 1947

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

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

KAROLTON KLASP—7½ x 10½

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