Thesis of

Gerald F. Bowers

Members of Master's Committee

A. J. Eardley Chairman

Eugene H. Walker

Thesis accepted by :

A. J. Eardley Signature	May 18, 1949 Date
Eugene H. Walker Signature	May 19th, 1949 Date
[illegible] Signature	5/19/49 Date

The Geology of the Kissick Canyon Area, Beaverhead County, Montana

by

Gerald F. Bowers

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Table of Contents

ILLUSTRATIONS

ABSTRACT

The area mapped is a part of the Tendoy Mountains and is located in Beaverhead County, Montana. It embraces some thirty-three square miles.

The oldest existing rocks exposed in the area are pre-Cambrian granite gneisses that have been overthrust on Paleozoic strata. The Paleozoic formations are Mississippian Madison limestone, the Mississippian and Pennsylvanian Amsden limestone, shale and sandstone, and the Pennsylvanian Quadrant quartzite. Tertiary sedimentary beds are represented by the Red Rock conglomerate and the Sage Creek and Cook Ranch shales and sandstones.

Laramide thrusts and the post-Laramide block faults are the chief structures. There are three major thrusts in the area: the Tendoy, the Beaverhead, and the Medicine Lodge. Normal, high angle faults occurred during mid-Tertiary times and cut the major thrust sheets.

Three erosion surfaces are described.

INTRODUCTION

Location and description of the area

The name of the thesis was taken from Kissick Canyon that drains part of the area on the west. The area of Kissick Canyon was mapped during the summer of 1948 by the author and James Seglund, graduate students of the University of Michigan. It covers some thirty-three square miles and is in Beaverhead County of southwestern Montana. It is located in the northern half of T. 11 S. Medicine Lodge Creek limits its western boundary, and the railroad station of Red Rock marks its eastern boundary.

The lands of this area are used exclusively for the grazing of stock and the raising of hay.

The Tendoy Mountains form the central highlands of the thesis area. They are part of the Beaverhead Mountains which are a component of the Bitterroot Range. The Beaverhead Mountains trend in a northwest-southeast direction, whereas the Tendoy Mountains, to the east of the Beaverhead Mountains, have more of a north-south alignment.

The Tendoys are bordered on the east by the Red Rock basin and on the west by the Medicine Lodge basin. These two basins are floored by Quaternary alluvium and Tertiary shales and sandstones.

The Bitterroots and Beaverhead mountains form the Continental Divide in this general region. Medicine Lodge Creek drains the area on the west and flows northward and then eastward to join the Red Rock River at Armstead. The Red Rock River drains the area on the east and flows northward through Armstead.

After Raisz

Index map of southwestern Montana

The Tendoys are moderately rugged and exhibit about 2500 to 3000 feet of local relief in the thesis area. Trails and wheel tracks can be seen in many places throughout the mountains.

Highway 91 is a macadam surfaced road that runs north and south along the eastern flank of the Tendoy Mountains. A well graded road follows the Medicine Lodge Creek. The area is readily accessible during good weather.

Previous and present work

Relatively little work of any significance has been done in the thesis area. During the summer of 1946, Professor E. S. Perry and Professor U. N. Sahinen of the Montana School of Mines made a reconnaissance map of southwestern Montana, but it has not yet been published. In 1947, the University of Michigan began a program of mapping the southwestern portion of Montana, and the area of this report is one of several studied during 1947 and 1948. The adjoining area to the south was mapped by R. I. Davis and R. L. Plank, to the east by K. Keenmon, and to the north by R. Brant, N.C. Elmer, W. A. Gillispie, and J.R. Peterson — all graduate students of the University of Michigan.

The field work proceeded from July 24 to August 17, 1948. Aerial photographs were used for mapping. Their approximate scale is 1 : 20,000.

Acknowledgments

The author is greatly indebted to Professor A. J. Eardley for his supervision and assistance with the field work, the construction of the cross-sections, the editing of the written report and for his interpretation of the chronology of events. James Seglund and the author worked coextensively in the field and on the preparation of the map and cross-sections. Gratitude is also expressed to Walter O. Kupsch whose Ph.D. thesis area adjoins the area of this report on the south. Kupsch has also assisted considerably in the structure and stratigraphy. Professor E. W. Heinrich, of the University of Michigan, aided in the identification of the pre-Cambrian granites. Graduate students from the adjoining thesis areas also rendered helpful suggestions and information: K. Keenmon, R. I. Davis, R. L. Plank, R. Brant, N. C. Elmer, W. A. Gillispie, and J. R. Peterson.

STRATIGRAPHY

Introduction

The exposed stratigraphic column in the Kissick Canyon areas is rather limited. The oldest rocks present are the pre-Cambrian gneisses. The oldest sedimentary rocks are late middle and upper Paleozoics. No Mesozoic rocks are exposed, but Tertiary rocks are present, and Quaternary alluvium is widespread.

Two stratigraphic columns follow: one demonstrates the lithology of the Kissick Canyon area, and the other shows the lithology of the area immediately adjoining to the north. With the exception of the basin beds and Quaternary alluvium, the exposed rocks are all members of thrust sheets.

It was impossible to measure complete sections in the Kissick Canyon area, because, either the base of the section was not exposed, or the top of the section had been worn away by erosion. The measured sections used in this report are from adjoining areas of southwestern Montana which have been mapped by graduate students of the University of Michigan.

Plate III

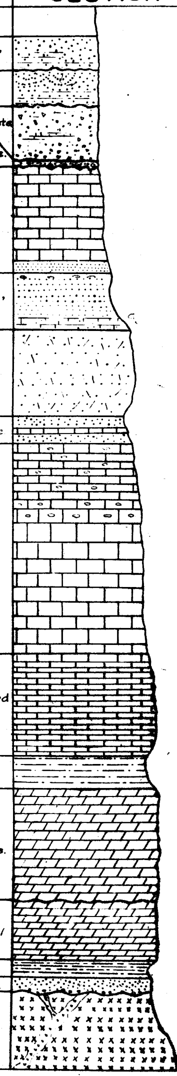
Stratigraphic Column

Kissick Canyon Area, Montana

Era	Period	Formation
Cenozoic	Quaternary	Alluvium
	Upper Eocene (?)	Sage Creek and Cook Ranch fms.
	Upper Paleocene or Lower Eocene	Red Rock conglomerate
Paleozoic	Pennsylvanian	Quadrant quartzite
	Pennsylvanian	Amsden formation
	Mississippian	Madison limestone
Proterozoic	Pre-Cambrian	Pre-Belt granite gneiss

COLUMNAR SECTION ~ ARMSTEAD AREA

Era	Period		Formation		Feet	Character	Section
CENOZOIC	QUATERNARY		ALLUVIUM				
	TERTIARY	OLIGOCENE	COOKRANCH ?		?	Basin beds, sandstones, shales, bentonite.	
		EOCENE	SAGECREEK ?		?	Basin beds, sandstone, shales.	
		PALEOCENE	REDROCK		2000?	Red, angular, subangular conglomerate	
MESOZOIC	CRETACEOUS		KOOTENAY		?	Large, smooth cobble conglomerate.	
	TRIASSIC		DINWOODY		800	Buff, fossiliferous, crystalline limestone which weathers to a rotten texture.	
PALEOZOIC	PERMIAN		PHOSPHORIA		400	Chert, sandstone, sandy limestone, phosphatic in basal part.	
	PENNSYLVANIAN		QUADRANT		900	Tenacious, red, buff, white quartzites	
	MISS.-PENN.		AMSDEN		208	Friable sandstone, massive limestone	
	MISSISSIPPIAN		MADISON	MISSION CANYON MEMBER	1700	Upper 450 ft. "wavy" limestone, thinly bedded, containing chert. Lower 1250 ft. massive, blue-gray limestone.	
				LODGEPOLE MEMBER	550	Tabular, yellowish-gray, evenly bedded limestone.	
	DEVONIAN		THREE FORKS		300	Yellow brown shales	
			JEFFERSON		800	Massive, buff gray dolomite which weathers to dark brown. Petroliferous.	
	CAMBRIAN		MEAGHER		200	Thinly to thickly bedded dolomite and dolomitic limestone.	
			WOLSEY		10 ?	Light green micaceous shales.	
			FLATHEAD		10-15 ?	Massive, quartzitic, arkosic sandstone.	
	PRE-CAMB.		PRE-BELT			Gneisses, pegmatite, and quartz veins.	



(Brant, Elmer, Gillespie, Peterson, 1949).

Pre-Cambrian system

Granite gneiss. The pre-Cambrian rocks exposed in the subject area are a pre-Beltian complex that have been overthrust on the Madison limestone. Professor E. W. Heinrich (personal communication) believes that it may be Blacktail granite gneiss that has been intruded into the Pony or Cherry Creek. No petrographic examinations were made. Whether Cherry Creek or Pony or Blacktail granite, it is undoubtedly pre-Beltian.

The granite gneiss is strongly schistose and weathers pink. The thickness of the pre-Beltian is unknown. A. C. Peale (1896, p. 2) first named the Cherry Creek series. Tansley, Schafer, and Hart (1933, p. 8) recognize the Pony series in addition to the Cherry Creek, but they state: "There is no positive evidence that such a division of the Pony and Cherry Creek rocks is justified." They also assert that the two series might belong to either the Archean or Proterozoic eras.

Mississippian system

Madison limestone. The Madison limestone might be more correctly designated as the Madison group. It is of lower Mississippian age, and it was first named by A. C. Peale (1893, pp. 33-39) who located the type section in the Madison Range of Montana.

Having first been considered as a single formation, the Madison in several localities is now divided into the Lodge Pole and Mission Canyon formations. This division is based on lithologic evidence (Weller, et. al, 1948, p. 138). The Lodge Pole, the lowest member, is a thin bedded limestone, whereas the Mission Canyon member is a massive limestone. Although both members were observable in the thesis area, the authors considered the Madison as a single unit for mapping purposes.

The base of the Madison is nowhere exposed in the subject area, but two thousand feet is a conservative estimate of its thickness. Kupsch and Scholten (1947) measured 980 feet of the series, but that was only a partial measurement. They estimate three to five thousand feet to be present in southwestern Montana.

There are two thrusts that involve the Madison and both display a Madison facies that is somewhat different from the other. The basal part of the eastern thrust (Tendoy thrust, contact not exposed) consists of a darkly weathered, laminated, thin-bedded, limestone that contains black chert. The chert becomes more conspicuous toward the bottom. Above this is a grayish limestone that weathers white and exhibits a shapely crenulated folding. The field party called it the "wavey limestone". Above this a third unit of dark gray, more massive limestone occurs. The Madison exposed in a thrust sheet from the west (the Medicine Lodge thrust) is a monotonous, massive, blue-gray, cliff forming limestone with conspicuous and numerous calcite veins.

The fossils contained within the Madison are very difficult to extract and to identify. Several attempts to collect them were made without success. The poor preservation of fossils was evident wherever any observations were made. Generally the Madison is intensely broken and the fossils are likewise shattered.

A partial section of the Madison was measured in the central-eastern part of Section 1, T. 11 S., R. 11 W. along Limekiln Canyon, because it differed a great deal in appearance from the surrounding Madison.

5. Limestone, dark blue, slabby, weathering chocolate brown 33'

4. Limestone, greenish-gray, weathers to a light tan, almost lithographic in texture ------------------------ 5'

3. Limestone, dark gray, slabby, thin bedded, weathers to a dark grayish-brown, very fine grained ------------ 10'

2. Same as # 4 -- 51'

1. Limestone, light gray, spotted with green, weathers to an orange yellow color. It is thin bedded and almost lithographic in texture. ------------------------------ 124'

Madison formation measured by Kupsch and Scholten in Sections 7, 8, 9, 17, T. 17 S., R. 10 W.

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

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

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

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

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

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

6.	Limestone, gray, thin-bedded, slope forming, chert nodules, calcite veins	15'
5.	Limestone, dark gray to black, fan-like laminations, breccia layers, regular chert beds, calcite veins, fossiliferous	100'
4.	Limestone, gray weathering pink, laminations in brown and red colors, massive, chert nodules, calcite veins, corals	30'
3.	Limestone, dark gray, thin-bedded, chert and calcite, fossiliferous	25'
2.	Shale, brown and sandstone, violet-pink	30'
1.	Limestone, dark gray, breccia with sandstone fragments, rusty brown, few fossils, some lenses of recrystallized crinoid stems	60'
	Total thickness	980'

Pennsylvanian system

<u>Amsden formation</u>. The Amsden formation was named by N. H. Darton (1904, pp. 394-401). He described the formation from the type section on the Amsden branch of the Tongue River west of Dayton, Wyoming. The formation was then believed to be of Pennsylvanian age, but it has now been proven to be both Mississippian and Pennsylvanian in age. C. C. Bransen (1937, p. 650) has proposed that the Mississippian portion of the Amsden be designated as the Sacajawea formation with the type section located on Bull Lake Creek, Wyoming. Ruth Bachrach (1946, p. 71) states that the term Sacajawea has not been generally accepted, for the Mississippian strata is not a mapable, geologic unit. The Amsden formation is found in Montana and rather widespread in Wyoming.

The Amsden thins considerably from south to north. Krusekopf and Wallace (1948) find 2022 feet of Amsden about eight miles northwest of Lima, but Brant (personal communication) measured 208 in the Armstead area. There is about 1800 feet of thinning in a twenty-five mile distance.

The correct identification of the Amsden formation is uncertain in the author's mind. In the thesis area, the Darwin sandstone members are completely absent, and the beds have been found to be unfossiliferous. It also overlies the Madison without apparent unconformity.

There are two thrusts that involve the Amsden formation and both display an Amsden facies that is different from the other. The Amsden of the eastern thrust sheet (Tendoy thrust) displays four different zones and is about four hundred feet thick:

(4) on top is a quartzitic, yellow conglomerate.

(3) next is a slope forming gray (?) limestone

(2) next is a bluish to gray limestone that contains chert and is arenaceous

(1) on the bottom is a conglomeratic, arenaceous limestone that is buff in color. The pebbles of the conglomerate are smooth.

The Amsden on the western thrust sheet (Medicine Lodge thrust) is an arenaceous limestone that is light to gray in color and weathers to a buff or tan. It is conglomeratic to quartzitic and somewhat massive where it outcrops on a ridge. The ridge is upheld by Madison limestone.

Brant reports a twenty foot bed of limestone that is pinkish-gray, finely crystalline, and stratified into one foot beds. It weathers gray-white and acquired a rough, fretted surface. This limestone unit was found in the center of the 208' foot section.

Amsden section measured in NW 1/4 section 36, T. 13 S., R. 10 W., by Krusekopf and Wallace.

29. Limestone, dark gray, weathering to light gray, fine grained	2'
28. Sandstone, light tan, friable	6'
27. Limestone, dark gray, weathering to light gray, fine grained	8'
26. Covered interval	58'
25. Limestone, dark gray, weathering to light gray, massive, dense	10'
24. Covered interval	139'
23. Limestone, gray, weathering to buff, crystalline, well bedded, contains numerous thin bands of dark chert	43'
22. Shale, gray, grading downward into brown, upper part of bed is covered	389'
21. Sandstone, light brown, thin bedded, calcareous, bedding planes well developed, weathers in places to a reddish purple	120'
20. Sandstone, tan, weathers to a rusty brown, massive and friable	24'
19. Covered interval	269'
18. Limestone, gray, finely crystalline, contains numerous organic fragments	12'
17. Limestone, dark gray, weathers to buff, argillaceous thin bedded, some interbedded chert	38'

16.	Limestone, gray-brown, weathers to buff, finely crystalline, fossiliferous ------------------	62'
15.	Shale, gray, thin bedded, calcareous, containing numerous pelecypods ----------------------------------	80'
14.	Sandstone, light tan, weathering to orange buff, hard, quartzitic ------------------------------------	3'
13.	Shales, gray, calcareous, thin bedded ---------------	29'
12.	Limestone, dark gray, weathering to buff, crystalline containing productids -------------------------------	21'
11.	Shales and limestones, gray, alternating and grading upward into brownish and buff colored beds ----------	106'
10.	Limestones and shales, argillaceous, dark gray, weathers to light tan, thin bedded, calcareous, contains gragments of gypsum ----------------------	245'
9.	Limestone, medium gray, medium grained, highly fractured ---	29'
8.	Shale, dark gray, weathering to light gray, calcareous, thin bedded with some interbedded argillaceous limestone ------------------------------	67'
7.	Limestone, light to medium gray, weathers to buff, finely crystalline, highly fractured, fractures filled with secondary calcite ------------------------------	14'
6.	Shale, dark gray, weathering to light gray, calcareous, thin bedded with some interbedded argillaceous limestone ------------------------------	43'
5.	Limestone, gray, thin bedded, argillaceous ----------	67'
4.	Limestone, buff, thin bedded, silty ----------------	10'
3.	Limestone, dark gray, fine grained, petroliferous odor --	4'
2.	Shale, gray, weathering to lighter gray, thin bedded, calcareous, contains pelecypods --------------------	86'
1.	Limestone, dark gray, weathering to buff, dense, compact ---	46'
	Total thickness	2022'

Amsden-Quadrant beds. Amsden-Quadrant is the name given to the beds exposed in Sections 4, 5, 6, T. 11 S., R. 11 W. This nomenclature was used to coordinate the lithology of the Kissick Canyon area with the lithology of the Armstead area. No agreement could be reached by the two mapping parties. This compromise name is used. The disputed rock is in a synclinal valley and is hardly more than a veneer clinging to the dip slopes of the syncline. In places this veneer may be worn off and the Madison limestone shows through. The Amsden-Quadrant is a conglomeratic, arenaceous limestone that weathers to tan or light brown.

Quadrant quartzite. The name Quadrant was first proposed by A. C. Peale (1893, pp. 32-43) after conferring with I. P. Iddings and W. H. Weed. Iddings and Weed used the term Quadrant formation for exposures in Quadrant Mountain of the Gallatin Range on Yellowstone National Park. They worked out the geology of the Gallatin Range from 1883-1893 (Iddings and Weed, 1899, p. 33).

Scott (1935, p. 1019) asserts, "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."

The Quadrant quartzite caps the prominent synclinal valley along the eastern flank of the area. The basal contact with the Amsden is observable and no unconformity is noted. The Quadrant is relatively thin here with less than two hundred feet unconsumed by erosion.

The Quadrant in the thesis area is a part of the eastern (Tendoy) thrust sheet. It is a durable, fine grained sandstone that is highly quartzitic, and it is light brown to cream-buff in color. The Quadrant forms characteristic talus slopes that have large, blocky accumulations of the quartzite. In referring to the Quadrant as a quartzite, it is inferred that it is an orthoquartzite.

Quadrant quartzite section measured by Lipp, Becker, and Krusekopf in the 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 lower beds, otherwise similar -- 8.8'

9. Dolomite -- 15.5'

8. Limestone, gray to light buff, weathers white to buff, finely crystalline, dense, slightly pitted ------- 5.0'

7. Dolomite, light gray to white, dense at base, sandy and cherty near top ------------------------------ 54.9'

6. Sandstone, soft, white, easily weathered forms rolling slope -- 131.0'

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

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

3. Sandstone, friable, massive, light tan, weathers to

light gray, interbedded with two inch thin layers of more quartzitic and slightly dolomitic near the center. Also another member of quartzitic, slightly dolomitic snadstone near top ---------------------- 109.4'

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

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

Total thickness 3319.1'

Tertiary system

<u>Red Rock conglomerate</u>. Red Rock conglomerate is the name tentatively given by Professor Eardley to thick series of coarse conglomerates and limestones that are widely exposed south of Lima. It is a coarse, orogenic deposit that is either upper Paleocene or lower Eocene in age. No fossils have been found to definitely determine its age. Structural evidence is used for this age decipherment. Structural evidence in southwestern Montana displays that it post-dates the earliest Laramide orogeny, but it pre-dates the major thrusting of the Laramide orogeny in this area. (Eardley, et. al).

The Red Rock is a heterogenous mixture of rounded, sub-angular, to angular boulders of Madison, Amsden, Quadrant, and Beltian formations. Considerable quantities of black chert are exposed that resemble the Rex Chert of the Phosphoria (see below). The limestone pebbles, cobbles, and boulders are quite well rounded, but the quartzite pebbles are more angular. The constitutents range from pebbles to boulders two feet in diameter, and they are cemented by a sandy, calcareous mattrix. In Sections 27, 28, T. 12 S., R. 10 W., is a fresh water, algal limestone.

Two thrust sheets involve the Red Rock conglomerate, and thus there are two facies. The facies on the eastern thrust sheet (Tendoy) range from pebbles to small cobbles. There is also considerable black chert float that resembles the Rex chert of the Phosphoria formation. The conglomerate of the western thrust (Medicine Lodge) sheet is much coarser with large boulders present.

Both exposures of the Red Rock lie unconformably over the Madison or the Quadrant formations. Adam and Benner (1948, p. 37) estimate 3000 feet of conglomerate in the Lima Peaks region. It forms the backbone of the Tendoys in the subject area.

Below is a pebble count taken from Section 8, T. 11 S., R. 11 W. by the author and J. Seglund.

Black limestone	14%
Black chert	18%
Pink quartzite	3%
Tan sandstone	17%
Gray limestone	36%
Yellow limestone	12%
Total	100%

Sage Creek and Cook Ranch formations. Sage Creek and Cook Ranch formations crop out widely to the southeast, and beds of similar lithology occur in the thesis area. The "basin beds" in Medicine Lodge Valley of the report were not differentiated, but it is fairly certain that one or both of these two formations occur there.

Sage Creek formation was named by Douglas (1903, pp. 145-146). H. F. Osborn (1909, p. 98)identifies the fossils as upper Eocene in age. H. E. Wood, 2d. (1934, pp. 253, 255, 277) claims that it is of Uinta or upper Bridger depending on the emended identification of Douglas's fossils. The type locality is in Beaverhead County, Montana. It is located north of Sage Creek, about seven miles northeast of Lima.

Cook Ranch formation was named by A. E. Wood (1933, pp. 134-135) from the type section the Cook Sheep Company, Home Ranch. It is located 8.1 miles by road north and east of the Dell railroad station in Beaverhead County, Montana. It is middle Oligocene in age.

The Sage Creek-Cook Ranch formation is a friable, poorly cemented sandstone containing some biotite. The sand grains are coarse and angular. The formation is massive, red colored and fractured by joint planes, and it weathers to a dark red-brown. Interbedded white sands can be observed in other exposures. The sands are better cemented with a calcareous cement, and they weather to a light gray. In other exposures, calcite veins are present. Extensive igneous flows and bentonites are found throughout these beds. The flows are a dark red in color and of a vessicular nature. The bentonite occurs as red, tuffaceous, bentonitic shale. Light colored acid tuffs and mudstones have also been noted. Except for the lava flows, the beds are poorly consolidated.

Volcanics. The volcanics have been mentioned in the Sage Creek-Cook Ranch basin beds. The fact that they are confined to the basin beds dates the period of volcanism. This volcanism correlates with the Absarokan Revolution which started during late Eocene times. (Eardley, personal communication) (Love, 1939, p. 117.)

Quaternary system

Alluvium. Alluvium deposits of pebbles, sand and silt mantle all of the stream valleys in the thesis area. Alluvial fans and terraces flank the main valleys. Considerable time and study would have been necessary for a complete investigation of these features. Alluvium and terrace gravels are prominent in the Red Rock basin. Alluvial fans form a piedmont to the fault scarps of Red Rock Basin. Two terrace levels appear above the present river level. In certain places pediment surfaces have been sculptured in the bed rock which might be confused with alluvial fans.

STRUCTURAL GEOLOGY

Introduction

The Tendoys Mountains and their structures have been formed by a series of events that began with the subsidence and accumulations of sediments in the Cordilleron geosyncline. The sediments were subsequently deformed during two disturbances: (1) the Laramide folding and thrusting, and (2) the post-Laramide block faulting.

It is believed that the Tendoy Mountains in the area of this report are located in about the transition zone from the geosyncline to the eastern shelf zone. At times subsidence was rapid, and at times it was slow and rather thin deposits of sediments accumulated. On the cross-section and map of Plate I, a complex structure dominated by three thrust sheets appears. The complete character and thickness of the sediments in the thrust sheets is difficult to make out, but to the east in the Blacktail area the sediments are relatively undisturbed by thrusting, and Keenmon (personal communication) estimates there that 4000 feet of Paleozoic and 4000 feet of Mesozoic sediments are present. The thicknesses are more those of the shelf zone than the geosyncline.

Laramide orogeny

Early Laramide orogeny. Early Laramide cross-folds in the Tendoy Mountains have been recognized by several students (Adam, 1948, p. 42); (Lipp, 1948, p. 38; Cummings, 1948, p. 35). They trend in a northeast-southwest direction parallel to the Snowcrest Range which is the major element of the northeast structures. No evidence of the cross-folds was observed in the subject area. They have been called cross-folds, because they trend almost normal to the thrust fronts. It has been postulated that the deformation that produced the folds occurred during late Cretaceous or early Paleocene times, because they preceded the deposition of the Red Rock conglomerate. The deformation produced the landmass that became the source for the sediments of the Red Rock conglomerate.

Late Laramide orogeny. Three thrusts have been mapped in the thesis area. They all strike in a northerly and northwesterly direction (see cross-sections and map, Plate I.).

The Tendoy thrust is the easternmost of the three. In the Lima Peaks and Sheep Canyon area to the southeast (Adam, 1948, p. 46), the thrust overrides the Red Rock conglomerate. In the area of this report, the top of the Tendoy thrust is exposed on the east front of the mountains, but the base of the thrust is buried by alluvium of the Red Rock basin. The Red Rock conglomerate has not only been overridden, but has also been carried on the back of the Tendoy thrust sheet, which clearly demonstrates that the Tendoy thrust post-dates the deposition of the Red Rock conglomerate. The Tendoy sheet is made up of the Madison limestone, Amsden formation, Quadrant quartzite, and Red Rock conglomerate. A syncline extends along the crest of the thrust sheet, just east of the Medicine Lodge thrust contact.

The Medince Lodge sheet lies next to the west and is overthrust on the Tendoy sheet. The overriding Medicine Lodge thrust seems to have deformed the beds of the Tendoy sheet into the asymmetrical syncline just mentioned. The Madison limestone beds in the Medicine Lodge sheet are overturned along the thrust front, and high reverse dips are recorded. In addition to the Madison beds, the Amsden formation and the Red Rock conglomerate are the chief components of the thrust sheet in the thesis area. The Medicine Lodge thrust was first mapped by Kirkham (1927, pp. 26-29) in the Medicine Lodge Pass at the boundary of Montana and Idaho, about forty miles south of the area of this report. There the Madison is thrust on Madison, on Quadrant and on Red Rock.

The Beaverhead is the third thrust that occurs in the area and the most westerly. It has tentatively been given the name Beaverhead thrust pending further study (Eardley, personal communication). The thrust sheet is composed entirely of pre-Cambrian granite gneiss. The granite gneiss is overthrust on Madison and on Red Rock.

Post-Laramide orogeny

<u>Early Tertiary basins.</u> Following the Laramide orogeny, a long episode of erosion took place with possibly some crustal deformation. This produced great, broad, intermontane valleys. The Basin beds, Sage Creek and Cook Ranch, were deposited in the valleys. A. E. Wood

(1933, pp. 134-135) states that the Cook Ranch overlies the Sage Creek with an unconformity. The Sage Creek is upper Eocene and the Cook Ranch is middle Oligocene (see discussion under stratigraphy).

Volcanism. The deposition of volcanics in the Basin beds (see discussion under stratigraphy) is evidence of crustal unrest. The dating of the Basin beds also dates the volcanism. This correlates with the Absarokan disturbance that Love (1939, p. 117) describes in the Yellowstone Park region. There the Absarokan volcanism began in middle Eocene and had its climax in the Oligocene.

High angle faulting. High angle faulting followed the deposition of the Basin beds and thus post-dates the Basin beds. The block faulting is mid-Tertiary. In Section 6, T. 11 S., R. 10 W., Basin beds dip 27° to the east, and on the west side of the area of this report the beds dip 31° to the east. The deformation of the Basin Beds is believed to have been brought about by the high angle faulting of the mid-Tertiary. Wallace (1948, p. 46) reports Basin beds in the Muddy Creek basin that dip 20° to the east. He states that they were not deposited along a fault scarp, but were tilted in the fault movements.

The high angle, block faulting of the post-Laramide orogeny is found in several places in the Tendoys. High angle faults cut all the thrust sheets in the subject area. The downfaulting of the Beaverhead thrust (see map and cross section, Plate I) is at least 500 feet. A normal fault has elevated the conspicuous Madison cliffs (see Plate I) on the western flank of the area over 500 feet. The faulting that lifted the Madison cliffs is believed to have formed by drag folding the syncline in the Amsden (see Plate I) that is exposed just east of the westernmost normal fault. Local minor faulting accompanied the major block faulting (see eastern flank of Tendoys, map and cross sections, Plate I). The major high angle faults are traceable for several miles north and south.

The Tendoy and Beaverhead Mountains of the Bitterroot Range have a north-south orientation whereas other ranges in southwestern Montana trend in various directions. The north-south alignment is due to mid-Tertiary, high angle faulting. The north-south alignment of the mountains and the basins adjacent to them has been observed by many. The similarity between this area and the Basin and Range Province to the southwest is noted by Eardley (1947, p. 1176) who describes a belt of great trenches that extend from north-central Arizona northerly through the Basin and Range Province, through the eastern Idaho and western Wyoming-Montana region, far into British Columbia. The belt is approximately 2000 miles long.

In the Kissick Canyon area the Tendoy Mountains are bordered on the east and west by two basins, namely; the Red Rock basin and the Medicine Lodge basin. The mid-Tertiary block faulting elevated the Tendoy Mountain block and is responsible for the formation of the two basins (see map and cross section, Plate I). The down faulted basins are only two of the many basins in the northern Rocky Mountains. The high angle, block faults have been observed by several students (Adam, 1948, p. 47; Kupsch, 1948, p. 67; Smith, 1948, pp. 41-42; Wallace, 1948, p. 40), and their relationship to the basins is noted.

Lipp (1948, pp. 43-44) has found evidence of renewed movement along the Red Rock fault in the Sheep Canyon area.

PHYSIOGRAPHY

Erosion surfaces

The Tendoy Mountains are located near the edge of the southeastern boundary of Fenneman's Northern Rocky Mountain Physiographic Province. The Tendoys of the subject area are in an early mature stage of erosion. Their summits reach an altitude of 8,500 feet.

Erosion surfaces were not investigated to any extent in the Kissick Canyon area, but three are believe to be present and to correlate with the surfaces in the Nicholia Creek Basin (Kupsch, 1948, pp. 70-72). Above the 7,500 foot level, a gently rolling upland is believed to be the oldest erosion surface present. It is the gently rolling uplands and the ridge tops and summits of the Tendoys. On the western flank of the area a prominent pediment surface forms a piedmont slope to the range. It is somewhat dissected and has alluvial fans at the base. It ranges in elevation from 6,500 feet at the base to 7,000 feet at the head. The youngest surfaces are the present river terraces, and they are depositional. Their elevations are between 6,000 and 6,200 feet. All of the preceding figures are approximations.

Kupsch (1948, pp. 73-76) report evidence of two periods of glaciation in the Beaverhead Mountains and Nicholia Creek Basin area, but the Tendoys were probably not high enough to have been glaciated.

CRETACEOUS AND TERTIARY HISTORY OF SOUTHWESTERN MONTANA

At a meeting attended by graduate students of the University of Michigan who worked in southwestern Montana during the summer of 1948 and Professor A. J. Eardley, the following sequence of events was decided upon. The asterisks represent personal additions to the data of the meeting.

1. Uplift (probably orogenic) of Cordilleran geanticline and deposition of Kootenay clastics; conglomerate generally at base.
2. Uplift (probably orogenic and lasting through most of Upper Cretaceous) of Cordilleran geanticline and deposition of Colorado group clastics.
3. Early Laramide orogeny to form northeast trending folds. Snowcrest Range is prominent element.
4. Deposition of Red Rock conglomerate. Position of highland possibly to southwest in Idaho, but relation to northeast trending folds not yet clear. The distribution and lithologic variations of the conglomerate must be better understood before the location and character of the highland can be discerned. *Found to contain larger particle sizes in the western facies.
5. Mid-Laramide orogeny; second episode of northeast folding resulting in upturning of Red Rock conglomerate along the Snowcrest Range and folding of the conglomerate in other places.
6. Late Laramide orogeny: formation of three thrust sheets athwart the northeast trending folds. Thrusts strike northerly and northwesterly

and contain elements of the northeasterly folds. All override the Red Rock conglomerate. Thrusts from east to west are Tendoy - (north of Sheep Creek Canyon), Medicine Lodge (from Medison Lodge Pass, Idaho-Montana line to Armstead and beyond), and Beaverhead (pre-Cambrian, pink, granite gneiss sheet and klippen in Medicine Lodge Valley west of Armstead). *Tendoy and Medicine Lodge thrusts have Red Rock conglomerate carried on the thrust sheet.

7. Long episode of erosion and possibly some additional crustal movements during lower middle, and early late Eocene time, which resulted in great, broad, intermontane valleys.

8. Volcanism broke out in nearby regions, focussing in Yellowstone Park and Absaroka Range. Started in late Eocene. Volcanism of superior magnitude also in the Coast Range region of Oregon and Washington at this time. Resulted in daming of drainage ways and abundant ash and dust falls. Alluviation of great intermontane valleys of southwestern Montana was heavy. Deposition of Sage Creek formation (late Eocene) in Southwestern Montana, and other formations of equivalent age elsewhere over a wide region.

9. Local gentle deformation and erosion in early Oligocene.

10. Continued volcanism nearby and deposition of Cook Ranch beds in middle Oligocene time, on Sage Creek beds. Contact obscure and extent of erosion not known.

11. Early episode of block-faulting. Volcanism broke out at north end of Blacktail Range and extensively in Snake River Valley and Yellowstone Park and Columbia Plateau. Deposition of lower Miocene Black-

tail Deer beds and associated basalts, tuffs, and agglomerates in Upper Sage Creek, along northwest flank of Snowcrest Range and in Ruby Basin. Called Passamau by Dorr and Wheeler.*Block faulting in Tendoys.

12. Erosion to extensive surface of moderate relief. In places the pre-Sage Creek surface may have been reexhumed and become co-extensive with this post-Blacktail surface. Present now in summit areas of Blacktail Range where lower Miocene basalts and tuffaceous beds are gently beveled. *Highest erosion surface in Tendoys believed to be of this age.

13. Second episode of block-faulting. *Tendoys again elevated.

14. Deposition of upper Miocene and lower Pliocene Madison Valley beds in Ruby Basin.

15. Regional uplift, in places possibly more block faulting, and erosion of extensive pediments. Those on the northwest side of Snowcrest Range most extensively and perfectly developed. Pediments on basin beds of back valleys in Beaverhead Range (graben valleys) are of this age. In valleys like Beaverhead River, Blacktail Creek and Sweetwater, downfaulting was so extensive that alluvial aprons were deposited along the base of the fault scarps.

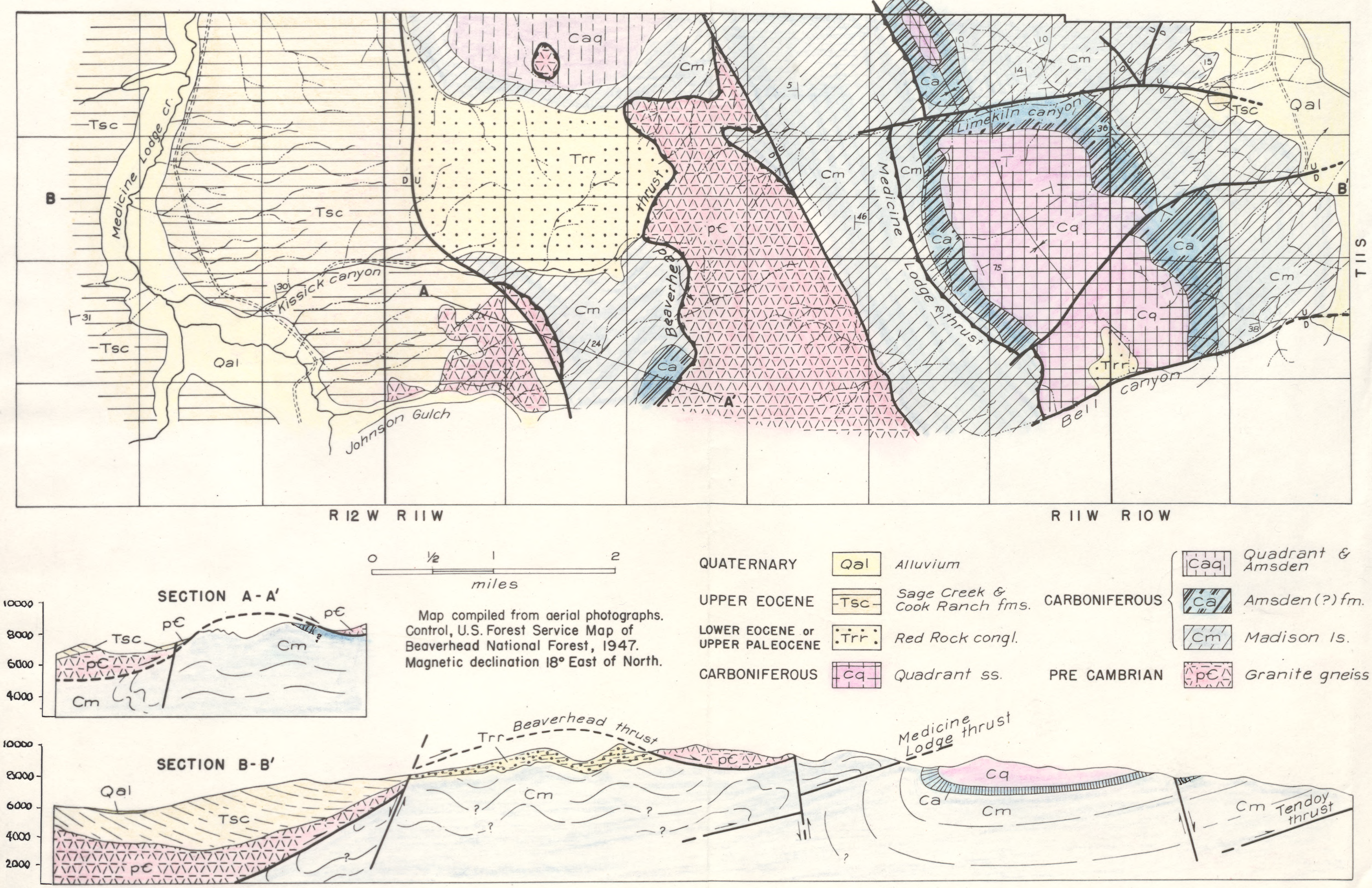
16. Third episode of block faulting and alluviation in places. Gentle uplift in places and dissection of pediments. Two episodes of glaciation in Beaverheads, probably one before dissection, and one after.

17. Continuation of block faulting at front of Tendoy range, in modern times.

GEOLOGY OF THE KISSICK CANYON AREA, TENDOY MOUNTAINS

BEAVERHEAD COUNTY, MONTANA

BY G.F. BOWERS & J. SEGLUND



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