GEOLOGY OF PART OF THE TENDOY MOUNTAINS, NEAR RED ROCK, BEAVERHEAD COUNTY, MONTANA.

by James Seglund

GEOLOGY OF PART OF THE TENDOY
MOUNTAINS, NEAR RED ROCK,
BEAVERHEAD COUNTY, MONTANA

by James A. Seglund

Submitted in partial
fullfilment of the
requirements for a
Master of Science
degree in Geology at
the University of
Michigan, 1949.

CONTENTS

ILLUSTRATIONS

ABSTRACT

The area is located in southwest Montana in Beaverhead County near the village of Red Rock. Geologic mapping was done directly on aerial photographs with an approximate scale of 1:20,000.

The Lower Mississippian Madison limestone underlies much of the area. The Lower Pennsylvanian Amsden formation and the overlying Pennsylvanian Quadrant formation are the other principal formations in the area. There are no Mesozoic rocks present, but the Tertiary is represented by the Paleocene or Lower Eocene Red Rock (Beaverhead) conglomerate and the Upper Eocene to Miocene Basin beds.

Northeast trending folds were created in the region during early Laramide time. North and northwest trending thrusts occurred in Later Laramide. The thrusting is represented by the Beaverhead, Medicine Lodge, and Tendoy thrust sheets of the area. In later Tertiary time, gentle folding and high angle faulting occurred. The high angle faults follow the trend of the Laramide structures, and there have been some indications of recent movement along the faults.

INTRODUCTION

Location of area

The area includes thirty-three square miles and is located in southwestern Montana in Beaverhead County west of the village of Red Rock. It is bounded on the east by Highway 61 and on the west by Medicine Lodge Creek. The northern boundary is defined by a line passing east-west through Limekiln Canyon on the east and Baker's Canyon on the west. The southern boundary is marked by a line passing east-west through Bell Canyon on the east and Johnson's Creek on the west.

Geologic mapping

The area here described was mapped by the writer and his collaborator, Mr. Gerald Bowers, during the month of August, 1949. Geologic mapping was done directly on aerial photographs with an approximate scale of 1:20,000. A land base was taken from a United Sates Forest Service map and the photographs were adapted to this base with the multiscope.

Physiography

The Tendoy Mountains pass directly through the central part of the area. The range trends north-south and has a relief of approximately 1,500 feet in this vicinity. The summit of the Tendoys present a landscape of gently rolling hills covered by sage brush, patches of pine trees, and sparse grass. The tree cover is composed mainly of Douglas fir, Mountain mohogany, and Lodge Pole pine.

West of the Tendoy Mountains in the area is the Medicine Lodge Creek basin. The Red Rock basin is located east of the Tendoy Mountains in the area.

The land in this region is dominantly used for sheep grazing. Field trips through the area included frequent encounters with deer, prairie chicken, and rabbits. Rabbits seemed to be particularly abundant. A few rattlesnakes were observed in the northeastern part of the area in and around Limekiln Canyon.

Drainage

The Tendoy Mountains are drained in the main by intermittent streams. Streams which flow down the west slope of the range enter Medicine Lodge Creek. Streams flowing down the eastern slopes enter the Red Rock River. The Medicine Lodge Creek runs northward until approximately five miles west of the village of Armstead where it turns eastward and enters the Red Rock River. The Red Rock River flows northward through the villages of Red Rock and Armstead. There are only a few spring-fed permanent streams in the area which afford good camping sites. These streams occupy the deep canyons.

Accessibility

The mapped area can be entered on the east by roads leading from Highway 61 to Limekiln Canyon and Bell Canyon. A good road branches off Highway 61 at Armstead and follows the Medicine Lodge Creek southward to the western side of the area. There are no roads entering the central part of the region. The roads in the area are difficult or impossible to traverse in wet weather. This is due to the bentonite prevalent in the basin beds of the area.

Climate

The climate of this part of Montana is typically semi-arid. The following data on the climate was obtained from "Climate of the States, Montana", Agricultural Yearbook, 1941.

January average temp. -----------16.3 F

July average temp. --------------62.9 F

Annual mean temp. ---------------39.3 F

The annual average precipitation is 9.27 inches. Thunderstorms and light showers are frequent in the mountains. They commonly occur in the afternoons.

Previous work

There has been little previous work done in this area. Professor E. S. Perry and U. N. Sahinen of the Montana School of Mines made a reconnaissance map of the region in 1946. The map has not yet been published. During the summers of 1947 and 1948 graduate students of the University of Michigan mapped the region in greater detail. Work there has not yet been completed and more of the region will be mapped by future graduate students.

Acknowledgements

The author is indebted to Professor A. J. Eardley for his invaluable assistance in the field and his equally valuable aid in the construction of the geologic map and the writing of the thesis. Mr. Walter

Kupsch acquainted us with the stratigraphy and problems of the area, and Dr. Heinrich of the University of Michigan assisted us on the pre-Cambrian of the region. The author wishes to thank Mr. Kenneth Riehle for his competent aid as field assistant.

I wish also to express gratitude to Mr. Gerald Bowers for his aid as a collaborator in the mapping and writing of the thesis. Special thanks must be given to R. I. Davis, R. L. Plank, W. Gillespie, R. Brandt, N. Elmer, and R. Peterson who mapped the adjoining areas and helped us obtain a more complete picture of the combined areas by frequent discussions of mutual geologic problems.

Fig. 1

Location of thesis area.

STRATIGRAPHY

Introduction

The formations exposed in the area are largely late Paleozoic in age. The Lower Mississippian Madison limestone underlies much of the area. The Lower Pennsylvanian Amsden formation and the overlying Pennsylvanian Quadrant formation are the other principal formations in the area.

There are no Mesozoic rocks in the area but the Tertiary is represented by the Paleocene or Lower Eocene Red Rock conglomerate and the Upper Eocene to Miocene Basin beds.

The Madison limestone and Quadrant orthoquartzite are the prominent cliff-formers of the region. No complete section of any formation could be found in the thesis area for measuring thickness or description of lithology. This was due to the somewhat complicated structure produced by thrusting, high-angle faults, erosion, the cover of Recent alluvium, and soil and vegetation cover.

No description is given of formations that do not outcrop but which are undoubtedly present at depth in the thesis area. For description of these formations the reader is referred to Master's thesis written by W. Kupsch, R. Scholten, Lipp, Becker, Krusekopf, W. Adams, W. Smith, and several others at the University of Michigan.

Stratigraphic column

(near Red Rock, Montana)

Era	Period/Epoch	Formation	Thickness
	Quaternary	Alluvium	Variable
Cenozoic	Upper Eocene-Miocene	Basin beds	Unknown
	Upper Paleocene or Lower Eocene	Red Rock	2,000' (estimated)
	Pennsylvanian	Quadrant	1,000-1,600' (estimated)
Paleozoic	Lower Pennsylvanian	Amsden	150-400' (estimated)
	Lower Mississippian	Madison Group	3,000' (estimated)
Proterozoic(?)		Pre-Beltian schist and gneiss	Unknown

Stratigraphic column

Section near Armstead (10 miles north of thesis area)

by R. Brandt and R. Peterson

Period/Epoch	Formation	Thickness
Quaternary	Alluvium	Unknown
Miocene-Oligocene	Basin beds	Unknown
Lower Eocene or Upper Paleocene	Red Rock	Unknown
Lower Cretaceous	Kootenai	Unknown
Triassic	Dinwoody	800'
Permian	Phosphoria	600-700'
Pennsylvanian	Quadrant	900-1,000'
Lower Pennsylvanian	Amsden	300'
Lower Mississippian	Madison Group	2,300'
Upper Devonian	Three Forks Jefferson	300' 800'
Mid-Cambrian	Meagher Wolsey Flathead	200' 20' 10-50'
Pre-Cambrian	Blacktail granite gneiss Cherry Creek Pony Series	Unknown Unknown Unknown

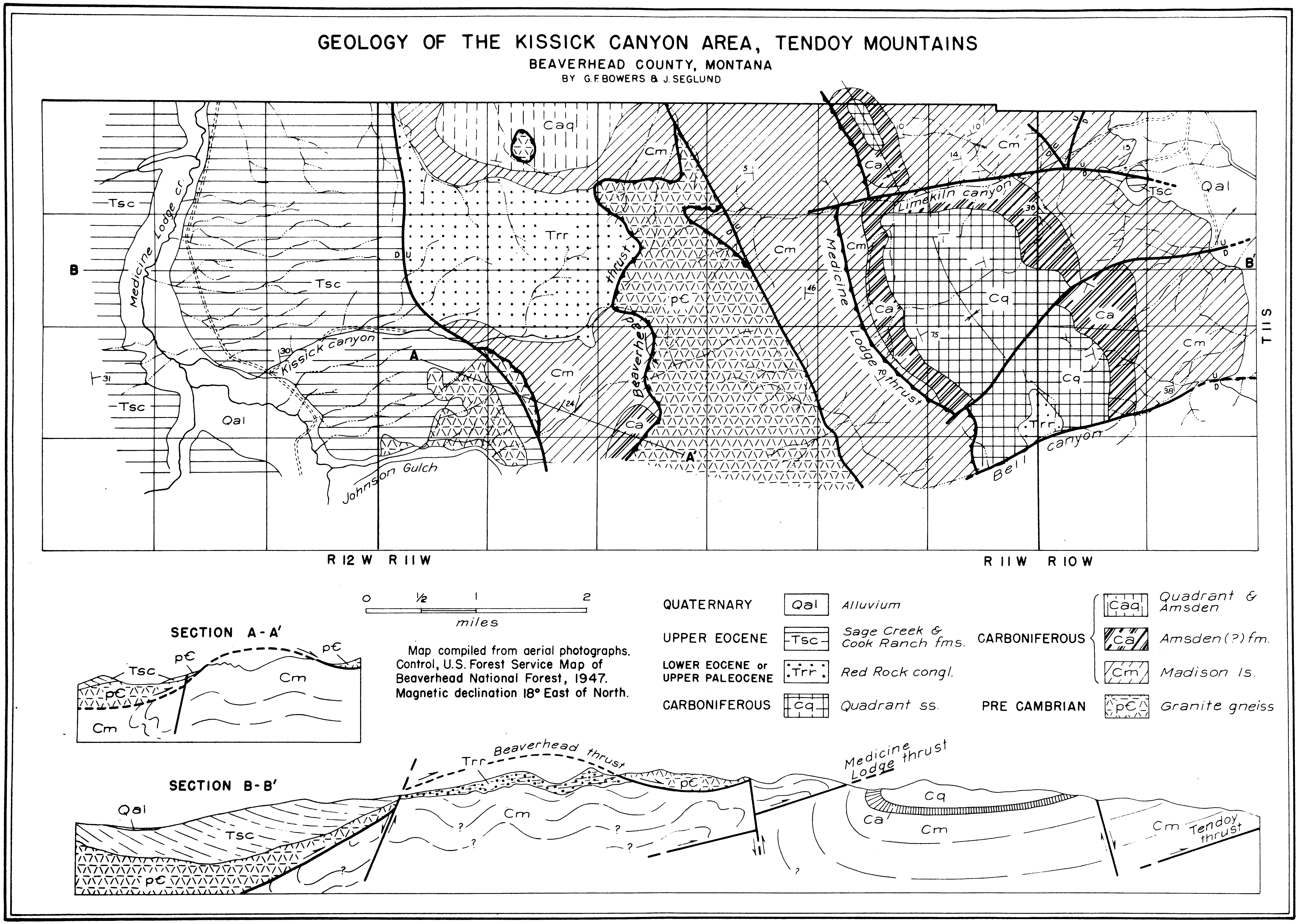

GEOLOGY OF THE KISSICK CANYON AREA, TENDOY MOUNTAINS
BEAVERHEAD COUNTY, MONTANA
BY G.F. BOWERS & J. SEGLUND
Caq
Cm
Ca
Cq
Trr
pC
Tsc
Qal
Medicine Lodge cr.
Kissick canyon
Johnson Gulch
Limekiln canyon
Bell canyon
Beaverhead thrust
Medicine Lodge thrust
T 11 S
R 12 W R 11 W
R 11 W R 10 W
0 ½ 1 2
miles
QUATERNARY Qal Alluvium
UPPER EOCENE Tsc Sage Creek & Cook Ranch fms.
LOWER EOCENE or UPPER PALEOCENE Trr Red Rock congl.
CARBONIFEROUS Cq Quadrant ss.
CARBONIFEROUS Caq Quadrant & Amsden
Ca Amsden (?) fm.
Cm Madison ls.
PRE CAMBRIAN pC Granite gneiss
Map compiled from aerial photographs.
Control, U.S. Forest Service Map of Beaverhead National Forest, 1947.
Magnetic declination 18° East of North.
SECTION A - A'
SECTION B - B'
Tendoy thrust

Fig. 2

Pre-Cambrian system

Pre-Beltian schist and gneiss: The pre-Cambrian rocks are present in the area as a klippe from the western-most thrust fault. They lie on the Mississippian Madison formation. A normal, high-angle fault defines the eastern boundary of the pre-Cambrian klippe. The faulting has placed the pre-Cambrian on the west side of the fault plane against the Madison formation on the east side of the fault plane. The relationship can be seen better in the cross-section accompanying the geologic map.

The klippe was at first believed to be an exposed intrusive stock. The evidence supporting our belief that it was an intrusive rock was;

(1) The isolated position of the rock in the midst of the adjacent Paleozoic formations.

(2) The granitic nature of the rock.

(3) The presence of intrusives in nearby areas.

(4) The presence of mineralization in the Paleozoic formations adjacent to the rock.

(5) The base of the rock was not recognized.

A field trip with Dr. Heinrich of the University of Michigan to outcrops of similar lithology, which he said resembled the pre-Cambrian of nearby areas, caused us to later give the "intrusive" a pre-Cambrian age. Later discussions with Dr. Eardley of the University of Michigan and other graduate students supported the pre-Cambrian age of the rock on structural evidence. The facts supporting the pre-Cambrian age of the rock are;

(1) The strong lithologic resemblance to the pre-Cambrian exposed in nearby areas.

(2) The strongly schistose nature of the rock; a schistosity that is not reflected in the adjacent Paleozoic rocks.

(3) The schistosity does not run parallel to the contact with the adjacent Paleozoic formations, thus making improbable a schistosity due to primary foliation.

(4) The concentration of most of the mineralization along a fault at the eastern edge of the rock.

(5) The presence of a rock of very similar lithology in the thrust sheet immediately west.

(6) The long, straight eastern edge of the rock which supports the postulation of a fault with the consequent preservation of the pre-Cambrian on the ~~down~~ up-thrown side of the fault.

The pre-Cambrian rock has not been correlated definitely with any pre-Cambrian formation. Not enough of the rock was present to make the complete lithologic study so necessary in correlating pre-Cambrian formations. At present, it is believed the rock may be either the Cherry Creek formation or the Blacktail granite gneiss.

Mississippian system

Madison group: The Madison group was first described and named by A. C. Peale (1893, p. 33) from exposures in the Madison Range in the Three Forks Quadrangle, Montana. It has been assigned to the Lower Mississippian period. The group has been divided into two formations; the upper Mission Canyon and the lower Lodgepole. The formations were first named and described by A. J. Collier and S. H. Cathcart. The Mission Canyon was originally described as a massive, marine limestone not as fossiliferous as the Lodgepole, which is a thinly-bedded limestone and shale formation. The two formations were not differentiated in the geologic mapping of the area although both were recognized in the field.

Madison limestone of different facies has been brought into the area by thrusting. Thus, a definite difference in the lithology of the Madison can be noted in an east to west traverse.

The most easterly facies of the Madison in the area is as follows; the Mission Canyon formation consists of thin beds of light gray, massive limestone which weather to a lighter gray color. The limestone is finely granular in texture and contains fossils. A few brachiopods were collected from the formation with the faint hope that they might be identifiable. Subsequent examination proved that these fossils were so poorly preserved that a positive identification could not be made. The beds of the formation are highly incompetent and were described as "wavey" in the field because of their intricate folding throughout the area.

The Lodgepole formation is a cherty, laminated, dark gray, limestone that weathers darker than the Mission Canyon. It is slightly arenaceous near the base.

In the thrust sheet next west, the Madison overall is slightly more massive and the Mission Canyon formation is slightly darker gray. The Lodgepole formation is not so thin-bedded as equivalent beds east of the thrust. A small portion of the western

Lodgepole was measured in Limekiln Canyon. It consisted of the following units;

Top (1) Limestone, slabby, dark gray, weathering chocolate brown -------------------- 33'

(2) Limestone, greenish-gray, weathers to a tan color, almost lithographic ----- 5'

(3) Limestone, slabby dark gray, thin-bedded, very fine grained, weathers to a dark gray-brown------------------------- 12'

(4) Same as (2) ----------------------- 51'

(5) Limestone, light gray, spotted with green, weathers to an orange-yellow, thin-bedded, almost lithographic ----------------124'

The Madison carried in the thrust sheet next west, is a massive, dark gray to blue limestone which weathers to a light gray. It contains many cup corals and crinoid stems. In many places it is badly broken by the thrusting and high-angle faulting and in these places is filled with a multitude of calcite veins. The veins are usually about one-half inch wide but some range up to one foot in width. A breccia consisting of angular limestone fragments is present in places and may indicate deformation. The breccia has been recemented with calcite. The Madison group facies here could not be differentiated into the Mission Canyon and Lodgepole formations. This may be because the Lodgepole is located at depth and not exposed, or that the eastern Madison group grades into the Madison described above.

The Madison seems to grade, therefore, from a thin-bedded, light gray limestone overlying a cherty, laminated shale and limestone facies on the east, to a massive, dark gray to blue limestone facies on the west.

Walter Kupsch and R. Scholten measured and described a partial section of the Madison in an area approximately ten miles to the south. The total thickness of their partial section is 980 feet. Kupsch and Scholten's section describes a dark to light gray, massive limestone with many cup corals and crinoid stems, with calcite veins and breccia layers. Lithologically it strongly resembles the most western facies of the Madison in the thesis area.

Natural bridges sculptured out of the Madison limestone can be seen in the region. Such bridges are present at the upper surface of the Madison group and represent an unconformity. At the close of the Mississippian period, the Madison group was lifted above water level and solution channels were eroded into the limestone. The formation was innundated again and the eroded caverns were filled with a red sandstone. Thus, the

Madison is splotched with red spots near its upper surface in some regions.

Pennsylvanian system

Amsden formation(?): The Amsden formation of the area was the most difficult to identify. The lithologic differences between it and the underlying Madison formation are slight, and in places the boundary between the Madison and Amsden was chosen arbitrarily. Further difficulties were due to an unusually thin section in the region and the tendency of the formation to form a covered slope.

The Amsden formation in the syncline on the eastern side of the area consists at the top of a yellow-brown, calcareous cemented, quartzite conglomerate. The breccia of quartzite are light gray in color and very angular in outline. Their average size is approximately two to three inches in width. Below the quartzite conglomerate is a slope of gray limestone. It is underlain by a cherty, dark gray limestone which is arenaceous toward the bottom. The basal member of the Amsden is a conglomeratic sandstone about ten feet thick which contains smooth pebbles of quartzite. The estimated thickness of Amsden is 400 feet.

The Amsden in the thrust sheet next west also was distinguished on a lithologic basis. It is located on the north-central edge of the area and designated on the map as Amsden-Quadrant. The formation here is a yellow-brown, calcareous cemented, quarzite conglomerate. Cursory inspection in the field showed it to be devoid of fossils and poorly cemented. The fragments of quartzite are highly angular in nature and the average size is approximately three inches in diameter. It was assigned to the Amsden formation by the mappers. Below it is a light gray, slope forming limestone which was also assigned to the Amsden formation. No other members were noted. The estimated thickness of Amsden here is 150 feet.

The yellow-brown, calcareous cemented, quartite conglomerate described above created some confusion in correlating the area mapped by G. Bowers and the author with the area mapped immediately north. R. Brandt and R. Peterson assigned the same unit to the Quadrant formation and recognized no Amsden in the area. Because the workers in each areas were equally convinced that they had assigned it correctly, a compromise was established whereby the disputed area is called Amsden-Quadrant on the geologic map until further study.

The quartzite conglomerate described above is seemingly limited in lateral extent. It was carried into the area by thrusting from the west. It must therefore post-date a disturbance of local extent somewhere to the west. The quartzite fragments resemble the quartzite of the Beltian group and the quartzite of the Ordovician Kinnikinnic formation. The highly angular nature of the fragments indicates that they were not transported far. The calcareous-arenaceous cementing material indicates deposition near shore in a marine environment. These facts suggest that the member may represent the beach and off-beach deposits of the Amsden sea. Because the pebbles are not rounded, deposition and burial must have been rapid. Perhaps the conglomerate was created by waves pounding a cliff of quartzite.

To the south in an area mapped by W. Adams and R. Benner, the Amsden contains a gypsum facies. Similar gypsum facies are known in the Amsden of Northwest Wyoming in the Jackson Hole region.

The Amsden formation was first described by N.H. Darton (1904,p.394-401) from an exposure on the Amsden branch of the Tongue River west of Dayton, Wyoming. Earlier A. C. Peale had included the "cherty limestone" in the lower Quadrant from exposures at Yellowstone National Park. It was later shown that this member should be correlated with the Amsden formation of Central Montana.

Quadrant formation: The Quadrant formation was first described by A. C. Peale (1893, pp. 32-43) from exposures in the Quadrant Mountains of the Gallatin Range in Yellowstone National Park. It was later redfined by D.D. Condit, H.W. Scott, and W. H. Weed as a western extension of the Tensleep formation. It is now believed by some that the Tensleep formation correlates only in part with the Quadrant of Montana.

The Quadrant is identifiable in the field by persistant lithologic characteristics. Most often it is found as a light brown to tan colored orthoquartzite which weathers to a dark brown. It is fine grained and a cliff-former, and generally has a talus slope formed by large angular blocks of the orthoquartzite.

The Quadrant in the easternmost thrust sheet fits the general description given above. But the Quadrant in the thrust sheet next west is lighter in color than the Quadrant found to the east. It is light brown and has a conchoidal fracture. The lighter color is due to a higher percentage of pure quartz in the formation.

A strange type of Quadrant was found near the fault running north-south through the central part of the area and immediately north of the Pre-Cambrian klippe. The Quadrant here was an oval-banded, brown and white quartzite. It strongly resembled the leisigang type of banding. The peculiar banding was probably caused by mineralization along the nearby fault plane.

The thickness of the Quadrant varies considerably within short distances. Thicknesses measured throughout the region range from the 3,319.1 feet measured by Lipp, Becker, and Krusekopf in the E ½, section 35, T. 13 S, R 10 W to the 900-1,000 feet measured by R. Peterson and R. Brandt northwest of Armstead. The Quadrant in the thesis area was estimated to be approximately 1,900-1,600 feet thick.

Tertiary system

Red Rock (Beaverhead) conglomerate: The Red Rock conglomerate is the provisional name given by Dr. A. J. Eardley of the University of Michigan to a conglomeratic formation prevalent throughout the region. Professor Lowell of Montana State University has made a special study of the conglomerate and intends to name it the Beaverhead conglomerate (personal communication).

The formation lies unconformably on Paleozoic and Mesozoic formations and is over-ridden by Laramide thrust sheets. Thus, the formation has been determined to be Paleocene or Lower Eocene in age. At this date no diagnostic fossils have been found that definitely correlate it with the early Tertiary epochs. It is separated from the younger overlying Sage Creek formation by an unconformity.

Two exposures of Red Rock are in the thesis area. One remnant lies in front of the middle thrust of the three thrust sheets present in the area. On the geologic map of the area it is located in the southeast corner. This remnant is part of the most eastern reaching thrust sheet. Another remnant is in the western part of the area and is contained in the middle sheet of the three thrusts sheets.

In the area the formation is a massive, boulder conglomerate. It contains limestone, quartzite, and chert pebbles and boulders. The limestone pebbles are well-rounded and the quartzites and chert fragments are more angular in outline. In the thesis area the formation has a tan, calcareous-arenaceous cement. It weathers to a light brown. The more western facies is coarser in texture than that to the east. The more eastern facies also contains a greater amount of black chert.

The author and his collaborator made a pebble count of the more western facies from an coutcrop on the drainage divide at the head of Kissick Canyon. The pebble count is as follows;

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

This pebble count may be resolved into formations as follows;

Madison (?) formation	68%
Amsden (?) formation	12%
Quadrant (?) formation	20%
Total	100%

The thickness of the formation has been estimated to be from 2,000 to 3,000 feet.

Basin beds (undifferentiated): Of the Basin beds that have been distinguished by other authors, the Sage Creek and the Cook Ranch formations may be present in the thesis area. No attempt was made to differentiate the formations due to a lack of time.

The Sage creek formation was named by Douglas (1903, pp. 145-146) and H. F. Osborn (1909, p. 98). The type locality is in Beaverhead County, Montana north of Sage Creek and about seven miles northeast of Lima. The Cook Ranch formation was named by A.E. Wood (1933, pp. 134-135) from the type section near the Cook Sheep Company, Home Ranch, 8.1 miles by road north and east of the Dell railroad station in Beaverhead County, Montana.

Outcrops of the Basin beds were studied in the southwest part of the thesis area near the western high angle fault. The outcrops dipped thirty degrees east. One member is poorly cemented and composed of coarse, angular grains of quartz. It is massive, red in color, and fractured by numerous joint planes. It contains some biotite which has been little altered. The member weathers to a dark, red-brown surface. It contains some interbeds of less friable, white sandstone. These lighter colored, better cemented beds, have a calcareous cement and weather to a light gray color. The white sandstone contains some small calcite veins. These veins may have resulted from mineralization along the nearby fault plane, or from leaching of the calcareous cement and consequent deposition in joint planes.

An extrusive igneous flow overlies the member described above in the southwest part of the thesis area. It is dark red, rhyolitic, and rather vesicular.

Another exposure of Basin beds was examined in Kissick Canyon near the western high angle fault. The member consists of a fifty foot bed of red, tuffaceous, bentonitic shale overlying a 25 foot bed of red sandstone. The red sandstone seems to correlate with the red sandstone bed that crops out in the southwestern part of the area. Lithologically it is very similar in texture, color, and composition.

On the eastern side of the area about one mile west of the village of Red Rock and at the mouth of Limekiln Canyon, there is a small outcrop of mudstone and fresh-water limestone. It was assigned to the Basin beds. The outcrop here has five feet of light tan mudstone lying over an eight foot exposure of silver-white, fresh-water limestone. Both beds are poorly consolidated and dip twenty seven degrees to the east.

The Basin beds noted elsewhere throughout the area are composed of vesicular, basaltic flows and rhyolitic tuffs. A hasty reconnaissance in the Medicine Lodge

Creek region showed the Basin beds to contain many beds of tuff, basaltic flows, sandstones, fresh-water limestones, shales, conglomerates, and bentonitic shales.

The tuffs and igneous flows of the Basin beds probably had their origin in the Absaroka orogeny which was active in the Yellowstone Park and Absaroka Range regions during late Eocene and early Oligocene time. Extensive lakes must have been formed by damming of the rivers by tuffs and flows. The lakes gave rise to the fresh-water deposits of the group. The black basaltic flows seem to indicate near by volcanism.

Alluvium: The deposits of alluvium in the region occur as flood plains along the margins of present streams and as small alluvial fans. The alluvial fans do not seem to be large enough to warrant any detailed exploration for a possible water supply.

The gravels and sands of the alluvium indicate the change from a period of erosion to the present epoch of deposition.

The thickness of the alluvium is variable but, in general, is not very thick. The pediments on the east and west borders of the Tendoy Range are covered with a thin veneer of alluvium and at first may be mistaken for large alluvial fans.

LARAMIDE-TERTIARY HISTORY OF THESIS AREA
(Figure 3, opposite page)

Legend:

Tcr---Tertiary Cook Ranch formation.

Tsc---Tertiary Sage Creek formation.

Trr---Tertiary Red Rock conglomerate.

M-----Mesozoic formations

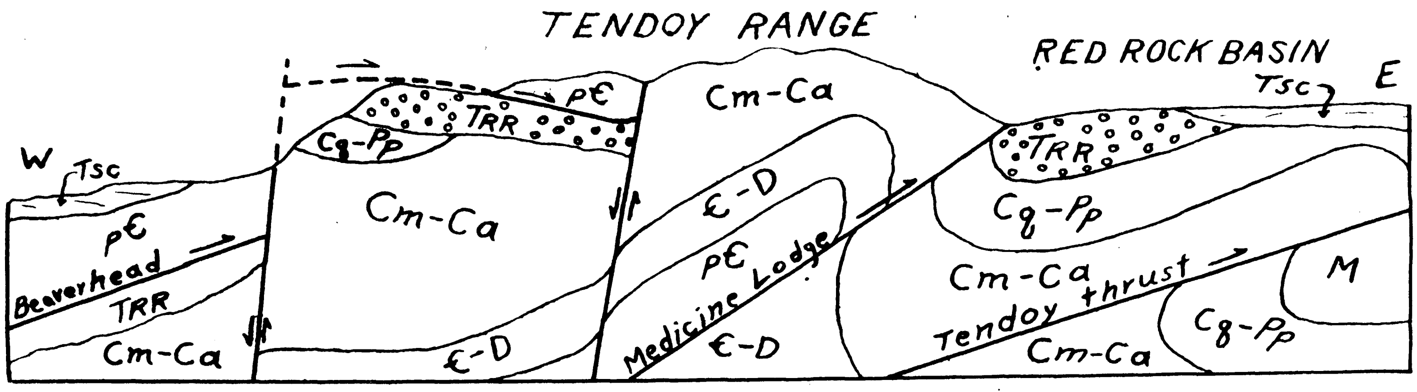
Cq-Pp-Carboniferous Quadrant and Permian Phosphoria formations.

Cm-Ca-Carboniferous Madison and Amsden formations.

Ꞓ-D---Cambrian through Devonian formations.

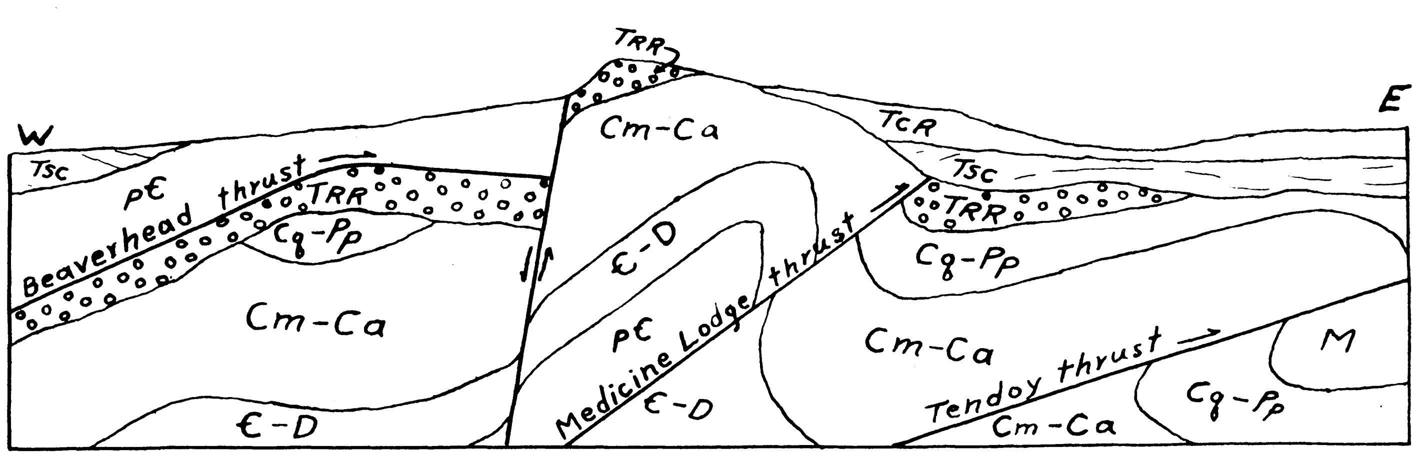
pꞒ----Pre-Cambrian formations.

5.



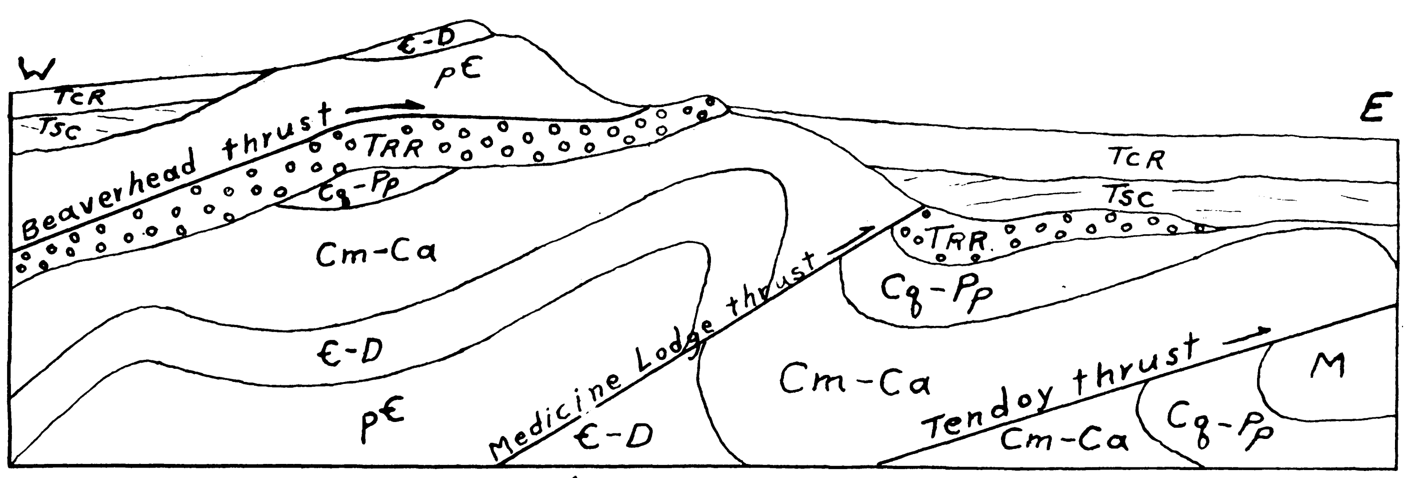
Later block faulting, regional uplift, and erosion.

4.



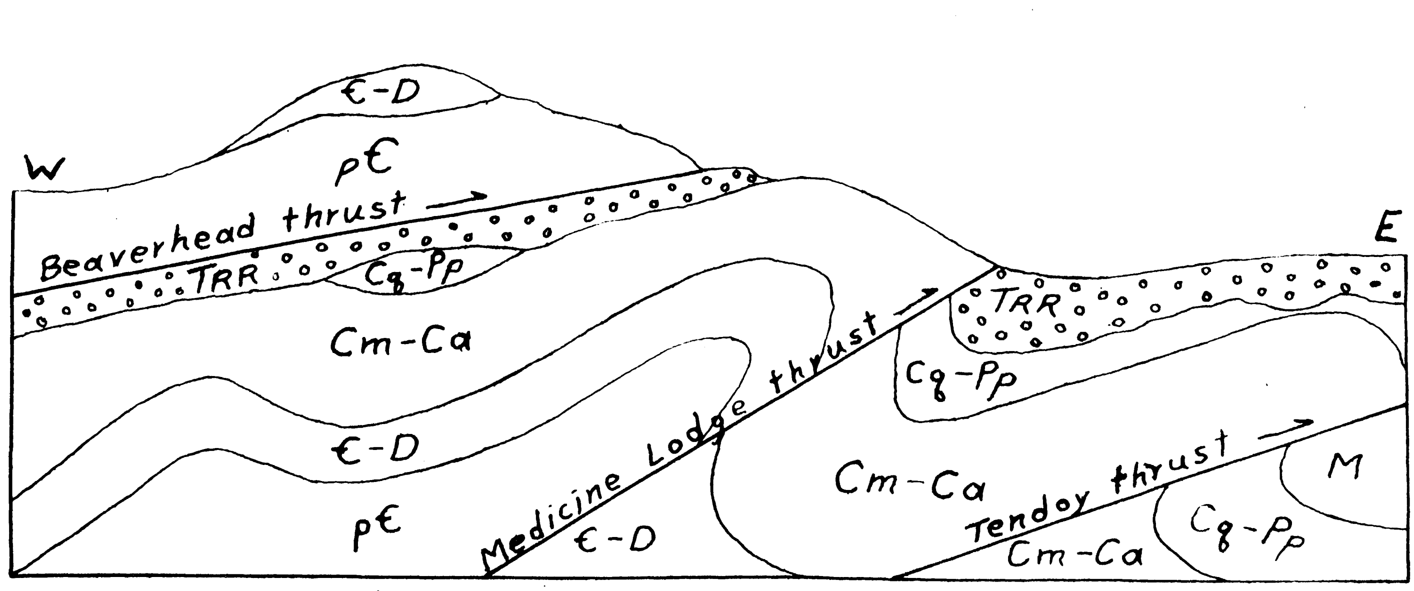
Early block faulting and erosion.

3.



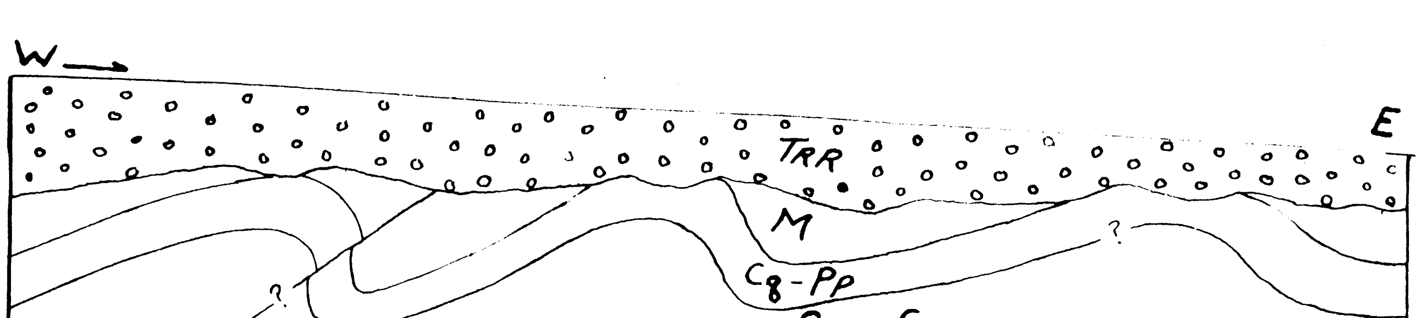
Deposition of Sage Creek (late Eocene), gentle deformation and erosion, deposition of Cook Ranch (mid-Oligocene).

2.



Late Laramide thrusting followed by a long period of erosion.

1.



Early Laramide folding, deposition of Red Rock formation.

Fig. 3

STRUCTURE

Introduction

The major orogenies reflected in the region are;

(1) The crumpling and crushing of the pre-Cambrian rocks near the close of the Algonkian period, accompanied by regional metamorphism (Kupsch, 1948, p. 56).

(2) The folding, thrusting, and faulting during the Laramide orogeny.

(3) The faulting and gentle folding during the Tertiary period.

Algonkian orogeny

Little evidence to support an Algonkian period of deformation is present in the area. A single exposure of pre-Cambrian rock shows a strongly schistose nature that is not reflected in the adjacent Paleozoic rocks. The schistosity has been attributed to the deformation which occurred during the Algonkian period (Kupsch, 1948, p. 56).

Laramide orogeny

Northeast trending folds were created during the

Early Laramide orogeny. A prominent element of the folding is the Snowcrest Range in this region (See diagram 1, figure 3). The folding was followed in later Laramide time by thrusting from the west. The thrusts do not follow the earlier Laramide folds but trend more to the north and northwest. They are present in the area as three imbricating thrust sheets (See diagram 2, figure 3).

V. R. D. Kirkham (1927) mapped four major thrusts to the south in Idaho, and the Tendoy Mountains are approximately in line with the northward extension of the eastward edge of this zone. Kirkham (1927, p. 27) thinks that the Medicine Lodge overthrust is the extension of the Bannock overthrust. This fault plunges under the basalts that cover the Snake River Plains and rises again on the north side of the plains near Medicine Lodge Creek.

The thrust sheet extending farthest to the east in the area is the Tendoy thrust. The actual trace of the thrust front is not present in the thesis area but is covered on the west side of the Red Rock basin by the younger Basin beds and Recent alluvium. The thrust was mapped from the south as far north as the thesis area where it is covered by the Red Rock basin alluvium. The trace of the thrust front reappears from beneath the cover to the north in the area mapped by W. Gillespie and N. Elmer. In the thesis area the thrust consists mainly of Madison limestone. The Quadrant, Amsden, and Red Rock formations are preserved as remnants in a syncline approximately a half-mile west from the front of the thrust. The attitude and physical condition of the bedding demonstrate that the Tendoy thrust is present in the thesis area.

The Medicine Lodge thrust sheet lies on the Tendoy thrust sheet and is immediately to the west of it. The front of the Medicine Lodge thrust is composed of Madison limestone overriding the Amsden, Quadrant, and Madison formations in the Tendoy thrust. At the front of the thrust sheet, very steep to vertical dips were recorded.

The Beaverhead thrust sheet lies upon the Medicine Lodge thrust sheet and is located immediately west of it. This thrust seems to have had the greatest lateral displacement. It may have completely covered the other two thrusts at one time. A klippe of pre-Cambrian from the Beaverhead thrust remains in back of the Medicine Lodge thrust front. The relation of the thrusts can best be seen in the cross-section accompanying the geologic map.

Tertiary orogeny

An erosional interval creating large, broad intermontane valleys occurred after the late Laramide thrusting. Next came deposition of the Sage Creek formation, followed by gentle folding and deposition of the Cook Ranch formation (See diagram 3, figure 3). This was followed by two periods of high angle faulting and regional uplift (See diagrams 4 and 5, figure 3). The faults strike approximately parallel to the Laramide structures, thus they may be revivals of faults formed during the Mesozoic era. Some recent movement has taken place along the faults (Wallace, 1948, p. 41).

Two north-south striking high-angle faults are present in the area. One is located on the west side and the other runs through the central part of the area. The western fault has concealed the surface trace of the Beaverhead thrust but some pre-Cambrian of the thrust remains exposed. The fault through the center of the area aids in the preservation of the pre-Cambrian klippe. Both faults are down-thrown on the west side of the fault plane.

Minor faulting occurs running at right angles to the main north-south trending high angle faults. The minor faults may have been caused by readjustments in the earth's crust to stresses created by thrusting.

Folding in the Red Rock conglomerate and Sage Creek formation record the gentle folding which occurred in the Tertiary. The folding has a north-south trend in the thesis area.

Cretaceous and Tertiary history of southwestern Montana

The following Cretaceous and Tertiary history of southwestern Montana was outlined during a meeting of the graduate students with Dr. Eardley. It represents the joint efforts of all graduate students who studied thesis problems in southwest Montana and Professor Eardley who directed those efforts.

1. Uplift (probably orogenic) of Cordilleran geanticline and deposition of the Kootenay clastics; conglomerate generally at base.
2. Uplift (probably orogenic and lasting through most of the Upper Cretaceous) of the Cordilleran geanticline and deposition of the Colorado group clastics.
3. Early Laramide orogeny to form northeast trending folds. The Snow Crest Range is a prominent element.
4. Deposition of the Red Rock conglomerate. Position of highland possibly to southwest in Idaho, but the relation to the northeast trending folds is 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.

5. Mid-Laramide orogeny; second episode of northeast folding resulting in upturning of the 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. The thrusts strike northerly and northwesterly and contain elements of the northeasterly folds. All override the Red Rock conglomerate. The thrusts from east to west are the Tendoy (north of Sheep Creek Canyon), the Medicine Lodge (from Madison Lodge Pass, Idaho-Montana line to Armstead and beyond), and the Beaverhead (pre-Cambrian, pink, granite gneiss sheet and klippen in Medicine Lodge Valley west of Armstead).
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, focusing in Yellowstone Park and Absaroka Range. It started in late Eocene. Volcanism of superior magnitude also

in the Coast Range region of Oregon and Washington at this time. This 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 the Blacktail Range and extensively in the Snake River Valley and Yellowstone Park and Columbia Plateau. Deposition of lower Miocene Blacktail Deer beds and associated basalts, tuffs, and agglomerates in Upper Sage Creek, along northwest flank of Snowcrest Range and in the Ruby Basin. These called Passamari by Dorr and Wheeler.
12. Erosion to extensive surface of moderate relief. In places the pre-Sage Creek surface may have been reexhumed and become coextensive with this post-Blacktail surface. This is present now in summit areas of the Blacktail Range where lower Miocene basalts and

tuffaceous beds are gently beveled.

13. Second episode of block-faulting.
14. Deposition of Upper Miocene and Lower Pliocene Madison Valley beds in the Ruby Basin.
15. Regional uplift, in places possibly more block faulting, and erosion of extensive pediments. Pediments on the northwest side of the Snowcrest Range most extensively and perfectly developed. Pediments on basin beds of the back valleys in the 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 disection of pediments. Two episodes of glaciation in Beaverheads, probably one before disection and one after.
17. Continuation of block-faulting at front of the Tendoy Range, in modern times.

BIBLIOGRAPHY

Adam, William (1948), The geology of the Lima Peaks area, Beaverhead County, Montana and Clark County, Idaho, Master's thesis, Univ. of Mich.

Becker, Robert (1948), The geology of part of the Tendoy Mountains, west of Lima, Beaverhead County, Montana, Master's thesis, Univ. of Mich.

Berry, George W. (1943) Stratigraphy and structure at Three Forks, Montana, Geol. Soc. Amer. Bull., vol. 54, p. 18-19.

Collier, A. J. and Cathcart, S. H. (1922), Oil possibilities of the laccolithic domes in the Little Rocky Mountains, U. S. Geol. Sur. Bull. 736 F, p. 173.

Condit, D. D. (1918), Relations of late Paleozoic and early Mesozoic formations of southwest Montana and adjacent parts of Wyoming, U. S. Geol. Sur., Prof. Paper 120-F, p. 110-206.

Cummins, Dean L.(1948), Geology of the Tendoy-Medicine Lodge area, Beaverhead County, Montana, Master's thesis, Univ. of Mich.

Darton, N. H. (1904), Comparison of the stratigraphy of the Black Hills, Big Horn Mountains, and Rocky Mountain Front Range, Geol. Soc. Amer. Bull., vol. 15, p. 394-401.

Douglas (1903), New Vertebrates from the Montana Tertiary, Annals of the Carnegie Mus., vol. ii.

Humblin, R. H. and Sloss, L. L. (1942), Stratigraphy and insoluble residues of the Madison Group (Miss.) of Montana, AAPG Bull., vol. 26, p. 305-335.

Kirkham, V. R. D. (1927), A geologic reconnaissance of Clark and Jefferson and parts of Butte, Custer, Fremont, Lemhi, and Madison Counties, Idaho, Idaho Bur. Mines Pamphlet 19.

Krusekopf, H. H. Jr. (1948), Geology of the Tendoy Range, near Dell, Beaverhead County, Montana, Master's thesis, Univ. of Mich.

Kupsch, Walter (1948), Geology of part of the Beaverhead Mountains and Nicholia Creek Basin, Beaverhead County, Montana, Master's thesis, Univ. of Mich.

Lipp, E. G. (1948), Geology of an area east of Sheep Canyon, near Dell, Beaverhead County, Montana, Master's thesis, Univ. of Mich.

Mansfield, G. R. (1927), Geography, geology, and mineral resources of part of southeastern Idaho, U. S. Geol. Sur. Prof. Paper 152, p. 1-409.

Osborn, H. F. (1909), Blacktail Deer Creek beds of southwestern Montana, U. S. Geol. Sur. Bull. 361, p. 98.

Peale, A. C. (1893), The Paleozoic section in the vicinity of Three Forks, Montana, U. S. Geol. Sur., Bull. 110.

Peale, A. C. (1896), Three Forks folio, No. 24, U. S. Geol. Sur.

Scholten, Robert (1948), Geology of part of the Beaverhead Mountains and Nicholia Creek Basin, Beaverhead County, Montana and Clark County, Idaho, Master's thesis, Univ. of Mich.

Scott, H. W. (1935), Some Carboniferous stratigraphy in Montana and northwestern Wyoming, Jour. Geol., vol. 43, p. 1011-1032.

U. S. Dept. of Agriculture, Forest Service (1940), Map, Washington, D. C.

U. S. Dept. of Commerce, Weather Bureau (1941), Climate of the States, Montana, Agric. Yearbook, Separate no. 1844, p. 955-966.

Wallace, S. R. (1948), Geology of part of the Tendoy Mountains, Beaverhead County, Montana, Master's thesis, Univ. of Mich.

Wood, A. E. (1933), A new Heteromyid Rodent from the Oligocene of Montana, Jour. Mammology, vol. 14, no. 2, p. 134-135.