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GEOLOGY OF THE ARMSTEAD AREA
BEAVERHEAD COUNTY, MONTANA

By

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ILLUSTRATIONS

ABSTRACT

The area considered in this report is located in Beaverhead County, Montana immediately west of Armstead. It includes the northernmost part of the Tendoy Mountains and their northern extension.

Almost a complete stratigraphic column is represented in the Armstead area. The only systems absent are the Ordovician, Silurian, and Jurassic. More than 6,000 feet of sedimentary rocks are present.

Two distinct phases of diastrophism are recorded in the region; one in late Cretaceous and early Tertiary, and the other during the Tertiary. Early and middle Laramide orogeny resulted in north-eastward trending folds. The late Laramide is marked by thrusting from the southwest, and the sheets contain elements of the northeast trending folds. Two great thrust sheets are evident in the area and another one to the south. From east to west they are: Tendoy, Medicine Lodge, and Beaverhead. Tertiary rocks are overridden by all three sheets. Block faulting occurred in early Miocene

along the eastern front of the Tendoy Mountains and continued on into modern times.

INTRODUCTION

Location

The area under consideration is located immediately west of Armstead, in Beaverhead County, southwestern Montana, approximately twenty-two miles southwest of Dillon and twenty-seven miles northwest of Lima. Armstead is situated on U. S. Highway 91. A graded road in Horse Prairie Creek valley and another along Medicine Lodge Creek, together with several unmaintained ranch roads extending from these, make the entire area accessible by automobile and foot.

General description

In general the area is divided into northern and southern portions by Horse Prairie Creek which flows east into the Beaverhead River, and which in turn is one of the headwaters of the Missouri River. The southern portion included the northern end of the Tendoy Mountains. Medicine Lodge Creek flows north along the western edge of the area and empties into Horse Prairie Creek near Medicine Lodge. The eastern boundary in general is U. S. Highway 91. The southern limit is now intermittently dry Limekiln Canyon. The northern boundary is approximately five miles north of Horse Prairie Creek. More specifically the area under consideration includes sections 19, 30, and 31, T. 9 S., R. 10 W.; sections 6, 7, 18, 19, 30 and 31, T. 10 S., R. 10 W.; sections 23, 24, 25, 26, 27, 33, 34, 35 and 36, T. 9 S., R. 11 W.; and the entire township T. 10 S., R. 11 W.

Purpose

The purpose of this report is to discuss the geology of the Armstead area. One of the specific problems at hand was to trace the thrust faults of areas previously mapped to the south, northward through the Armstead area, and to relate them to the regional structure.

Method of investigation

The field mapping was done in August, 1948. The work was of a reconnaissance nature, using aerial photographs upon which the contacts were traced and geology recorded in the field. The field party consisted of R. A. Brant, N. C. Elmer, W. A. Gillespie, and J. R. Peterson. Field assistants were D. O'Halloran and R. Bussey.

The field work was done jointly by all four members of the party, and the drawing up of the report also was a joint effort. Responsibility for individual parts of the manuscript are as follows: Brant, stratigraphy and paleontology; Elmer, petrology and petrography; Gillespie and Peterson, structure and map compilation.

Acknowledgements

The field work was carried out under the supervision and guidance of Dr. A. J. Eardley. Valuable assistance in the field was also offered by Mr. Walter Kupsch, whose Ph.D. thesis will include the area. Help in the preparation of the manuscript from Dr. A. J. Eardley, Dr. L. B. Kellum, Dr. E. H. Walker, and Mr. Kupsch is gratefully appreciated. The field assistance of Messrs. F. R. Bussey and D. O'Halloran is acknowledged, as well as the friendly help of local residents in suggesting camp sites.

The authors are indebted to Mr. M. V. Denny for his advice and assistance in preparing the photographs, and to Dr. E. W. Heinrich for his aid in thin section analyses.

GEOGRAPHY

Topography and relief

In southwestern Montana the topography is one of the alternating wide valleys and comparatively narrow, high mountain ranges. The valley floors are about 6,000 feet above sea level, and the range crests are about 8,000 to 9,000 feet.

The flood plains of the broad valleys are relatively narrow. The bulk of the valley consists of low angle alluvial fan deposits or partially dissected pediment surface. From this surface, usually gently convex upward, the mountain ranges rise sharply 2,000 feet to 3,000 feet above the valley floors.

The mountain ranges have steep slopes and fairly extensive upland surfaces. Some idea of the smoothness locally of the surface can be gained from Plate 18, where a car can be driven on it for considerable distances. In the Tendoy Range, however, the surface is thoroughly dissected and is represened to small, smooth, flat areas on individual mountains.

In the area north of Horse Prairie Creek, the mountain range is represented by a series of high hogback ridges outlining a complex south-plunging anticline. The erosion surface is present only on the highest part of the ridges.

Climate, Vegetation, and Culture

The Armstead area lies in a steppe climate. The annual rainfall normally ranges from 10 to 20 inches. The climate is further characterized by a cold winter season and a mild summer season. Nights are considerably cooler than the days. The day air temperatures are mild but the open sunshine is warm. Short, but often intense, rains are common during the summer; they occur in the late afternoon.

The main vegetation types are: grass, sagebrush, and forest trees. The flood plains are extensively farmed for wild hay.

Sagebrush is found in greater proportions on the lower slopes. The heavier sagebrush cover gives way to grass on the higher slopes. The grass shares an open, sporadic forest cover on the higher elevations. Conifers prefer the Quadrant and Madison formations. The thickest forest cover is observed in the protected valleys. Limekiln Canyon in the southern part of the area is a good example. In the northern part of the area much of the surface is bare rock.

Local springs around the periphery of the pre-Cambrian gneiss in the southern part of the area give rise to local green spots where there is a lush grass cover. The springs also supplied watering holes for the few cattle that can graze in the area in the later summer months. The major industry is cattle raising. Winter snow and the spring rains supply enough moisture to provide wide grazing conditions through the early summer months.

Two ranches are located on the lower eight miles of the Horse Prairie Creek, and two are located in the lower ten miles of Medicine Lodge Creek.

Plate 3

Plate 3: Index Map

After E. Riasz

STRATIGRAPHY

General description

Most of the stratigraphic column is represented in the Armstead area. Rocks range in age from pre-Cambrian to Recent, and the only systems absent are the Ordovician, Silurian, and Jurassic. Major unconformities occur at the base of the Cambrian and at the base of the Tertiary. The lower Paleozoic rocks are incompletely exposed because of faulting. No Pleistocene deposits are recognizable.

The lithologies include gneisses, the various volcanics, quartzites, sandstones, conglomerates, limestones, dolomites, and shales. Two unusual conglomerates were found: one at the base of the Cretaceous, and the other at the base of the Eocene (?). The only well-preserved fossils found were in the Dinwoody limestone. A few were found in the Amsden formation.

The following table shows the formations found in the area and the respective thickness and age of each.

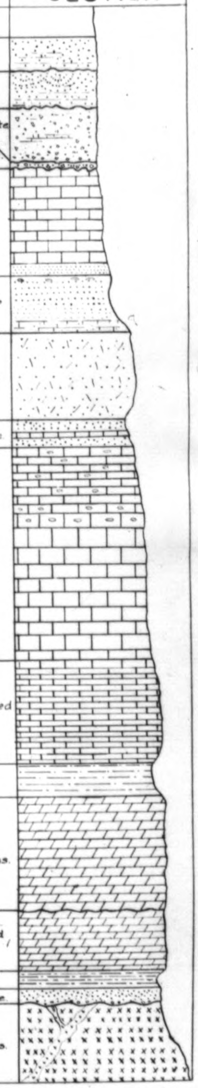
Figure 1

Figure 1: The stratigraphic column of the Armstead Area. Data from the north portion of the thesis area.

COLUMNAR SECTION ~ ARMSTEAD AREA

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

SECTION



Pre-Cambrian system

The oldest exposed rocks are in the core of the Armstead anticline. They consist of granite and hornblende gneisses which compare in gross appearance with the Pony or Cherry Creek Series described by Tansley, Schafer, and Hart (1933). The Pony and Cherry Creek Series are Pre-Beltian in age.

Cambrian system

General Characteristics.--The Cambrian formations found in the area are, from bottom to top, the Flathead quartzite, the Wolsey shale, and the Meagher dolomite. All are middle Cambrian in age. The Park shales, the Pilgrim limestone, and the Dry Creek shales which occur in adjacent regions are missing. Two hundred and seventy feet of Cambrian strata are visible in the area. Fifteen to sixteen hundred feet are measured in northwest Montana approximately 200 miles away.

Early workers who studied the Cambrian in adjacent regions in Montana include A. C. Peale and

W. H. Weed. Peale (1893, pp. 20, 21) mapped the Cambrian in the Three Forks quadrangle as the Flathead formation and the Gallatin formation. Weed (1899) mapped the entire Cambrian as the Barker formation in the Fort Benton quadrangle. The following table shows a comparison of the members recognized by Weed and Peale.

Table 1

Comparison of Formations

Peale (1893)	Weed (1899
Gallatin formation	Barker formation
Pebbly limestone	Yogo limestone
Dry Creek shale	Dry Creek shale
Mottled limestone	Pilgrim limestone
Obolella shales	Park shales
Trilobite limestone	Meagher dolomite
Flathead formation	
Flathead shale	Wolsey shale
Flathead quartzite	Flathead quartzite

Weed (1900, p. 285) raised his units to the rank of formations. He considered all the Cambrian rocks to be Middle Cambrian. However, Deiss (1936) and Bell (1941) believe that the Flathead, Wolsey, Meagher and Park formations are Middle Cambrian, and that the Pilgrim, Dry Creek, and Yogo are Upper Cambrian.

Flathead formation.--The Flathead rests unconformably on Pre-Cambrian metamorphic rocks, and where exposed stands vertically or overturned, and appears wall-like in places. The quartzite has alternate bands of purplish red and light buff which range in thickness from 1 to 10 mm. Indistinct layers of coarse and medium sand particles are bound together by a quartz cement. Some cross bedding is present. The particle sizes range from o.5 to 5mm. The rock varies from a friable sandstone to a tenacious quartzite.

The Flathead quartzite was originally named by Peale (1893, pp. 20, 21) for the exposure measuring 125 feet in thickness in the Flathead Pass in the Three Forks quadrangle nearly 200 miles northeast of Armstead. Flathead is found over a wide area in Montana and Wyoming. Originally the Wolsey shale was included in the term Flathead formation, but since Weed's publications (1899) Flathead is restricted to the quartzite.

Wolsey formation.--Because of faulting, exposures of the Wolsey shale are extremely limited in the Armstead area. The shale is exposed on the eastern side of the Armstead anticline in scattered sites; however, it is nearly completely faulted out of view on the western side.

The shale is a fine-grained, bright green to gray green, micaceous rock which is bent and crenulated in many places. It contains numerous calcarious nodules, and is more fissile when wet than when dry.

The Wolsey was named by Weed (1899, 1900, p. 285) for exposures of 125 feet of beds near Wolsey, Montana. Peale had previously included the rock equivalents in the Flathead.

Meagher formation.--The Meagher formation is composed on thinly bedded dolomitic limestones which are light pinkish buff in color and sandy in texture. A scattering of dark spots become more numerous near the top of the formation. Weathering causes a darkening in color and gives the rock a woody appearance with the grain normal to the bedding planes. Beds are irregular, measuring one to 16 inches thick. Very fine bedding laminae measure one to 2 mm. in thickness. One hundred ninety six feet of the Meagher formation are exposed in the Armstead area. This figure probably does not represent the total thickness of the Meagher because of numerous faults in the vicinity of the outcrop.

The Meagher was included in the Gallatin formation by Peale (1893) as the Trilobite limestone. Weed (1896) used Peale's terminology when working on the Three Forks quadrangle. However, when mapping the Fort Benton quadrangle (1899) he assigned all Cambrian rocks to the Barker formation. He renamed the Trilobite limestone the Meagher. On the basis of fossil and stratigraphic evidence, Weed considered all of the rocks Middle Cambrian in age.

Devonian system

<u>Jefferson formation</u>.--The only outcrop of the Jefferson formation in the Armstead area is located on the eastern side of the Armstead anticline where 758 feet were measured. It rests with apparent conformity on the Cambrian Meagher. The rock is a thinly bedded, pinkish gray, dolomitic limestone with calcite stringers. It has a petroliferous odor.

Plates 4 and 5

Plate 4. The Flathead Quartzite. Photo shows the wall-like nature of the formation. Evidence for small cross faults appear in the background where the beds are offset.

Plate 5. Part of the Paleozoic section showing the Jefferson, Three Forks, and Madison formations.

Dj
Dtf
Cm

The weathered rock is dark buff to brown and has a badly decayed appearance. Shale or clay partings separate the massive beds. A two foot shale zone occurs near the middle of the formation.

The Jefferson formation was first described by Peale (1893, pp. 27-29), as Middle Devonian. Recent work by Sloss and Laird (1947, pp. 1404-31) suggests that both Jefferson and Three Forks are Upper Devonian. They place the Jefferson in the Senecan series, and the Three Forks in the Chautauquan series.

Three Forks formation.--In the Armstead region the zone of the Three Forks formation is completely covered with a heavy yellowish soil, and no exposures were found. However, the 200 foot zone is well marked by the prominent limestone formations above and below.

Peale (1893, pp. 29-32) defined the Three Forks for the exposure at the three forks of the Missouri River. The formation is widely recognized throughout Montana, Wyoming, southeastern Idaho and western Utah. As previously noted, Sloss and Laird (1947, p. 1404) place the Three Forks in the Chautauquan series. There is no apparent unconformity between the Three Forks and the overlying Madison group.

Mississippian system

Madison formation.--The Mississippian system is represented by the Madison limestones. In the Armstead area the limestones overlie the Three Forks shale and are considered Kinderhook in age. Peale (1893, p. 20) named the Madison for exposures in the Madison Range in the Three Forks region. Two units are recognized in the Armstead area: namely, the Lodgepole and the Mission Canyon. A total thickness of 2250 feet is recorded.

Lodgepole Limestone is a dense, finely crystalline, laminated limestone which is yellow-gray in color. Weathering darkens the color and produces fine pitting on the surface. The 550 feet of Lodgepole are stratified in four to eight inch beds that are separated by ½ to 1 inch clay partings. As the base of the Madison group, the Lodgepole is widespread in Montana and Wyoming. Collier and Cathart (1922, p. 122) named the limestone for exposures in Lodgepole Canyon south of the Little Rocky Mountains.

<u>Mission Canyon limestone</u> is a massive, resistant formation with two members. The lower member is dark gray to blue gray in color, and coarse to finely crystalline in texture. Chert nodules are present. Weathering produces a rough, pitted, and fretted surface that is light gray in color. A few caves and hollow spots are present.

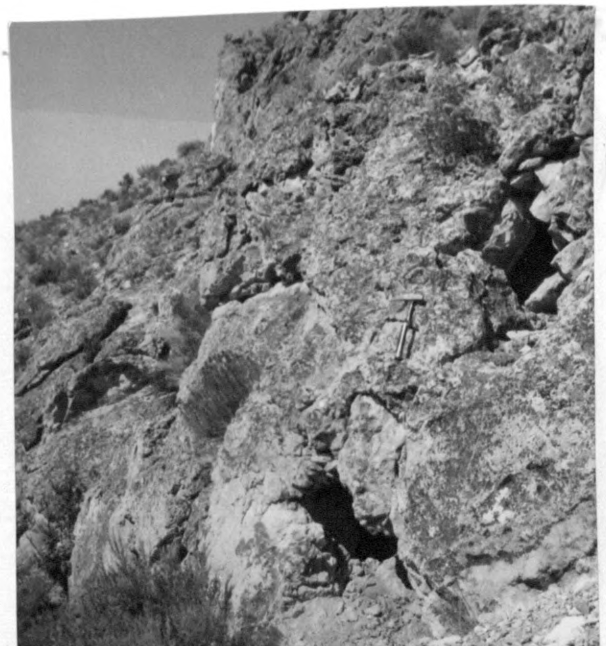
The upper or "wavy" unit is 450 feet thick in the Armstead area. The "waves" are small, tight, folds that seem to pervade the unit in all exposures. Observe the photograph on Plate 6. The beds are 8 to 12 inches thick, and are composed of gray, medium to coarsely crystalline limestones with calcite stringers. Weathering produces irregular caves along the bedding planes, and a step-like relief. The origin of the "wavy" folding is unknown, and the member has not previously been recorded in the literature to the writer's knowledge.

Collier and Cathart (1922, p. 122) recognized and named the Mission Canyon formation for the section exposed in Mission Canyon in the Little Rocky Mountains, Montana. There are 1250 feet of the lower member of the formation in the Armstead anticline. Mission Canyon is widely recognized in

Plates 6 and 7

Plate 6. A view of the Lodgepole member of the Madison formation. Exposure is on U. S. Highway 91, three miles north of Armstead.

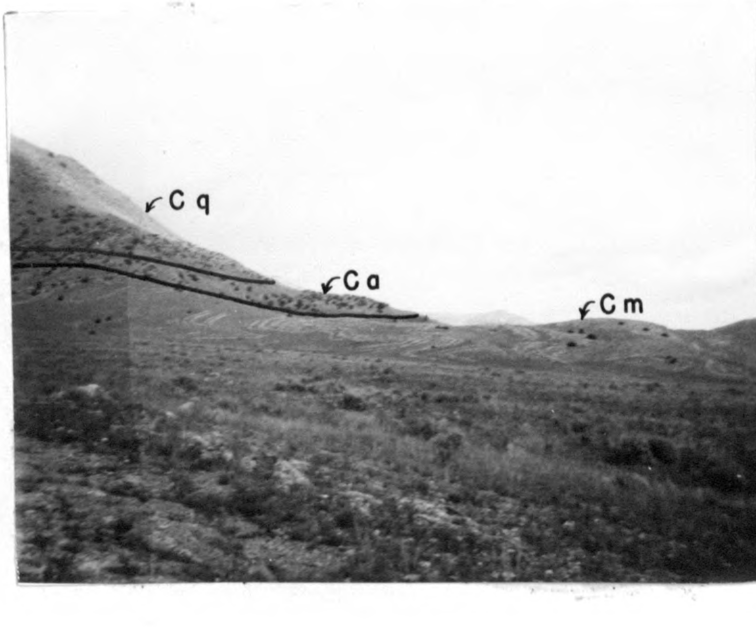
Plate 7. The massive weathered character of the Mission Canyon member of the Madison formation.



Plates 8 and 9

Plate 8. The "wavy" unit of the Mission Canyon limestone as it is seen in the northern portion of thesis area.

Plate 9. View on west limb of Armstead anticline showing Mission Canyon "wavy" unit, Amsden, and Quadrant formations.


Cq
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Montana, Wyoming, Idaho, and Nevada.

Mississippian-Pennsylvanian system

<u>Amsden formation</u>.--Between the Madison and the Quadrant is a 208 foot covered interval which has a 20 foot bed of limestone exposed near the center. The pinkish gray, finely crystalline limestone is stratified in one foot beds. Weathering changes the color to gray-white, and produces a rough fretted surface.

The soil is yellow-brown in color and contains a few fragments of a friable, buff colored, medium grained sandstone. Darton (1904, pp. 394-401) named the formation for the section exposed in the Amsden Branch of the Tongue River west of Dayton, Wyoming. The type locality and nearly all other exposures of the Amsden are Pennsylvanian in age according to E. B. Branson and C. C. Branson (1941, p. 131). C. C. Branson (1936) suggested the name "Sacajawea" for the Mississippian portion of the Amsden. Working in the Wind River Range, Branson and Branson (1941) map the older portion as the Sacajawea formation, and they include the Pennsylvanian part in the Tensleep.

Berry (1943) states that the lower part of the Quadrant in the Three Forks area corresponds to Darton's Amsden. Darton's type section consists of red shales, white limestones, and sandy limestone. It underlies the Quadrant without apparent unconformity.

Pennsylvanian system

Quadrant formation.--The Quadrant consists of 980 feet of quartzite. It crops out in Indian Head Mountain 2½ miles northeast of Armstead at Horse Prairie Creek. The quartzite is a fine grained, tenacious, highly jointed, dense rock. It is red-brown to cream-buff. Large amounts of very blocky talus accumulate on the dip slopes.

Peale (1893) described the type section of the Quadrant for exposures in the Three Forks region. At that time the Amsden was included. Although Peale used Quadrant as a formational name in the Three Forks region, Wilmarth (1938) states that his sections were named after consultation with Arnold Hague with whom Weed was also associated. Weed (1896) described the Quadrant formation in Quadrant Mountain in the Gallatin Range of Yellowstone Park.

Permian system

Phosphoria formation.--The Permian system is represented in the Armstead area by an arenaceous series of rocks. Three lithologic units are present: 1. sandy phosphatic limestone, 2. sandstone, and 3. chert. The basal 125 feet is composed of light gray to white, speckled, sandy limestone that contains phosphate. Exposures are seen in the synclinal valley on the east side of Indian Head Mountain.

A prominent section of approximately 300 feet of massive, friable, buff colored sandstone lies above the limestone. Weathering produces a pitted and sculptured surface. The outcrop is located south of Indian Head Mountain.

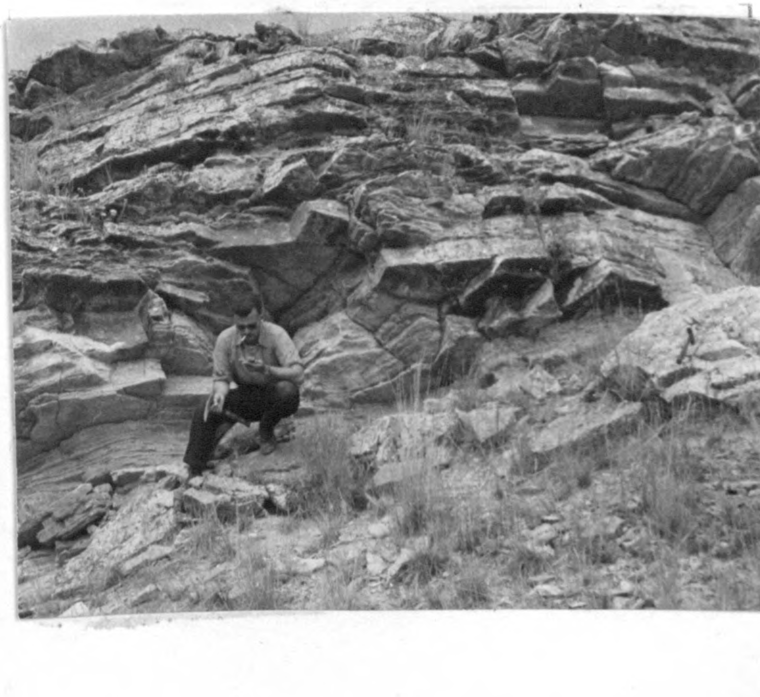
A massive, blue chert measuring as much as 2 feet occurs over the sandstone. This chert may be part of the Rex member recognized in great thickness in other localities. (Gale and Richards, 1909).

Richards and Mansfield (1912, pp. 683-689)

Plates 10 and 11

Plate 10. Valley underlain by the Phosphoria formation. Trees are growing on the Quadrant formation.

Plate 11. The Dinwoody formation in Garfield Canyon.



named the Phosphoria for exposures in Phosphoria Gulch in Meade Park, Idaho. The formation is widespread in southeast Montana, western Wyoming, Idaho, and Utah.

Triassic system

Dinwoody formation.--Seventy five feet of basal siltstones of the Dinwoody formation overlie the Phosphoria. The thin layers of siltstone are dark brown to yellow-brown in color. The best exposure is in a narrow gulch on the western side of Indian Head Mountain.

There are approximately 700 feet of cream colored, medium to coarsely crystalline limestones above the siltstone. Weathering produces a very decayed appearance and changes the color to dark brown. There is no further break in the lithology until the Kootenay conglomerate contact is reached.

Fossils that were collected by Gillespie and Elmer in the lower part of the formation have been identified by Dr. L. B. Kellum as Dinwoody fauna. Ten of those sufficiently preserved are included in the following list.

Ophiceras (*Leptophiceras*) *dubium* Spath?
Ophiceras (*Leptophiceras*) cf. *subplatyspira* Spath
Ophiceras subdemissum?
Pseudomonotis (*Eumorphotis*)? sp.
Eumorphotis multiformis Bittner?
Monotis? sp.
Anodontophora (*Myacites*) *canalensis* Catullo
Myalina? sp.
Lima? sp. cf. *Lima striata* Schlotheim
Lingula borealis Bittner

The Dinwoody formation is found in western Wyoming, southwestern Montana, and adjacent regions. It was defined by Blackwelder (1918, p. 425) for exposures in Dinwoody Canyon, Wind River Range. A total of 800 feet of the formation is present in the Armstead area.

Cretaceous system

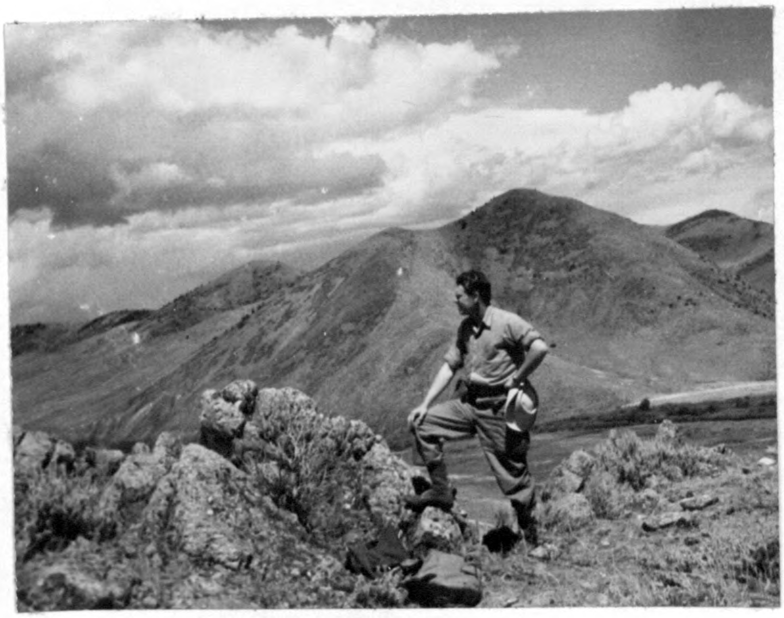
Kootenai conglomerate.--The Kootenai is represented by a resistant conglomerate, which caps small ridges in the area. Most of the usual thick section found in adjacent areas has been eroded away or truncated by thrust faulting. Only about 10 feet of the basal conglomerate is present in the area.

The rock consists of smooth chert and quartzite cobbles ranging in size from ½ inch to 2½ inches in diameter and cemented in a cherty matrix. The cobbles are apparently derived from a number of formations of pre-Cambrian to Mississippian age.

Plates 12 and 13

Plate 12. General view of northeast portion of the area. In the foreground are the strata of the Dinwoody. Background shows quadrant mounts to the left, and the anticlinal valley exposingpre-Cambrian rocks near the center of the photo.

Plate 13. Foreground Kootenai conglomerate. Background mountains of Quadrant



Gillespie and Elmer record the following pebble count from the exposure 2½ miles south of Indian Head Mountain.

Quartzite	Gray-green	30%
"	Brown	25%
"	White	13%
"	Dark gray	6%
Chert	Black	20%
"	Brown	17%
"	Gray	9%

(Figures to the nearest 1%)

The Kootenai was described by J. W. Dawson (1885, pp. 531-532) for a thick series of shales, sandstones, and conglomerate containing coal beds that occur in Bow valley in Alberta, Canada. The name was suggested by Sir Wm. Dawson for the Kootenai Indians who formerly inhabited the region. Lee (1927, p. 41) correlated the Kootenai with the middle portion of the Cloverly formation in Wyoming.

Tertiary system

Red Rock conglomerate.--Red Rock is the tentative name applied to a thick series of subangular conglomerates associated with the Laramide orogeny.

in the Armstead area the conglomerate is found lying unconformably on the Madison and the Quadrant. It is associated with the Beaverhead overthrust. Wallace (1947, p. 32) states that the Tendoy thrust sheet rides over the Red Rock. The age of the Red Rock is tentatively placed in the Paleocene. No fossils have been found. Walter Kupsch (personal communication) states that there are three units of Red Rock. From bottom to top they are:

1. Conglomerate with mostly Madison limestone. pebbles
2. Concretionary limestone.
3. Conglomerate with mostly quartzite pebbles.

In the west part of the area, north of Baker Canyon, the conglomerate projecting out of the Tertiary Basin Beds show the following pebble count.

Quartzite	Purple	22%
Quartzite	Gray	14%
Quartzite	Brown	6%
Limestone	Black	26%
Limestone	Gray	16%
Chert	Black	12%
Chert	Red	1%
Siltstone	Buff	1%
Sandstone	Gray	2%

(Figures to the nearest 1%)

Dr. Eardley estimates the thickness to be approximately 2000 feet. The angular to sub-angular pebbles and small cobbles are cemented by calcite. The Red

Rock conglomerate and the Basin Beds are separated by a major unconformity.

Basin Beds.--The Tertiary Basin Beds were formerly considered under the all inclusive term "Bozeman Lake Beds". Iddings and Weed described them for exposures in the Gallatin Basin near Bozeman, Montana. Haynes (1916, pp. 276-278) showed that much of the bedding is fluviatile and sub-aerial in deposition, making the term "Lake Beds" in a large part inappropriate.

In Medicine Lodge Valley and Horse Prairie Basin in the Armstead area the lithology of the Basin Beds consists of poorly cemented arkosic sandstone, pebble conglomerate, clays, and bentonitic shale. A number of plant fossils and fish scales were found which are not as yet identified. No estimate of the thickness of the deposits was made.

Iddings and Weed (1894) placed the age of the formation as Miocene and Pliocene in Gallatin Valley. In the Armstead area, beds of similar lithology have been assigned to the Sage Creek formation of late Eocene time, and the Cook Ranch formation of Middle Oligocene time (Douglas, 1903 and Wood, 1933).

In this report no differentiation was made, and the deposits are mapped as one unit.

Three Tertiary formations found in the Ruby Basin are listed in the work of Dorr and Wheeler (1948, pp. 8-18, and Plate 3). From bottom to top they include the Red Rock conglomerate; the Passamari formation of lower or middle Miocene age; and the Madison Valley formation of Miocene - Pliocene time.

Recent

Quaternary alluvium.--Recent deposits are present in alluvial fans and valley flood plains. Certain pediments which are carved in the bed rocks may be confused with alluvial fans in the area. The possibility of artesian water has not been fully explored.

STRUCTURE

Regional setting

The Tendoy Mountains lie within the Laramide structures of the northern Rocky Mountain Province. They are flanked by the Beaverhead River Valley and the Red Rock Mountains on the east and the Beaverhead Mountain Range on the west. The surrounding mountains, including the Tendoy Range, trend generally north-south. The continental divide follows the Beaverhead Range which extends west and northwesterly along the Montana-Idaho state border.

The Laramide structures in southwestern Montana trend generally to the north and northeast. Overthrusting by three great thrust sheets is also to the northeast. The folded structures and the thrusts, when traced southward into Idaho, are buried under the Snake River lava flows. They reappear south of the Snake River and extend into Wyoming south of Yellowstone Park.

Kirkham (1931, pp. 456-482) has adequately described the great Snake River downwarp which extends from the Yellowstone Plateau to Oregon. It lies directly to the south of the area mapped by Drexler, Kildal and McUsic (1949) ten miles south of Lima, Montana.

Laramide structures

Folding.--Early and middle Laramide orogeny folded the general area into north and northeast trending structures. In the specific area mapped by the authors, the Kootenai conglomerate is the youngest formation involved in this early folding. In the northern part of the area the Kootenai dips approximately 20 degrees to the west and to the northeast in the south-central portion of the area.

To the north and south of the area the Red Rock conglomerate, which was deposited following the early Laramide orogeny, has been folded by a middle Laramide disturbance. This orogeny was apparently a continuation of the earlier disturbance since it further elevated and folded the north-east trending structures.

Armstead anticline: A prominent element of the folding is found in the region north of Horse Prairie Creek. This is a south plunging, asymetrical anti-cline which the authors propose to call the Armstead anticline. Hayden (1871, p. 145) first noted the structure while on a traverse up the Beaverhead River valley but did not name it.

The eastern flank forms a prominent ridge which is upheld by Paleozoic rocks. The oldest formation is the Flathead quartzite, and the youngest is the Madison limestone which upholds the crest and dips steeply eastward. The Lodgepole member of the Madison formation is exposed on the eastern flank of the gentle syncline which parallels the ridge on the east. The beds dip to the west 15 degrees. The photograph in Plate 6 was taken in the direction of the dip. See also section A-A', Plate 2.

The beds of the western limb of the anticline dip to the west approximately 35 degrees. A small syncline and anticline are developed west of the larger structure. The Quadrant quartzite,a resistant ridge formerly in the west limb of the anticline, reappears in a small anticline immediately adjacent on the west, and again in a small ridge where it is thrust up on the dip slope of the main Quadrant strata. The formation thus forms three prominent, irregular ridges which stand 100 to 200 feet above the surrounding terrain. See Plate 14. The youngest formation exposed in this western portion is the Kootenai conglomerate.

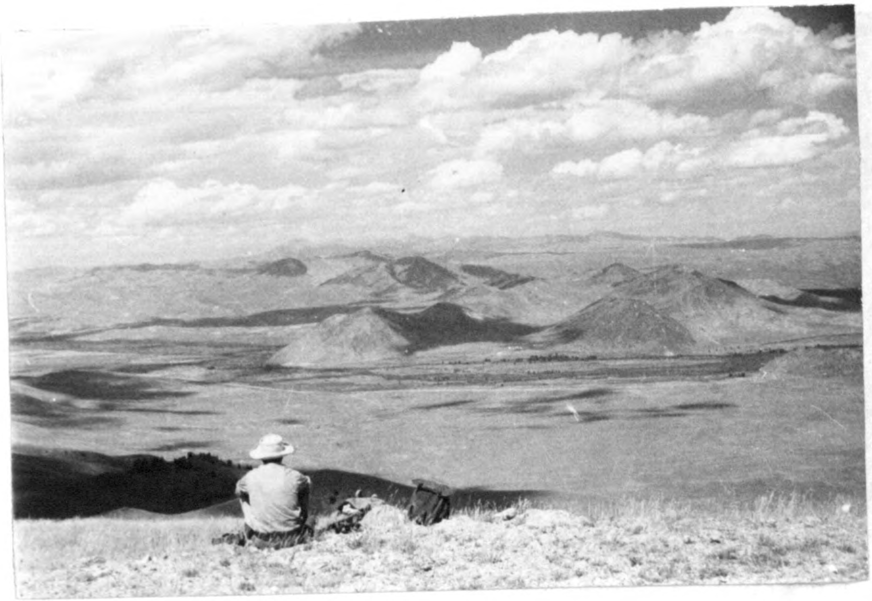
Minor structures: South of Horse Prairie Creek the Armstead anticline plunges southwest. At its southern extremity the beds are deformed into a number of small folds which apparently converge and die out in the larger plunging structure. In section 25, T. 10 S., R. 11 W. (see geologic map) a small dome, exposing the Quadrant, Amsden, and Madison formations is capped by a veneer of Tertiary volcanics. See Plate 2, section D-D'. This structure is slightly elongate east-west and conforms with the convergence of the smaller structures in the vicinity with the Armstead anticline.

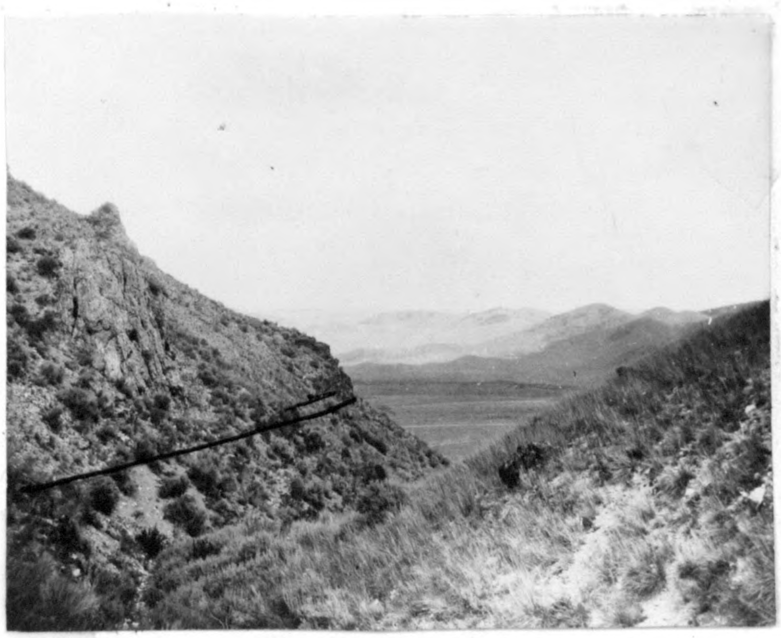
High angle faulting.--High angle faulting occurred during or following the middle Laramide folding. A vertical fault with its upthrown side to the east has exposed pre-Cambrian igneous rocks in the core of Armstead anticline. This fault trends north along the western portion of the anticline at the contact between the Madison limestone and the pre-Cambrian. It can be traced southward as far as Horse Prairie Creek where it is lost beneath

Plates 14 and 15

Plate 14. View looking north across Horse Prairie Creek valley. The prominent ridges are Quadrant quartzite. They are on the west limb of the Armstead anticline.

Plate 15. View looking north, one mile northwest of Garfield Canyon. Madison limestone of the Medicine Lodge thrust sheet is thrust upon Koetenai conglomerate.





the valley alluvium. See geologic map, Plate 1 Dr. Eardley (personal communication) states that the high angle fault here is anomalous with the high angle faulting that appears in the areas to the south in the Tendoy Mountains where the upthrown block is on the west side. It is impossible to date the fault by relations to the Red Rock conglomerate, Basin Beds and the Middle Laramide thrust faults, because it was not found in contact with any of these features.

North of Horse Prairie Creek the pre-Cambrian exposure, about a mile wide, extends northward more than five miles along the axis of the anticline. A small patch of this igneous rock is also exposed protruding through the alluvium just south of Horse Prairie Creek.

On the eastern side of the pre-Cambrian core another fault strikes north-south. This fault, having less displacement than the one on the opposite side of the anticline, cuts through the Wolsey shale and Meagher formation. In section 25, T. 9 S., R. 11 W., a normal fault just to the east of the above mentioned one has dropped the intervening block down and repeated the formations.

There are at least nine short cross faults along the east side of the core which strike east-west. These are seen to best advantage in the vertical standing, wall-like Flathead formation in this vicinity, which is offset in places up to 30 feet. This faulting post-dates the larger north-south fault since the latter is terminated in places by small transverse ones. See Plate 1.

Two faults present on the western flank of the Armstead anticline seem to be closely related to the original folding of the structure. The sharp flexure in the southern portion of the easternmost Quadrant ridge undoubtedly was formed at the time of the faulting. The distortion of the formation caused a slight break and displacement in the strata. The larger fault to the west was previously mentioned in connection with the most westerly Quadrant ridge. This fault has thrust Quadrant over Quadrant to form a double ridge which extends for more than three miles north of Horse Prairie Creek. See Plate 2, section A-A'.

Only one large normal fault is evident south of Horse Prairie Creek. (Sections 22 and 27, T. 10 S., R. 11 W.) This fault strikes generally north-south with the upthrown side to the west.

Its length is approximately two miles, although to the north it is lost beneath the alluvium.

Thrust faulting.--During the late Laramide orogeny three great thrust sheets cut across the earlier Laramide folds. The easternmost thrust is the Tendoy. It has been described to the south by Drexler (1949, p. 43) south of Sheep Creek, and by Krusekopf (1948, p. 39) north of Sheep Creek.

The Medicine Lodge thrust lies to the west of the Tendoy, and extends from the Idaho-Montana line near Medicine Lodge Pass northward into the area west of Armstead. The Beaverhead thrust lies to the west of the Medicine Lodge thrust but does not extend into the area mapped by the authors. It probably lies to the west.

Tendoy thrust: The Tendoy thrust is exposed only in the southeast corner of the area. See geologic map, Plate 1. At the eastern edge of the region the thrust is lost beneath the alluvium of the Beaverhead River valley. It reappears again further south in the area north of Sheep Creek Canyon. Westward in the mapped area it disappears under the Medicine Lodge thrust sheet one mile east of Garfield

Canyon. Within the area the Tendoy thrust everywhere consists of Madison limestone which is thrust over Quadrant quartzite. However, to the south the thrust has overridden the Red Rock conglomerate, probably of Paleocene age. (Drexler, 1949, p. 43.)

Medicine Lodge thrust: The Medicine Lodge thrust to the immediate south passes through the area mapped by Seglund and Bowers (1949). It appears in the southeast corner of the area mapped by the authors. See geologic map, Plate 1. It trends northwest and then swings to the southwest as the front passes above the underlying Tendoy thrust trace. West of Garfield Canyon the present front of the thrust swings back again toward the north and continues northward for four miles until it is lost beneath the alluvium of Horse Prairie Creek.

The thrust sheet for the most part is composed of Madison limestone which rests upon the Madison of the Tendoy thrust sheet in the southern part of the area. To the north the Madison rests upon the Quadrant quartzite and the Phosphoria and Dinwoody formations in Garfield Canyon, and upon the Kootenai conglomerate to the northwest of the canyon. (See Plate 15.)

The front of the thrust in sections 21 and 28, T. 10 S., R. 11 W. is broken by an auxiliary fault, and a wedge of Madison and Quadrant lies beneath the main body of the thrust sheet. The wedge rests in turn upon the Cretaceous Kootenai. See geologic map Plate 1, and section C-C', Plate 2.

A klippe composed of Quadrant and Madison is present in section 16, T. 10 S., R. 11 W. It rests on the Kootenai formation. The narrow neck of Kootenai shown on the geologic map, Plate 1, between the klippe and the main thrust is not clearly exposed, but it represents the best interpretation the writers were able to make. See Plate 2, section B-B'.

Within the main sheet to the south is a syncline, which for the most part, strikes north-south and swings to the east at its southern end. The center of the downfolded structure is occupied by Quadrant quartzite, and Madison limestone is present on either side. Southwest of the syncline Tertiary basin beds rest unconformably upon the thrust sheet.

The Medicine Lodge thrust as well as the other two thrusts override the Paleocene Red Rock conglomerate south of the mapped area. In the region under discussion the Red Rock rests upon the Madison limestone of the Medicine Lodge thrust sheet. The conglomerate forms a rather thin cover in the highest southwestern part of the area. Since the evidence from those areas mapped to the south dates the thrusting as post-Red Rock, it seems evident that the conglomerate in the authors' area was deposited much further to the west upon the exposed Madison. Subsequent thrusting brought the conglomerate to its present high position apparently on the top of the thrust sheet.

Post-Laramide structure

Following the late Laramide thrust faulting in southwestern Montana, a long period of erosion and deposition took place. Alluviation was heavy in the great intermontane valleys. In the Medicine Lodge valley it is believed that both the late Eocene Sage Creek formation and the Cook Ranch of middle Oligocene time are present. These beds on the east side of Medicine Lodge Creek, in sections 1 and 2, T. 11 S., R. 12 W., dip as much as 40 degrees to the east. Since a normal fault in this area is known to exist close to the south in the area mapped by Seglund and Bowers (1949), it is postulated that the same fault extends northward into the authors' area. It has downdropped the basin beds on the western side while uplifting the Paleozoic formations to the east. Extensive erosion followed the faulting of the basin beds until at present time an alluvium covered pediment, with no displacement apparent, is found where the basin beds have been stripped away.

In the immediate Armstead area there is no evidence of Recent faulting or movement. Lipp (1948, p. 43) has noted evidence of Recent faulting along the eastern front of the Tendoy Mountains 20 miles to the south, near Dell, Montana. Triangular facets are present and a dark gray band immediately above their base is thought to be evidence of renewed movement in Recent times. It is possible that this fault extends north along the front of the Tendoy Mountains as far as Armstead where it either dies out or is buried beneath the valley alluvium of the Beaverhead River.

PHYSIOGRAPHY

General Characteristics

The terrain of the thesis area which includes the northern portion of the Tendoy Mountains is in the Northern Rocky Mountain Province as outlined by Fenneman (1931, p. 213). It is maturely dissected with residual mountains of anticlinal, monoclinal, and thrust nature giving relief to the area. The resistant rock composing the mountains is principally limestone of the Madison formation and quartzite of the Quadrant formation. The mountains are bounded by broad valleys. The valley on the eastern side of the area is formed by drainage of the Beaverhead River and Red Rock Creek, and the basin on the west is formed by Medicine Lodge Creek and Horse Prairie Creek. The slopes on the east mountain flanks grade into alluvial fans, whereas, those on the west merge into a rock pediment.

Structural control of the physiography

The topographic features of the area reflect thrust faulting, folding, and high angle faulting. Great sheets of Madison limestone have been repeated in the thrusting, and uphold elevations of 2,000 feet or more above the valley floor. The east slopes of the thrust sheets are very steep, whereas, those on the west are gentle. There are minor secondary structures in the thrust sheet that express themselves topographically. An example is seen near the head of Baker Canyon where the Quadrant quartzite, present along the axis of a syncline, stands conspicuously above the massive limestones that are well developed in the thrust itself. At the head of Garfield Canyon a block fault has brought pre-Cambrian rock in contact with the Madison limestone with relatively little difference in topographic relief. The low slopes on the east side of the Tendoy Mountains are alluvial fans that have resulted from normal faulting along the mountain front. On the west side the slopes are upheld by a rock pediment. The pediment is developed on Paleozoic and Tertiary rocks and is dissected to depths of several feet. Somewhat deeper gorges are developed on the actively running stream drainages.

Physiographically the folded portion of the area west of Horse Prairie Creek included from east to west; an anticlinal mountain of Quadrant quartzite; a synclinal valley underlain by calcareous sandstone of the Phosphoria formation; a monoclinal ridge caped by the Quadrant; a block faulted anticlinal valley; a monoclinal ridge upheld by Madison; and a synclinal valley underlain by the Madison formation (see Plate 2, section A-A'). Topographically, the mountains of the folded portion are much lower than those of the thrust sheet in the southern part of the area, but they are well expressed by strong ridges of quartzite and somewhat subdued ridges of limestone. A large anticlinal valley which is underlain by block faulted pre-Cambrian rock is evident about two miles northwest of Armstead. The authors have proposed the name "Armstead Anticline" for the structure. Immediately to the east of the anticline a synclinal valley is developed which trends beneath the Beaverhead River. Hayden (1871, p. 146) describes both of these features. The surface of the western limb of the anticline is apparently a pediment surface. No evidence of alluviation is present. The slopes are also deeply dissected by gorges 30 to 40 feet in depth.

This feature constitutes a distinct difference from the alluvial fan development found at the eastern foot of the Tendoys immediately to the south.

Stream drainage

The master stream of the area is Horse Prairie Creek. It is probably a superimposed consequent stream. Its main tributary streams show evidence of a variety of types including subsequent, resequent, and insequent. Of special interest is the annular drainage around an isolated prominence of Dinwoody and Kootenai rocks 4½ miles due west of Armstead. Some drainageways on the pre-Cambrian rocks in the Armstead anticline make right angle turns which may indicate faults or joints.

The Medicine Lodge and Horse Prairie creeks at present are flowing in extremely wide valley bottoms. The wide flood plains with numerous abandoned channels attest that the streams once carried much more water than they do at present. Probably the wide bottoms were developed in glacial time when a much wetter climate enveloped the region. A small sluggish stream runs parallel to Red Rock

Plates 16 and 17

Plate 16. The great intermontane valley of the Beaverhead River. View from east flank of the Armstead anticline looking south past Armstead towards Lima.

Plate 17. Photograph illustrating the dissected pediment surface in Medicine Lodge Valley.

Creek between Highway 91 and the front of the Tendoy Mountains; it appears to be an abandoned channel of the Red Rock Creek.

Erosion surfaces

The summits of the Tendoy Mountains are flat or gently undulating slopes. These surfaces are probably correlated with the other high surfaces that are recognized in the region. The elevation is 8000 feet or higher.

The next lower readily apparent surface is the rock pediment which rises with an increasing slope toward the mountains to a few hundred feet above the floor of the valley. It is dissected in places as much as 75 feet or more. Parts are either truncated by the Medicine Lodge Creek valley proper or disappear beneath Recent alluvium at the very foot of the pediment.

Plates 18 and 19

Plate 18. View along crest of northern Tendoy Mountains looking south.

Plate 19. Photograph illustrating local flatness of the erosion surface on the crest of northern Tendoy Mountains. In the background the outline of the Red Rock Mountains to the east, truncated by the same erosion surface, is visible.

PETROLOGY AND PETROGRAPHY

Sedimentary Rocks

General statement.--The sedimentary rocks exposed in the Armstead area are of remarkably uniform lithology within the individual formations. In general, the horizontal textural and color variations exceed the vertical. The lithologic descriptions given in this section are primarily those found in front of the overthrust sheet. It was found necessary to restrict the stratigraphic and lithologic descriptions in this manner, due to the limited number of formations found in the overthrust sheet in the Armstead area. The few contrasts observed between the lithologies of the overthrust and underthrust rocks will be discussed under the formational headings.

Organization.--Of the schemes of organization possible for a discussion of the petrologic and petrographic character of a sedimentary series, the stratigraphic arrangement was chosen as the most efficient and the most practical. Thus each rock unit will be described in the order in which it occurs in the stratigraphic column.

<u>The Flathead formation</u>.--Highly resistant to erosion, the Flathead formation forms massive ridges. In composition, it is an orthoquartzite. The color ranges from cream white to a dark mulberry red. Weathering apparently has little or no effect upon its color. There is considerable variation along the strike and in the form of color banding and zoning. Cross-bedding is developed locally and is usually defined by color banding or by alternate layers of fine and coarse material. The grain size ranges from medium fine sand to a poorly sorted conglomerate containing pebbles as large as twenty millimeters. The base of the formation tends to be more conglomeratic than the upper portions. The pebbles and grains are generally crystalline quartz but some pebbles of black chert and even some feldspathic material have been noted. They are subangular to rounded in shape. Plate 20 is a photomicrograph of the finer phase of this formation. It illustrates the development of secondary or authogenic quartz in optical continuity with the original

rounded grains. The outlines of the pebbles and grains are made plainly visible, within the oriented authogenic material, by zones of inclusions which mark the surface of the original grain. Widely spaced joints are extensively developed. None of the fracturing and brecciation observed in other quartzites in this area is present. Most of the outcrops of this formation are the dense, hard quartzite described above, but some outcrops of more porous semi-friable material were observed. The cement is exclusively silicious, with sufficient iron oxide to result in dark stains. There are no fossils present as far as could be determined. No concretions of any sort were noted.

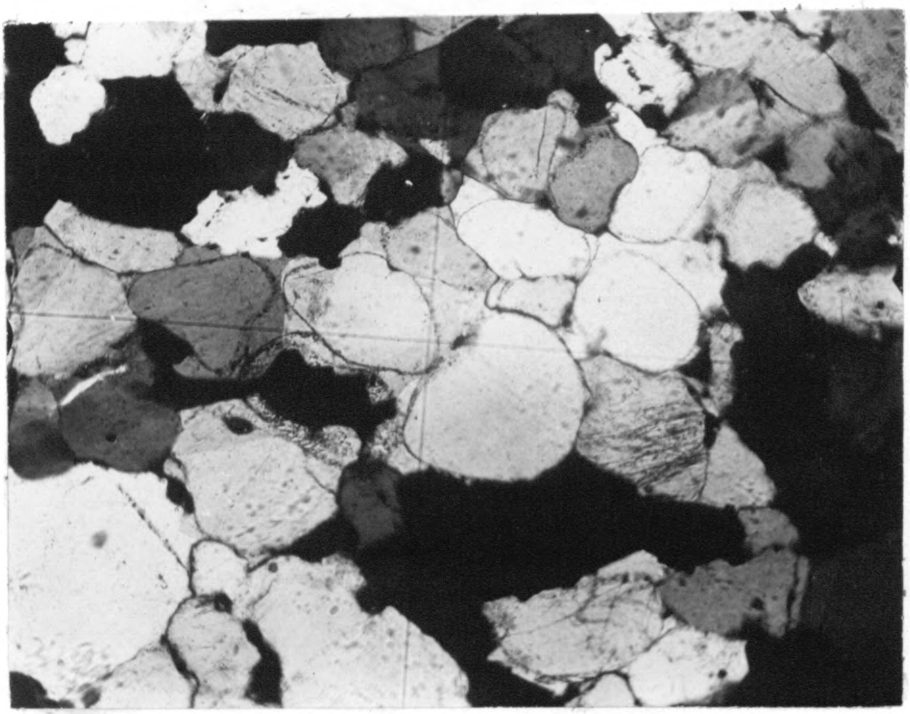
The Wolsey shale.--The Wolsey shale is especially susceptible to weathering. It weathers to a green clay which mantles the shale in outcrop and makes it difficult to secure a fresh specimen. Only a small part of the section was exposed in the Armstead area, where a stream channel cut sharply across the formation. The samples available for this study are therefore limited. The rock is dark green in color and weathers to light greens and browns. It is very finely bedded. The beds range in thickness from one to twenty millimeters and average about five or six millimeters. The beds are extensively crenulated, and are illustrated in Plate 21. Considerable mica is present in large enough grains to be easily perceived by the unaided eye. These mica grains are oriented parallel to the bedding planes and impart a phyllitic appearance to the shale. The folds and crenulations seem to have developed around long, thin, branching concretions of sandy material. This is not merely a feature of differential compaction, but is the result of differential movement as shown by the pattern of shear folds diagonal and at right angles to the tiny sand lenses. These folds are apparently the result of the superior plasticity of the shale and the superior resistance to deformation of the sand lenses. No fossils were observed. There are some calcareous nodules present.

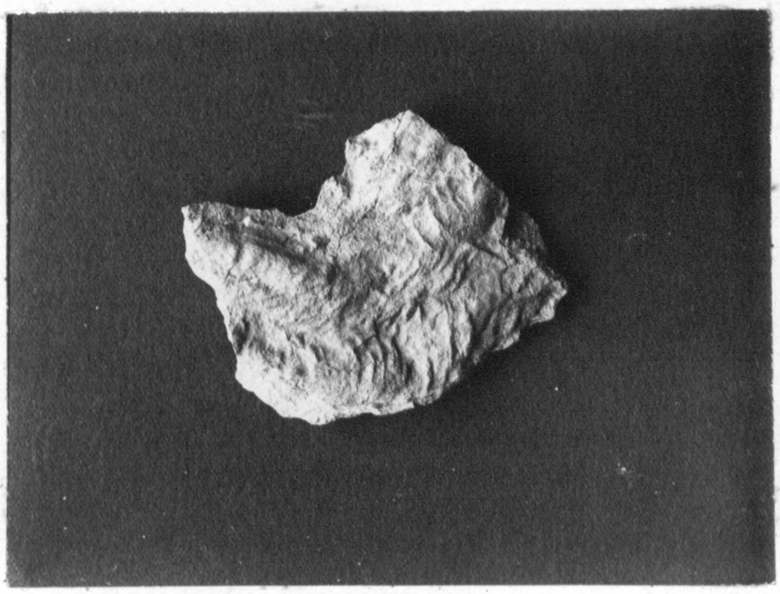
The Meagher formation.--The Meagher formation forms prominent and continuous ridges near the core of the Armstead anticline. The rock is a crystalline dolomite, buff in color when fresh and weathering to a light tan or yellow-buff. The color is constant

Plates 20 and 21

Plate 20. Photomicrograph of Flathead Quartzite, showing the development of authogenic quartz around the original grains. 100 Crossed nicols.

Plate 21. Photograph of bedding plane of Wolsey shale, illustrating small folds around sandy lenses. Approximately 3/4X.



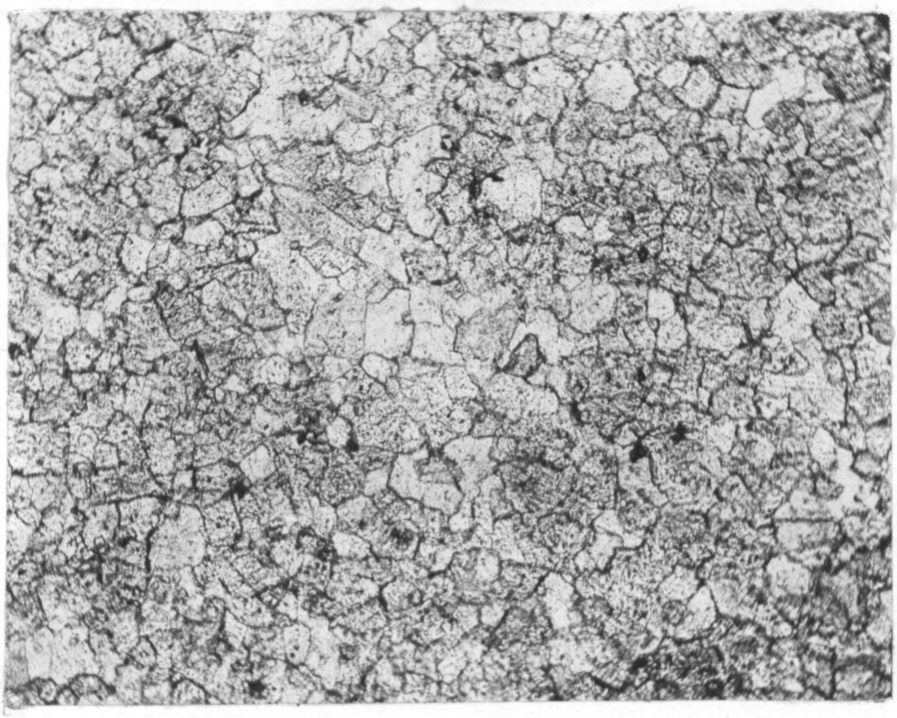


except for small iron stained patches, which center around numerous small solution cavities. The Meagher formation is well bedded, and the beds range from six to eighteen inches in thickness. No lithologic differences were observed between beds, although some variation along strike was noticeable. The variation referred to was observed in an outcrop in the far southern end of the Armstead anticline and consisted of silicious impurities in the dolomite. All other outcrops are of fine-grained crystalline dolomite. A photomicrograph of this material is illustrated in Plate 22. A sample of this dolomite contained 1.5% insoluble material; no heavy minerals were detected. Some fossils were noted in this formation but were relatively rare. No concretions were reported.

The Jefferson formation.--Like the Meagher formation the Jefferson forms prominent and continuous ridges. The rock is a dolomitic limestone. Brownish-grey on a fresh surface, it weathers to a light chocolate brown. It is petroliferous locally and exhibits a strong petroliferous odor. The beds in this formation are about six to eighteen inches

Plate 22

Plate 22. Photomicrograph of the Meagher formation. 1,00X Nicols not crossed.



in thickness and are massive and of constant lithology. This limestone is relatively impure as indicated by an insolu#ble residue content of 15.9%. No heavy minerals were detected in the residue. Dense and finely crystalline, this limestone does not have much apparent porosity or permeability. Some jointing is present. No fossils or concretions were noted.

The Three Forks formation.--The Three Forks formation cannot be described from this area. No outcrops are available for examination, as this formation of yellow shales and sandstones is a valley former and invariably covered by a thick soil zone.

The Madison formation.--The Madison formation is made up of two members, the lower Lodgepole and the upper Mission Canyon.

The Lodgepole member of the Madison limestone is a fairly resistant strata, forming good outcrops locally. It is a limestone. On a fresh surface, it is dark blue-grey in color and weathers to a dusty yellow-grey. No color variations were observed. It is very well bedded. The beds are two to four inches thick and separated from one another by thin shale partings. The limestone beds are finely crystalline limestone. They have a somewhat silty or sandy texture, indicating an appreciable content of impurities in those size grades. Plate 6 illustrates an outcrop of this material and shows the limestone beds standing out on the weathered surface. The folding noticeable in this photograph is typical of all Lodgepole outcrops in the Armstead area. The incompetence of this member is probably due to the lubricating effect of the shale partings. Some concretions were observed in the Lodgepole, mainly small chert nodules.

The Mission Canyon member is also a limestone and is a conspicuous cliff former. Cliffs of this material tend to be very massive and rounded. Solution caves and sink holes are often found associated with the larger outcrops. Little or no talus is developed, even around the most massive cliffs. It is blue-grey on a fresh surface and weathers to a dusty light grey. The Mission Canyon is remarkable in its lack of bedding. No bedding planes can be observed throughout the section. The rock is dense, finely crystalline limestone. It is impure to the extent indicated by the following insoluble residue determinations:

Sample 1--- 9.1% insoluble residue

Sample 2---11.2% insoluble residue

This formation is very fossiliferous, but collecting is poor because the fossils weather back at precisely the same rate as the matrix.

The lithology of the Mission Canyon is slightly different in the overthrust sheet. One large outcrop of overthrust Mission Canyon was observed in detail. In this outcrop, layers of brown chert concretions are distributed throughout the section. The individual concretions are about two inches in diameter and roughly circular in cross-section. They are present in layers approximately one foot thick and spaced three to five feet apart. Other outcrops of overthrust Mission Canyon had some brown chert but were not layered or otherwise grouped into a pattern. It is presumably a local feature and not necessarily typical of the Mission Canyon in the overthrust sheet.

The Amsden formation.--The Amsden formation has a very low resistance to weathering and is usually found covered by a fairly thick soil or talus zone. It normally occupies a valley between ridges of the resistant Madison and Quadrant formations. This formation is made up of three lithologic units; limestone at the base, calcareous sandstone in the middle, and limestone at the top.

The limestone is dark grey-brown on the fresh surface and weathers to a light brown or brownish grey. The weathered surface often shows solution fluting. The rock is medium grained, dense and compact. It is somewhat fossiliferous. No concretions were reported.

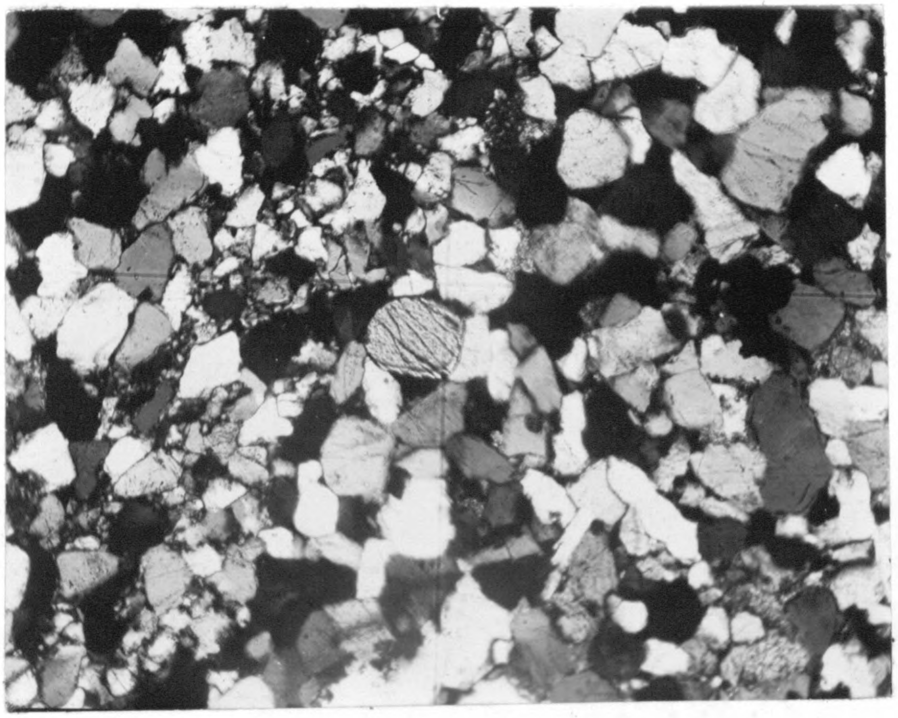
The sandstone member is poorly represented in outcrop due to a low resistance to weathering. It is buff to light brown in color on both fresh and weathered surfaces. It is fine grained, the individual grains average about one tenth of a millimeter. A photomicrograph of this material appears in Plate 23. The grains are angular to sub-angular and are poorly cemented by both silicious and carbonate material. Present are numerous grains of the heavy minerals such as zircon and hornblende. A grain of horneblende is noticeable in the center of Plate 23. The heavy mineral content serves well to differentiate the Amsden sandstone from that of the Quadrant, as the Quadrant sandstone has no comparable content of grains other than quartz and chert. Throughout this formation fossils are rare and concretions absent.

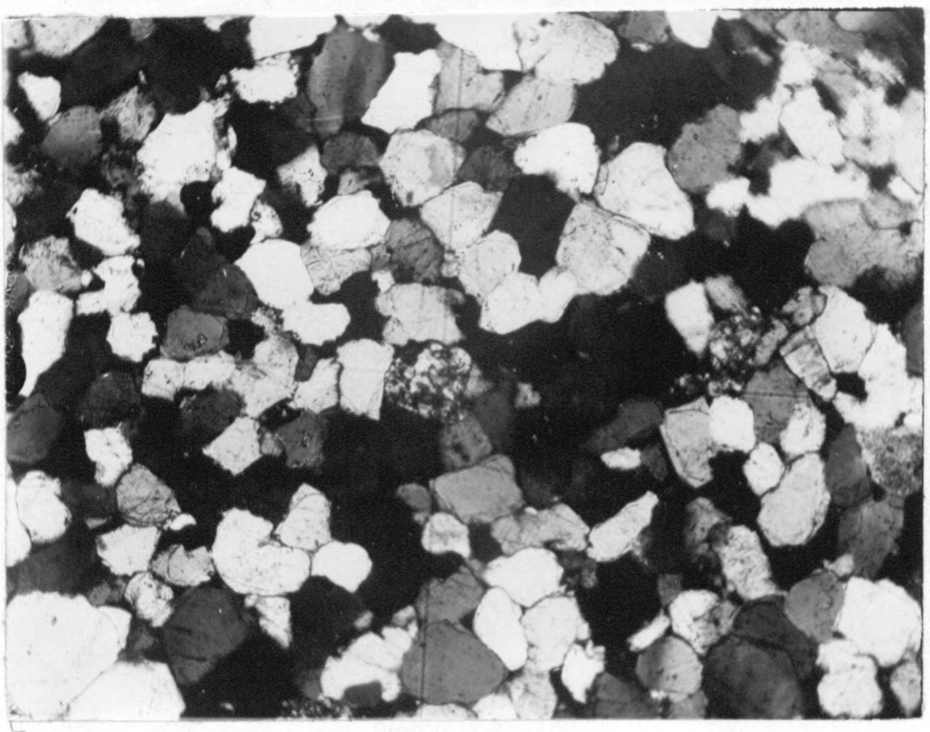
The Quadrant formation.--The Quadrant formation is a very prominent cliff and ridge former. The rock is an extremely massive and resistant orthoquartzite throughout most of the Armstead area. The color ranges from white to brick red on fresh surfaces and is not essentially different on a weathered surface. Bedding was not apparent in the field, but it may have been obscured to some extent by the fracturing and brecciation in the Quadrant. No lithologic differentiation is present of a stratigraphic nature. Some variation was observed along strike in front of the thrust, and between the overthrust and underthrust rocks. Under the thrust some outcrops of semi-friable, slightly iron stained sandstone were found. Most occurrences, however, are dense, hard orthoquartzite. A sample of the orthoquartzite is shown in the photomicro-

Plates 23 and 24

Plate 23. Photomicrograph of Amsden sandstone.
100X Nicols crossed.

Plate 24. Photomicrograph of Quadrant formation.
100X Nicols crossed.





graph illustrated in Plate 24. The authogenic quartz is not so obvious in thin-section as in the Flathead due to the close packing and smaller grain size. The grains range from one to five tenths of a millimeter in diameter. They are angular and thus allow closer packing than the more rounded grains of the Flathead, regardless of size. The composition, therefore, helps to explain the high resistance to weathering of the Quadrant.

The mode of weathering of the Quadrant formation merits some discussion. It is apparently very resistant to chemical weathering and not very resistant to mechanical weathering. In outcrop, it is heavily mantled with talus, which is made up of angular blocks ranging from one or two centimeters to two or three meters in diameter. Physical weathering in the form of frost pry is probably the cause of the talus.

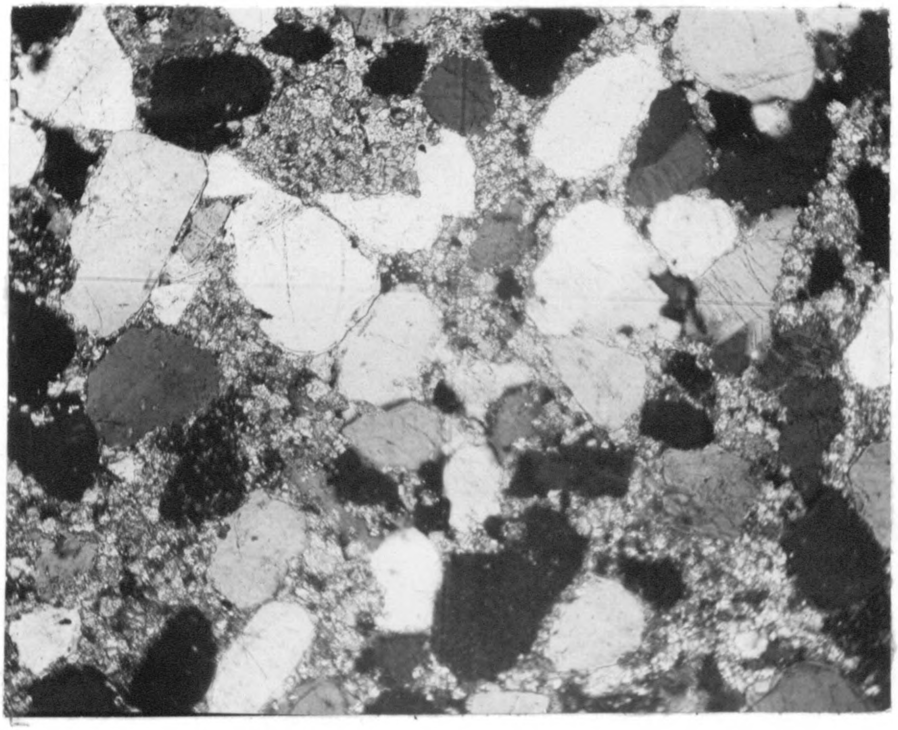
The only variations observed between the under and overthrust rocks of this formation are color patterns. A banding, analogous to Liesegang banding, was observed in the overthrust. It was expressed entirely as a rhythmic color banding, and no textural variation was observed. No fossils or concretions were noted in either the under or overthrust Quadrant formation.

The Phosphoria formation.--The Phosphoria formation forms low slopes but usually exhibits fairly accessible outcrops. It ranges upward from a basal phosphatic and calcareous sandstone to a calcareous sandstone containing chert at the top. The color is distributed stratigraphically, ranging from white with black specks, due to black chert grains, at the base, to buff or light brown in the central and upper portions of the formation. The bedding is irregular and not very well developed in most of the outcrops examined. On viewing outcrops from a distance, however, the bedding stands out better and it becomes obvious that the Phosphoria is an incompetent formation. The poorly developed beds become more distinct and show minor folds somewhat similar to those in the Lodgepole. The lithologic composition of the Phosphoria is rather distinctive. The sand grains are well rounded and are mainly quartz, but sufficient chert and other mineral grains are present to give the rock a salt and pepper aspect. A photomicrograph of this material in thin section is illustrated in Plate 25. The basal portion of the section gives a positive test for phosphorus and is cemented by a dolomitic calcite. The middle and upper portions of the formation are cemented by calcite and near the top have small concretions of the typical Phosphoria blue chert. No fossils are reported from the Phosphoria in this area.

The Dinwoody formation.--The Dinwoody formation forms well developed ridges and where it has a high angle of dip, it forms steep cliffs. The basal portion consists of fine brown siltstone, but the greater part of the section is a brown silty limestone. It is a smooth light brown throughout the section and weathers to a dark olive brown. It is very well bedded. The individual beds range from six to eighteen inches in thickness. The limestone weathers to an extremely porous condition, often in a somewhat fibrous form. Plate 27 illustrates an outcrop of Dinwoody intruded by a small volcanic neck of andesite, in Garfield canyon. The limestone is very fossiliferous and typical Dinwoody fossils were collected. No concretions were noted.

Plate 25

Plate 25. Photomicrograph of Phosphoria formation.
100X Crossed nicols.



<u>The Kootenai formation</u>.--The Kootenai formation forms rounded ridges by holding up steep slopes of less resistant formations. Only a relatively thin remnant of the Kootenai is present and, due to its high stratigraphic position, it forms the tops of ridges and hills. The rock is a quartzy pebble conglomerate. It is dark brown in color on both fresh and weathered surfaces. Due to its highly silicious nature, no effects of chemical weathering are apparent other than the fact that the matrix wears back faster than the grains or pebbles. It is poorly bedded and forms rounded outcrops. Plate 13 is a typical exposure of Kootenai on a slump block in Horse Prairie Creek valley. Lithologically, the Kootenai ranges upward from a coarse pebble and cobble conglomerate to a coarse salt and pepper sandstone. The pebbles and grains are very well rounded and polished. They are almost exclusively chert or quartzite. The cementing medium is siliceous and often is mixed in with a finer fraction of chert and sand grains. The formation is unfossiliferous.

<u>The Red Rock conglomerate</u>.--The Red Rock conglomerate forms isolated, rounded and resistant

outcrops. There are three lithologic phases included in this formation; namely, quartzite pebble conglomerate, a concretionary limestone, and a quartzite and limestone pebble conglomerate. Only the quartzite and limestone conglomeratic phase is present in the Armstead area. The rocks have a dark red color both on the fresh and weathered surface. Very little bedding is developed. The formation as a whole is very badly fractured and jointed. The pebbles and cobbles are angular to subangular and are composed of limestone or quartzite. The cement is calcareous. No fossils were noted.

The Basin Beds.--The Basin Beds are very poorly exposed in the Armstead area due primarily to the fact that they occur in the valley slopes under the alluvial veneer. No systematic discussion of their petrologic character is, therefore, possible. Light brown shales of a highly bentonitic nature were encountered a few miles to the west and south of the area. In the pediment surface west of Medicine Lodge Creek, two types of rock were observed: a coarse and very friable arkosic sandstone and a grey shale which was siliceous and highly indurated.

The outcrops examined are small and not continuous for long distances. It is, therefore, probable that they represent only a fraction of the lithologic types to be found in the Basin Beds. Both the bentonitic shale and the grey siliceous shale were fossiliferous. The bentonitic shale contained numerous fossil fish scales and bones, and the grey shale contained very well preserved plant remains.

Igneous rocks

General statement.--Only very limited exposures of igneous rocks were found in the Armstead area. All are the result of Tertiary vulcanism with the possible exception of some quartz veins.

Plutonic rocks.--The only rocks which can be classified as plutonic in origin are the quartz veins. Such veins were observed intruding the Triassic Dinwoody and various Cambrian and pre-Cambrian formations. Just south of the Armstead area in the area mapped by Bowers and Seglund, the same type of veins were noted intruding the

Mississippian Madison formation. The veins consisted of coarsely crystalline, milky quartz, associated with small amounts of chalcopyrite, magnetite, and an unidentified green encrusting mineral. Several prospect pits and claim sights were found in the regions where mineralization is supposed to have occurred. No direct evidence of such mineralization was observed however.

Hypabyssal rocks.--A volcanic neck is present in Garfield canyon. It is intrusive into the Triassic Dinwoody formation. Figure 27 is a photograph of the exposed Dinwoody rocks in the side of Garfield canyon, and it shows clearly the intrusive relation of the neck to the sedimentary strata. Megascopically, the rock is grey in color and somewhat altered. The zone of weathering extends deep into the exposed surface. The alteration does not seem to weaken the rock much, as it is still a tough and cohesive material. Microscopic investigation proves this rock to be andesitic in composition. It contains small phenocrysts of biotite and zoned plagioclase. The zoning in the plagioclase takes the form of zones of inclusions as well as zones of differing composition. One small phenocryst of quartz was noted surrounded by long thin crystals of biotite. The quartz in this phenocryst was not a single crystal but apparently an aggregate, strongly indicating that it was pseudomorphic after some other mineral. Other pseudomorphs were observed in the form of augite crystals partially or wholly replaced by calcite. The ground mass was composed of the holo-crystalline feldspar in the typical hypabyssal felted texture. All of the replacement observed in this rock, with the exception of the quartz pseudomorph, was in the form of calcite. Small grains of magnetite altered to hematite are present.

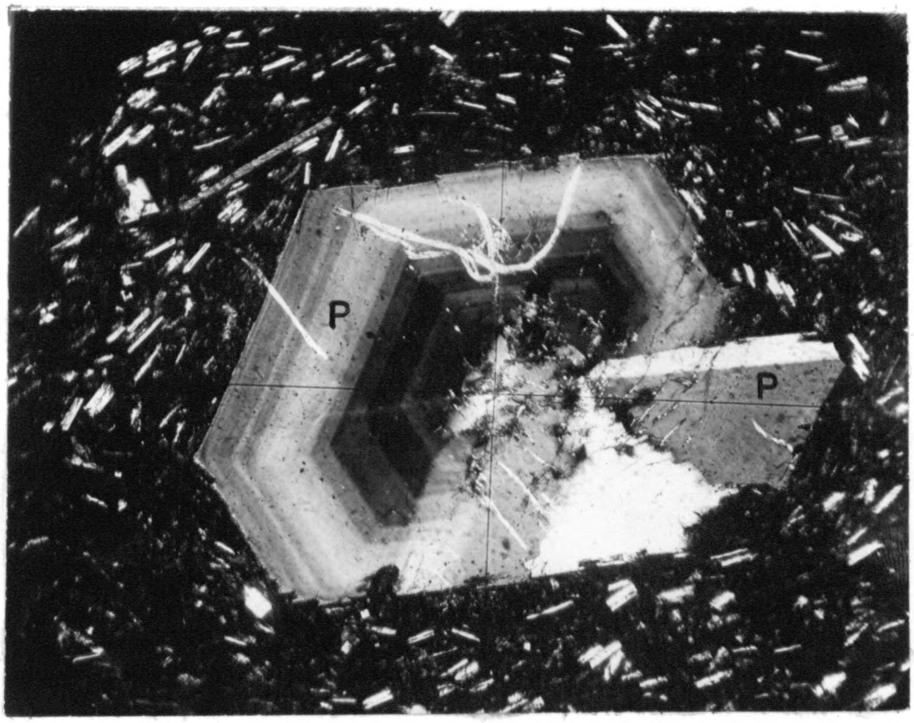
Extrusive rocks.--Andesite lava flows occur in the south-central part of the area mapped. They occur as capping layers on ridges and hills and were observed in one place to fill a vee shaped depression interpreted as an old stream channel. Megascopically, the lavas are dense and fine-grained. They range in color from light tan through white to blue-grey. Except for iron staining around individual grains, the color is independent of weathering. The rocks are fractured extensively. Examination of the rock in thin-section showed it to be an andesite. It contains phenocrysts of biotite, zoned plagioclase and hornblende. Plate 26 illustrates a large phenocryst of zoned andesine of the composition Ab_{70} to Ab_{60} in the albite-anorthite series. The ground mass exhibits some trachytic texture and is composed of lathes of plagioclase feldspar in a glassy matrix. A few lathes of biotite are also present in the ground mass. The structure of the groundmass is also well illustrated in Plate 26. Apatite, magnetite and hematite are found as accessory minerals.

Relation of neck to flows.--Both the flows and the volcanic neck observed in the Armstead area are andesite. Their mineralogic composition is similar and their texture differs precisely as would be expected from the variation in their occurrence. It is difficult to go any farther than this in a comparison of the two rock types, due to the extensive alteration of the volcanic neck. The contrast in apparent resistance to weathering isexplainable on two counts; first that the flows are more dense

Plates 26 and 27

Plate 26. Photomicrograph of Andesite lava flow showing zoned andesite phenocryst. 100X Crossed nicols.

Plate 27. Triassic Dinwoody intruded by volcanic neck of andesitic rock. Exposed in Garfield Canyon.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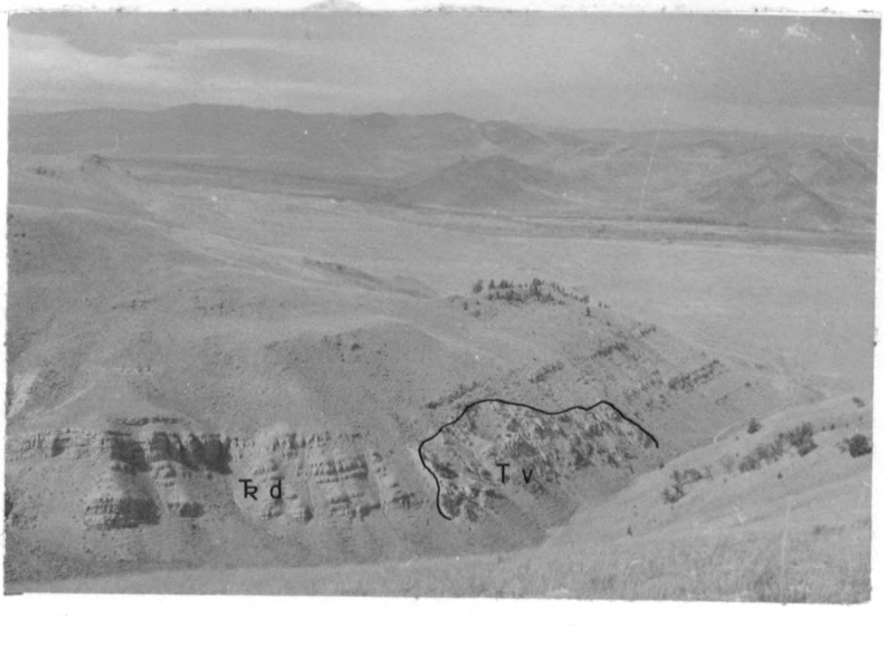
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and impervious due to their glassy matrix and secondly that the flows are topographically high and well drained while the volcanic neck outcrops at the bottom of a stream valley which handles a considerable portion of the local drainage. The evidence presented by the spatial relations of the two rock types is insufficient to justify any conclusion other than the statement that they occur in the same general locality. From all the evidence available, it is possible to conclude only that a genetic relation is probable but not proven.

The relation of the flows to the Basin Beds.--Where Tertiary volcanic flows occur interbedded with the Basin Beds, they are considered as a part of that rock series. In the Armstead area they occurred associated with older strata. The bentonitic shale of the Basin Beds, however, is evidence of the presence of volcanic activity during the deposition of that bed, and indicates an equivalent age for the volcanic activity and the deposition of the Basin Beds.

Metamorphic rocks

General statement.--All the pre-Cambrian rocks in the Armstead area can be classified as metamorphic rocks. Dr. E. Wm. Heinrich summarizes the occurrence of pre-Cambrian rocks in this area in the abstract of his article "Pre-beltian Rocks near Dillon, Montana." (1949, p. 278). He states: "Three major units of pre-beltian metamorphic rocks occur near Dillon, Montana. The oldest consists of a series of banded gneisses that are similar to rocks of the Pony series. Above these lies a group of marbles, schists, and quartzites, about two miles thick, belonging to the Cherry Creek series. Hornblende gneiss, which is interlayered with these meta-sediments, represents chiefly metamorphosed mafic sills, for vestiges of earlier contact metamorphic effects are preserved and locally the gneisses transect the marbles. Cutting both Pony and Cherry Creek rocks is a batholith of red granite gneiss (Blacktail granite gneiss). Transecting these units are dikes and irregular sheets of pegmatite, diabase, and periodotite, metamorphosed and unmetamorphosed and of uncertain age."

The metamorphic rocks in the Armstead area are similar to the rocks described by Dr. Heinrich and are presumably part of the same pre-beltian complex.

Pony series.--Rocks similar to the Pony series are recognized in the northern end of the Armstead anticline. To the south they are injected, lit-par-lit fashion, by pegmatite veins and other granitic material, eventually giving way to an intrusive mass of Blacktail granite gneiss. The rocks are very dark crystalline gneiss. Two thin sections were examined from the portion of the gneiss not injected by acid rocks. The locality for the slides is as follows:

No. 5---Far northern end of the core of the Armstead anticline.

No. 12--Same locality.

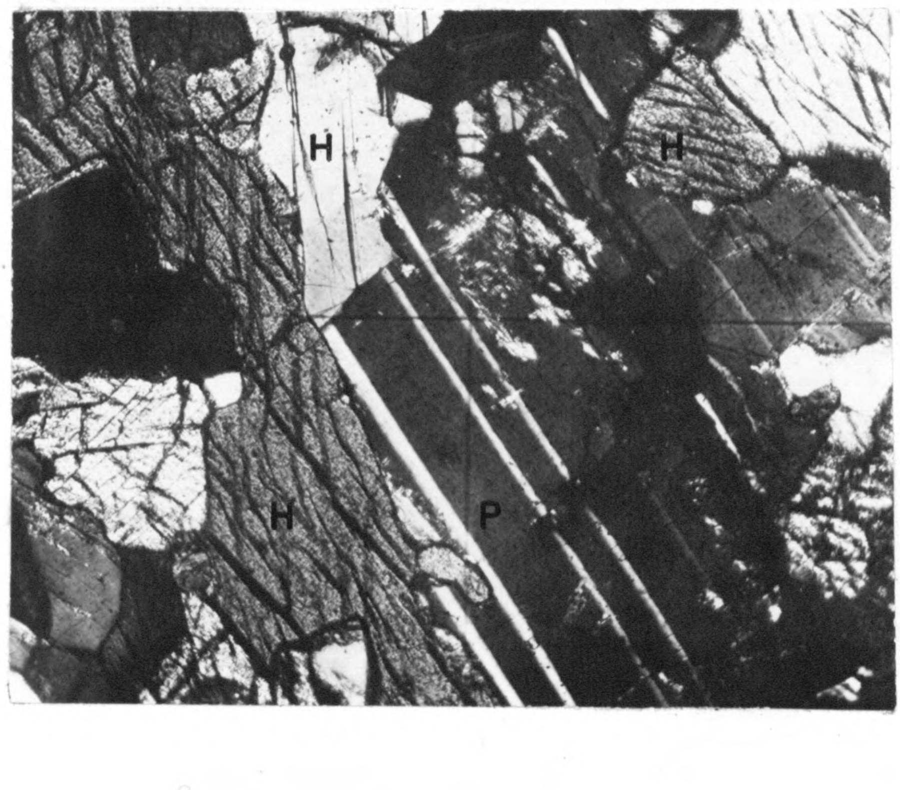
Microscopic examination proves the rock to be a hornblende gneiss containing an abundant amount of pyroxene and plagioclase feldspar. Plate 28 is a photomicrograph of a portion of slide No. 12. The gneissic texture is more apparent in hand specimen than in thin-section and consists of a lineation of the darker colored constituents. The abundant hornblende is accompanied by its secondary equivalent uralite. Three types of pyroxene are

Plate 28

Plate 28. Photomicrograph of hornblende gneiss from Pony series in the core of the Armstead anticline. Slide No. 12. 100X Crossed nicols.

H = hornblende

P = plagioclase


H
H
H
P

present; namely, augite, diopside, and magnesium rich hypersthene. Acid labradorite, in the range Ab_{40} to Ab_{50}, makes up the remainder of the rock. Some sericite and chlorite is present as the result of alteration.

The Cherry Creek series.--No rocks recognizable as related to the Cherry Creek series occur in the area mapped. The only criterion available for differentiating between the Pony series and the Cherry Creek series is the presence or absence of meta-sediments. Since no meta-sediments are found in the pre-Cambrian rocks of the Armstead area, it is assumed that the basic gneiss is best assigned to Pony age. Dr. Heinrich also is of the opinion that the gneiss is related to the Pony series (personal communication).

The Blacktail granite gneiss.--A body of the intrusive Blacktail granite gneiss occupies the central and southern portions of the core of the Armstead anticline. It grades northward into a country rock of injected hornblende gneiss of Pony age. Megascopically, it is a red to orange colored granite dotted with dark crystals of garnet. The garnet crystals are approximately one eighth of an inch in diameter. Iron stained patches are prominent on the weathered surface. The rock is well jointed. It weathers to a coarse orange colored sand which forms the bed of all streams draining the outcrop area. Twelve thin-sections of this material were examined for this study, four from the Armstead area and eight kindly loaned to me by Dr. E. Wm. Heinrich. Dr. Heinrich's slides were collected from localities ranging from the southern Ruby Mountains to the northeast, through the type area of the Blacktail granite gneiss (near Jaques Creek), southwest to the South Medicine Lodge Creek area. One of these slides is from an outcrop of Blacktail granite gneiss about ten miles north of Armstead or about five miles north of the northern end of the mapped area. The exact localities and slide numbers for these samples are listed below:

From northeast to southwest:

No. 29-1A--Southern Ruby Mountains, Stone Creek

No. 10-10--Southern Ruby Mountains, one mile north of Cactus Creek divide

No. 7-18--Southern Ruby Mountains, Carter Creek divide

No. 3- 1--Main granite gneiss (K. A. Keenmons area) Jaques Creek, type area of the Blacktail granite gneiss.

No. 3- 8--Same locality, aplitic rock

No. 25- 1--Happy's Highway (in K. A. Keenmon's area) also in type area

No. 9- 6--Ten miles north of Armstead

No. 23-2A-South Medicine Lodge Creek

The slides made from samples collected in the Armstead area for this problem are located as follows:

No. 2--Southern end of the core of the Armstead anticline, two miles southwest of Armstead

No. 14--North central portion of the core of the Armstead anticline

No. 19--South central portion of the core of the Armstead anticline

No. 42--Same locality

The microscopic examination of slides shows two mineralogical types of Blacktail granite gneiss. In the Armstead area the feldspar, which makes up the major portion of the rock, is predominantly microcline. Throughout the area represented by Dr. Heinrich's slides, the feldspar is predominately plagioclase, which occurs in two generations of development. One generation is optically positive, untwinned plagioclase of acid composition and the other is slightly more basic, well twinned plagioclase. In spite of this mineralogical contrast, very marked similarities exist between the petrographic characters of almost all slides examined of the Blacktail granite gneiss. These characters are a blebbed structure in the feldspar, both in untwinned plagioclase (see Plates 29 and 30) and in microcline (see Plates 32 and 33) and a reaction rimmed structure of both plagioclase and microcline. These features occur in slides No. 2, No. 19, No. 42, No. 9-6, No. 10-10, No. 3-1, No. 3-8, No. 25-1, No. 23-2a. Some of the structures are very poorly developed in individual slides and might easily have been overlooked had they not appeared so strikingly in others. The reaction rims around both plagioclase and microcline are shown in Plates 29, 30, 31, 32, and 33. Due to the small size of the blebs and rims in the plagioclase and microcline, it is difficult to correctly identify them. The blebs are invariably higher in index of refraction than the feldspar that contains them. This means that in the microcline, the blebs could be either quartz or plagioclase feldspar, and in the untwinned plagioclase, it could either be quartz or a more basic plagioclase feldspar. The relief in each case is the same, and since the index of the two types of feldspar is not the same; it follows that the blebs in one feldspar do not have the same index as the blebs in the other feldspar. Therefore, it is concluded that the blebs are probably plagioclase of acid composition where contained in microcline, and quartz where contained in the untwinned plagioclase. Such a combination is necessary to produce an equal amount of relief in each occurrence.

There is an interesting alternate hypothesis, which it has not been possible to verify. No attempt is made to defend this hypothesis, it is merely presented as possibility. It is entirely possible that the material referred to as untwinned plagioclase is an optically inverted potassium feldspar. The optically positive character of the material is the primary basis on which it has been determined as a plagioclase. All potassium feldspars are optically negative under normal conditioms, however, optically inverted potassium feldspars have been reported in some metamorphic rocks. If this were so, in the case at hand, then it would lead to a somewhat simpler and more logical identification of the blebs. They would be contained in material of essentially constant composition and therefore constant index. Since their relief was invariably the same in relation to the containing feldspar, then it follows that the index and composition of the blebs are equivalent. This leads to the simple conclusion that the blebs are plagioclase and are contained in potassium feldspar, a special case of perthitic structure. While this hypothesis leads to the simplest conclusion, it requires special conditions and time was not available for utilizing the special techniques required to verify or disprove it.

It would appear from this study that the blebbed structure and rimmed structure are characteristic of the Blacktail granite gneiss and should be looked for in identifying related occurrences of this rock. However, there exist other similarities of a mineralogic nature. Garnet is commonly found although not present in all slides examined. Zircon is an abundant accessory mineral in all slides examined. Biotite is also universally present. Most slides contained small scale occurrences of myrmekite consisting of quartz intergrown with the twinned plagioclase. Quartz is universally present as a replacing mineral or in long recrystallized grains. Its relation to all other minerals is a cross-cutting one. The slides collected near the contact with the Pony rocks showed development of secondary chlorite and sericite. Veinlets of unusually transparent and coarsely crystalline hematite were noted, chiefly from slides in or near the Armstead area. Apatite and magnetite are commonly present as minor accessories. Shreds and other small remnants of green hornblende were noted rather commonly.

The Blacktail granite gneiss offers an excellent opportunity for further research of a petrologic and mineralogic nature. The Gneiss is spread over a wide area and it would be interesting to see what correlations of a spacial nature exist between the two varieties of blebbed feldspar. More precise investigation by use of crushed fragments and other optical techniques is needed to shed more light on the problem of correctly identifying the feldspars. More extensive and systematic sampling of the Blacktail granite gneiss would help define the limits of variation and therefore allow significant generalizations about zones and directions of variation. Thus it is felt that the Blacktail granite gneiss offers a fertile field for further study, of a more detailed nature.

Plates 29 and 30

Plate 29. Photomicrograph of Blacktail granite gneiss from an outcrop approximately ten miles north of Armstead. Slide No. 9-6. Illustrates blebbed structure in untwinned plagioclase. 100X Crossed nicols.

My = myrmekitic intergrowth of quartz and plagioclase.

P = plagioclase

Q = quartz

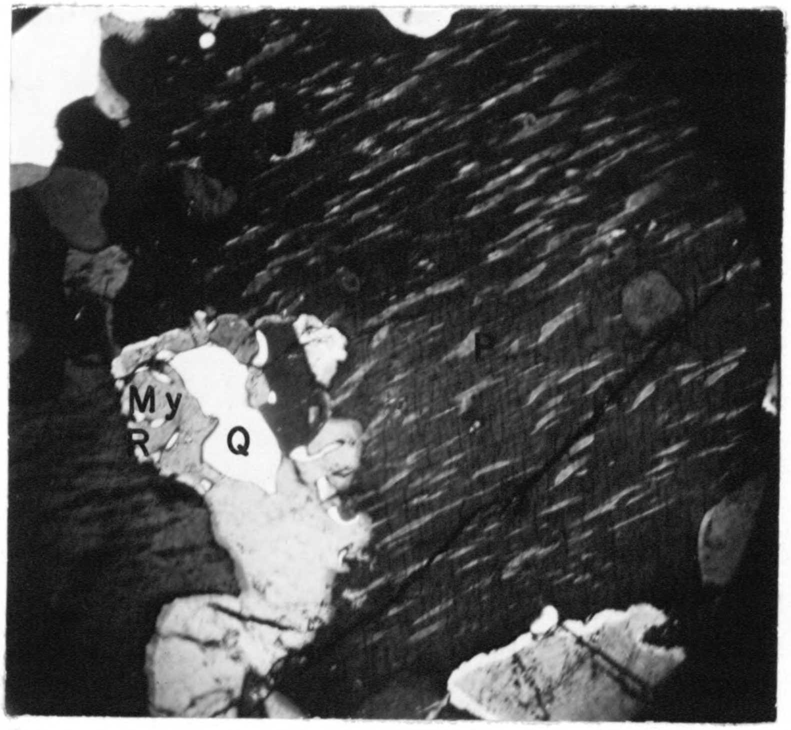
R = reaction rim

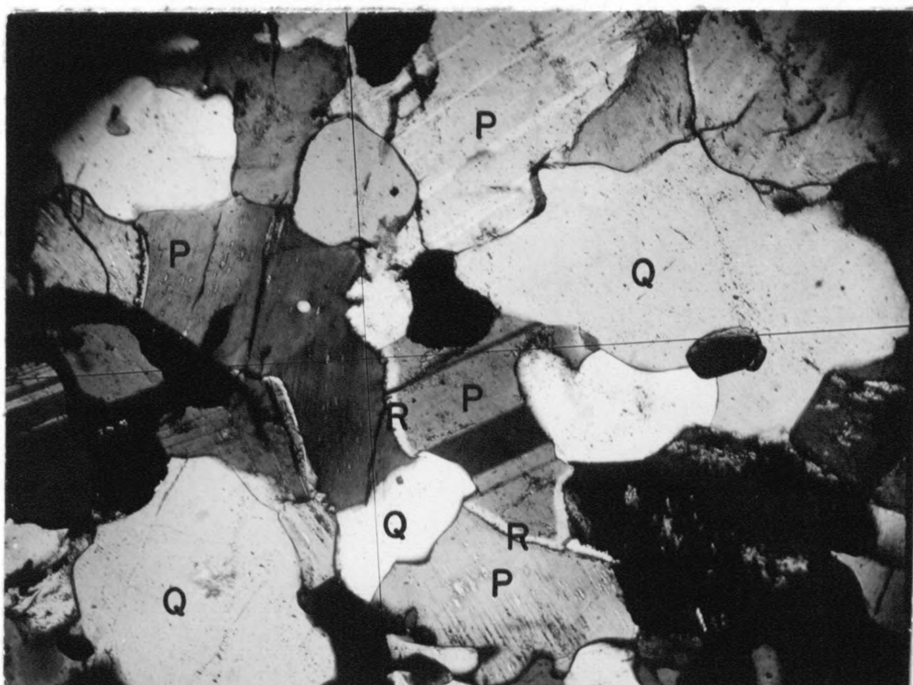
Plate 30. Photomicrograph of slide No. 9-6. Blacktail granite gneiss. Illustrating blebbed plagioclase, twinned plagioclase and the development of reaction rims. 100X Crossed nicols.

P = plagioclase

Q = quartz

R = reaction rim


My
R
Q
P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Q
R
P
Q
R
Q
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Plates 31 and 32

Plate 31. Photomicrograph of Blacktail granite gneiss, slide No. 9-6, illustrating reaction rimming of well twinned plagioclase. 100X Crossed nicols.

P = plagioclase

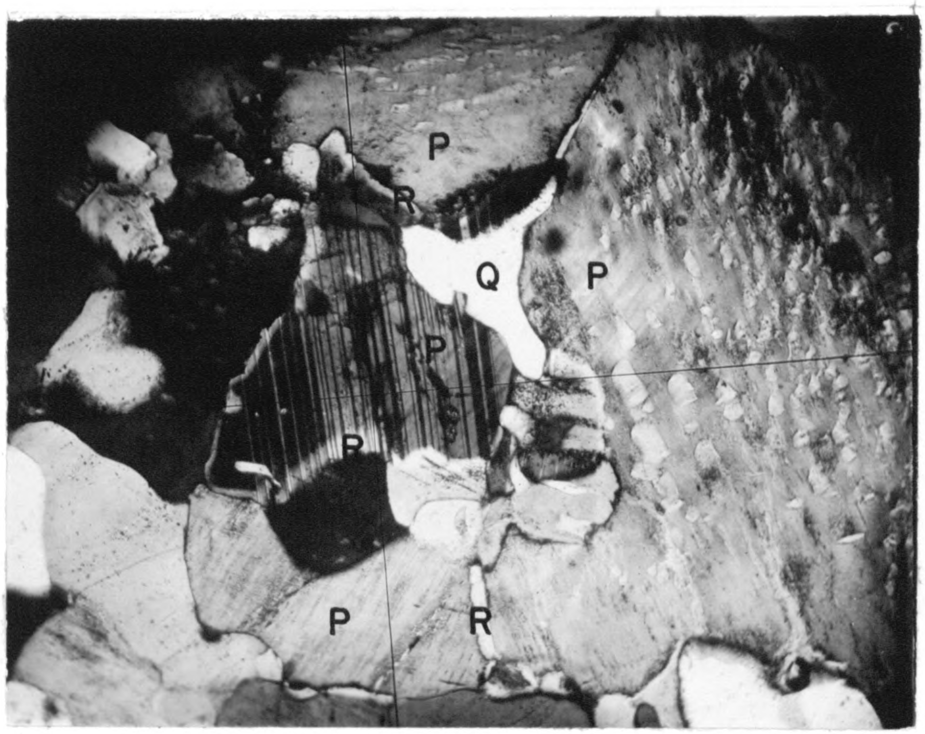
Q = quartz

R = reaction rim

Plate 32. Photomicrograph of Blacktail granite gneiss from outcrop two miles southwest of Armstead anticline, illustrating blebbed microcline and reaction rimming on microcline. Slide No. 2. 100X Crossed nicols.

M = microcline

R = reaction rim


P
R
Q
P
P
R
P
R

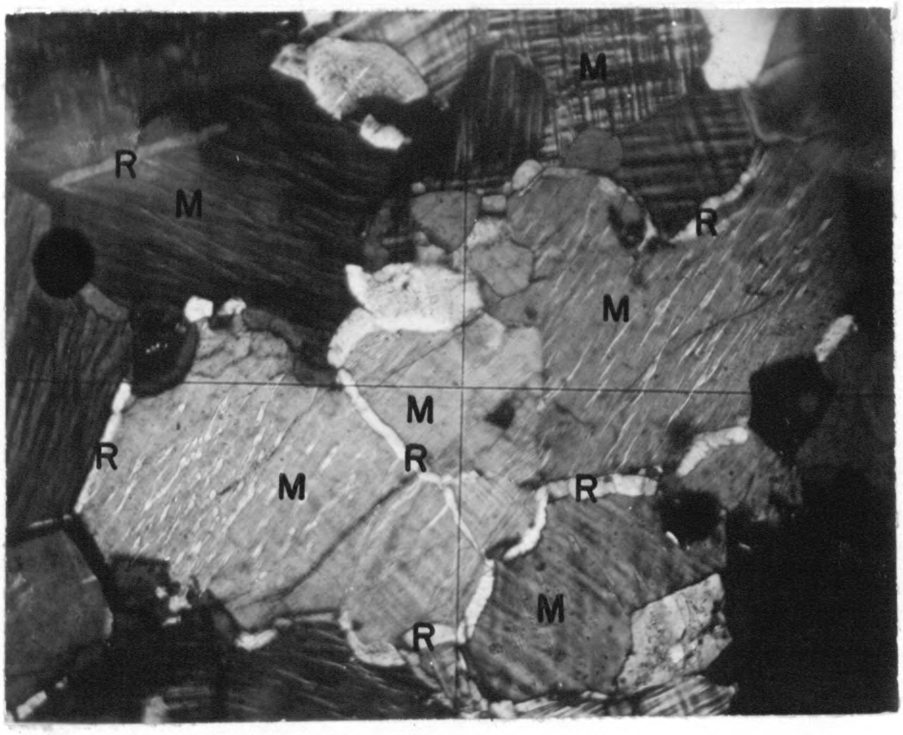
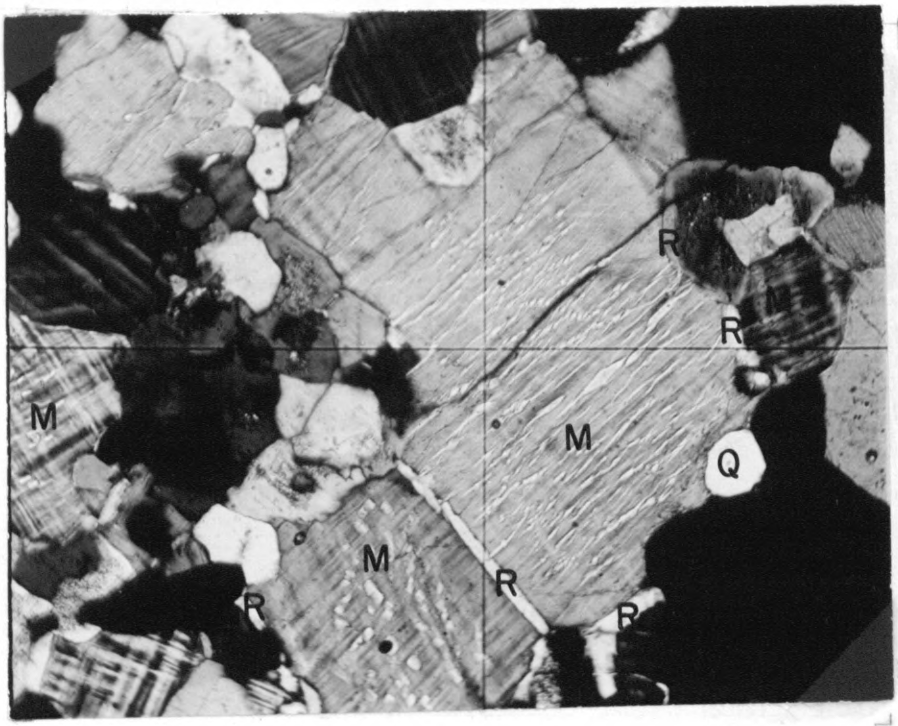

M
R
M
R
M
M
R
R
M
R
M
R

Plate 33

Plate 33. Photomicrograph of Blacktail granite gneiss, Slide No. 2. Illustrates blebbed microcline and reaction rims. 100X Crossed nicols.


R
M
R
M
M
Q
M
R
R
R

POST-JURASSIC HISTORY OF SOUTHWESTERN MONTANA

The following history of southwestern Montana was worked out at a meeting attended by Dr. A. J. Eardley and master's theses students of the University of Michigan who did field work in the region during the summer of 1948. Additions have been made to some of the original statements.

1. Uplift (probably orogenic) of Cordilleran geanticline and deposition of Kootenai clastics; conglomerate generally at the 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 a prominent element. The Armstead anticline and related structures were probably formed at this time.

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.

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 great 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 the east to west are Tendoy (north of Sheep Creek Canyon), Medicine Lodge (from Medicine Lodge Pass, Idaho-Montana line to Armstead and beyond), and Beaverhead. The Tendoy and Medicine Lodge thrusts have been traced across the Armstead area. Further work is necessary in order to trace the Medicine Lodge fault north of Horse Prairie Creek where it undoubtedly emerges from the alluvium.

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 resulted in damming 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 Blacktail Deer beds and associated basalts, tuffs, and agglomerates in Upper Sage Creek, along northwest flank of Snowcrest Range and in Ruby Basin. Called Passamari by Dorr and Wheeler. The before mentioned normal fault along the eastern edge of Medicine Lodge Creek Valley probably occurred at this time.

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. Present now in summit areas of 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 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. The pediment to the east of Medicine Lodge Creek developed at this time.

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

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

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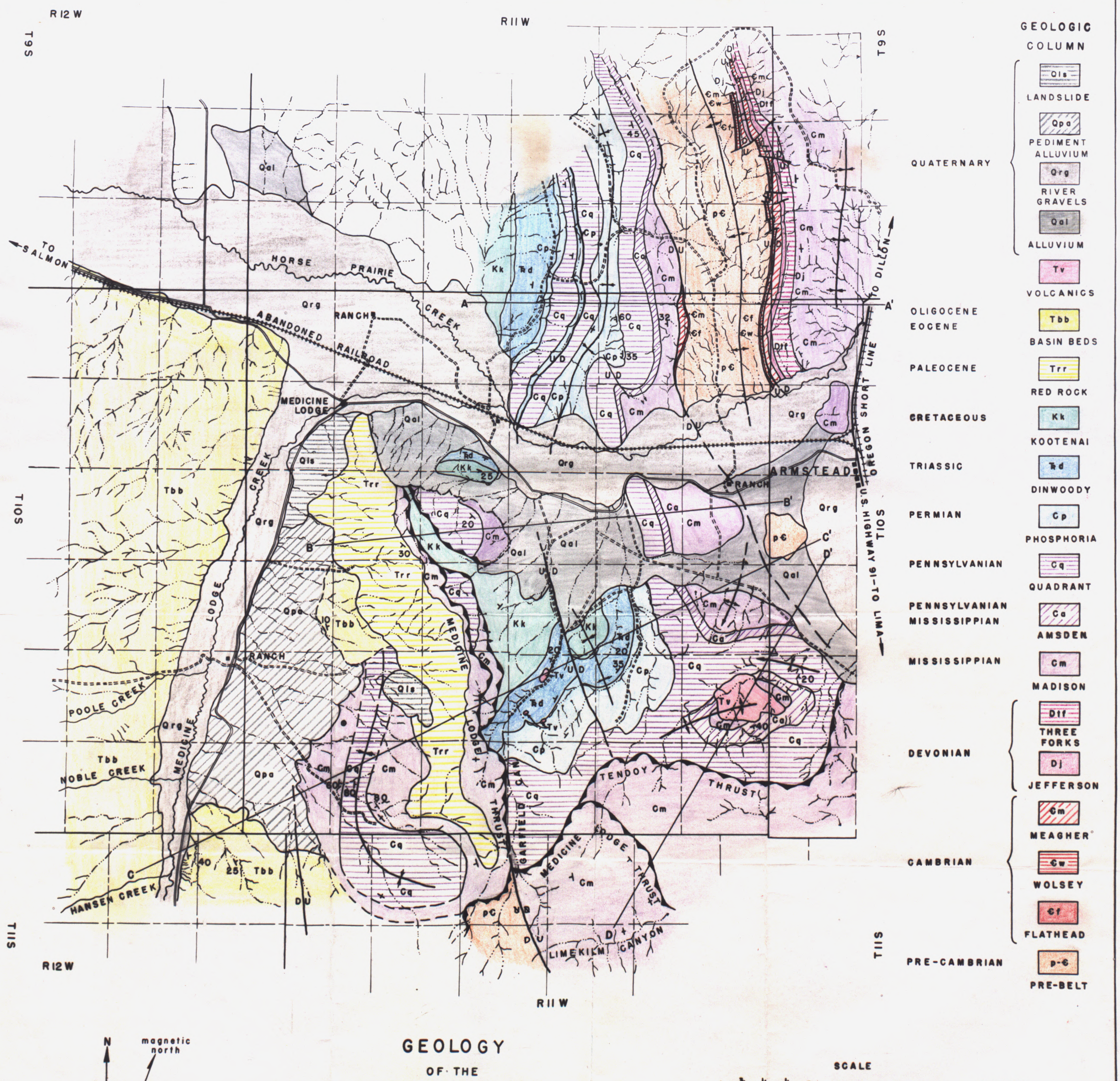


GEOLOGY

OF THE

ARMSTEAD AREA

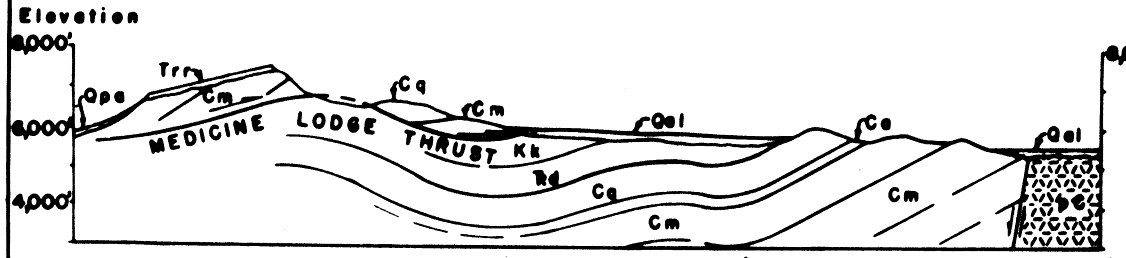
BEAVERHEAD COUNTY, MONTANA

BY

R.A. BRANT, N.C. ELMER, W.A. GILLESPIE & J.R. PETERSON

COMPILED BY RADIAL LINE ASSEMBLY OF AERIAL PHOTOGRAPHS

AUGUST 1948



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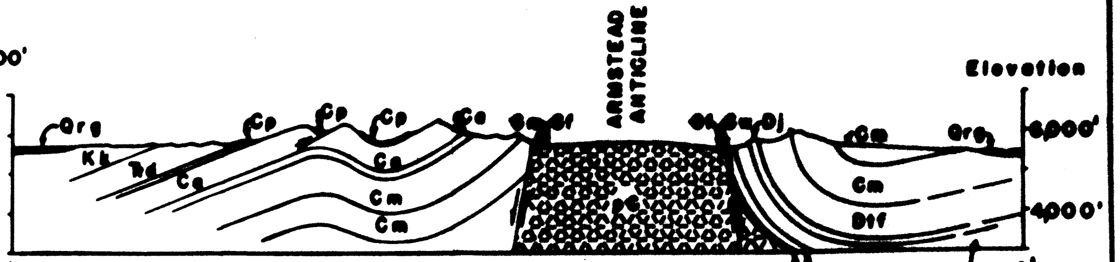

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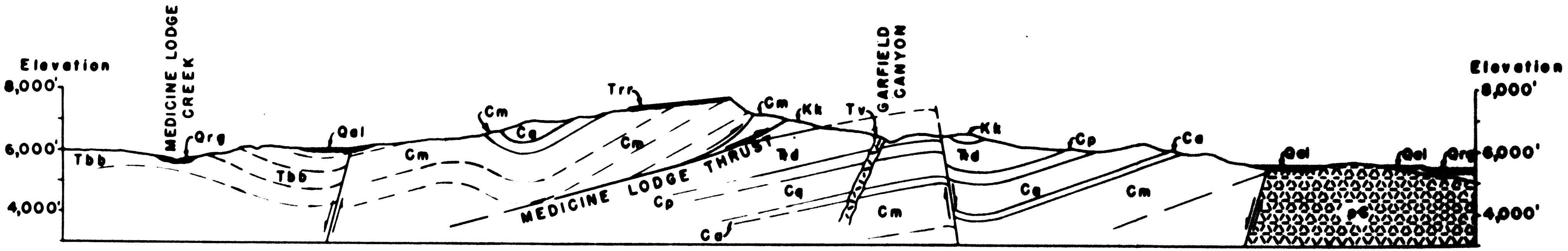


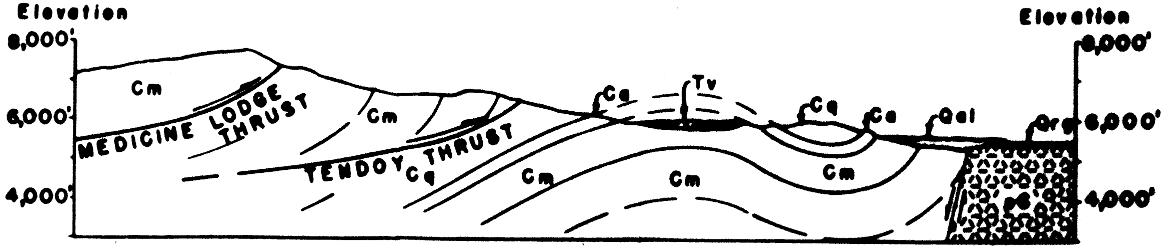
C SECTION C-C' C'

GEOLOGIC CROSS SECTIONS

ARMSTEAD AREA

BEAVERHEAD COUNTY MONTANA

VERTICAL AND HORIZONTAL SCALE
ARE THE SAME AS THAT OF MAP.



D SECTION D-D' D'

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