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I have read and approve the acceptance of the thesis submitted by James M. Drexler in partial fulfillment of the requirements for the M. A. Degree.

Eugene H. Walker

April 28th 1949

I recommend that the thesis of James M. Drexler be accepted.

(48)

A. J. Eardley

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THE GEOLOGY OF THE RED PEAKS AREA, BEAVERHEAD COUNTY, MONTANA, AND CLARK COUNTY, IDAHO

By
James Michael Drexler

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

CONTENTS

ILLUSTRATIONS

ABSTRACT

The area of the report is located in Beaverhead County, Montana and Clark County, Idaho. Formations range from the Lower Mississippian Madison to the Upper Cretaceous Aspen in age. In addition, the Tertiary is represented by the Red Rock conglomerate, volcanics, and recent alluvium. The Paleozoic section measures over 6,400 feet in thickness, the Mesozoic is represented by 7,800 feet of sediments, and the Tertiary thickness is unknown. The Tensleep sandstone and the Red Rock conglomerate are the most resistant formations in the area; therefore, they hold up the highest peaks.

The major Laramide structures are thrust faults and folds which trend northwest-southeast. Two thrust faults are found in this area, the Medicine Lodge and the Tendoy; both have Paleozoic strata thrust over Red Rock conglomerate. Early Laramide cross-folding is represented by the Sawmill anticline.

Plate 1. Index map

INTRODUCTION

Location of the area

The thesis area was mapped by James McUsic, Edwin Kildal and the author, all graduate students at the University of Michigan. The area is located in Beaverhead County, Montana and Clark County, Idaho and contains about 180 square miles. It includes all or part of ten townships including T13N-R35E, T14N-R35E, T13N-R34E, and T14N-R33E in Idaho; also, T15S-R8W, T14S-R8W, T15S-R7W, T14S-R7W, T15S-R6W, and T14S-R6W in Montana.

The area is bounded on the north by United States Highway 91; on the south, by the township line between the Idaho townships 13 North and 12 North; on the west, by Irving Creek in Idaho and roughly by the Lima Bird Refuge fence in Montana; and on the east, by Corral Creek and Modoc Creek.

The entire thesis area lies within a block formed by the lines 44°25' north latitutde, 44°40' north latitude, 112°20' west longitude and 112°40' west longitude.

Topography and drainage

<u>Idaho</u>. The topography is very rugged in the Idaho section of the thesis area. The highest peaks are

found along the continental divide, which is also the state line between Idaho and Montana. These are the Red Peaks from which the area takes its name. The Red Conglomerate Peaks, on the divide north of Irving Creek, rise 10,113 feet above sea level. The peaks become slightly lower eastward along the divide but all are over 8,000 feet in elevation. The ridges become lower south of the divide. The average elevation of the Idaho portion of the thesis area is 7,500 feet.

The major streams, from east to west, that drain the area are Irving Creek, Eidie Creek, Middle Creek, and the West and East Forks of Indian Creek. All of these streams flow into Medicine Lodge Creek south of the thesis area. Medicine Lodge Creek then joins the Snake River at a point still farther south.

A major topographic feature not yet mentioned is Middle Creek Butte which is located on Middle Creek, six miles south of the state line.

Montana. The most prominent topographic features in the Montana section of the thesis area are the Lima Peaks. These peaks are held up by the Tensleep formation and are very distinctive because of the great mass of tan talus that decorate their slopes. (See Plate 8)

North of the Lima Peaks and to the south along the divide are high areas developed on the Red Rock conglomerate. The rest of the area is comparatively low except for a few lava-capped buttes.

The major drainage streams from west to east are Deep Creek, Sawmill Creek, Shineberger Creek, and Beaver Creek. All flow northward and eventually reach the Red Rock River.

Accessibility

Idaho. The Idaho part of the area can best be reached from the town of Dubois, Idaho. Idaho state highway 22 leads westward from Dubois. From a point 9 miles west of Dubois, Medicine Lodge road leads northward paralleling Medicine Lodge Creek. From it secondary dirt roads branch off to parallel the major streams of the area. There are no connecting roads between these canyons.

Montana. The Montana section of the area can be reached from either Lima or Snowline, Montana. Both of these towns are located on U.S. Highway 91. One mile south of Lima on U.S. 91 is a dirt road that leads south to Deep Creek. The dirt road that runs south from Snowline divides at the junction of Shineberger and Beaver Creeks; one branch parallels Shineberger Creek and the other parallels Middle Creek.

Previous work in the area

Idaho. The earliest work done in the Idaho part of the thesis area was by V.R.D. Kirkham of the Idaho State Survey. In the summer of 1925 Mr. Kirkham made a reconnaissance map of Clark county and adjacent counties. He published a report on the area in 1927. No other published reports have been made on this part of Idaho until 1948 when W. L. Adams and Richard Benner submitted a report for their Master's thesis on the area just west of that of the present report.

Montana. Professors E. S. Perry and U. N. Sahinen of the Montana School of Mines made a reconnaissance map of this part of southwest Montana in 1946 but it has not yet been published. Areas adjacent to this thesis area have been mapped by other graduate students of the University of Michigan during the summers of 1947 and 1948.

Acknowledgements

The field work, construction of the geologic map and cross-section, and the writing of the report were done under the supervision of Professor A. J. Eardley of the University of Michigan. The author is indebted to Professor Eardley for his assistance in the work. Gratitude is also extended to Robert Scholten, in whose Ph.D. thesis area this area is located, for field assistance and for importing to the author his general knowledge of the area. Further credit is due to James McUsic and Edwin Kildal, graduate students of the University of Michigan, who collaborated with the author in mapping the area and preparing the map and cross-section. The author is also indebted to Edward Dillon, graduate student of the University of Illinois, who provided a great deal of stratigraphic information.

STRATIGRAPHY

Introduction

The rocks outcropping in the area include formations ranging from Lower Mississippian Madison to Recent alluvium in age.

Paleozoic formations found in the area are the Lower Mississippian Madison, the Amsden which is thought to represent Upper Mississippian and Lower Pennsylvania, the Pennsylvanian Tensleep, and the Permian Phosphoria. Older Paleozoic formations crop out to the west of the Red Peaks area, but will not be covered here as earlier reports have dealt with them in sufficient detail (Lipp, 1948). The Paleozoic strata in this area measure over 6,400 feet in thickness.

Overlying the Paleozoic rocks are some 7,800 feet of Mesozoic sediments. The Triassic and Jurassic formations total 2,800 feet, and the Cretaceous beds about 5,000 feet.

The Cenozoic is represented by the Paleocene (?) Red Rock conglomerate, Pliocene (?) rhyolite and basalt flows, and Quaternary alluvium.

Outcrops are good in the Lima Peaks area where a sequence of beds ranging from middle Amsden through the Aspen formation is found. Many high angle dips aided in measuring sections. All these formations are found in the Tendoy thrust sheet. There are also good outcrops of Madison limestone in the Medicine Lodge thrust sheet. Aside from these two places, the outcrops are poor especially in Idaho where the Red Rock conglomerate is covered by a stony soil.

Stratigraphic column

Age	Formation	Lithology	Thickness
Quaternary	Alluvium	Pebbles, sand and silt	
Pliocene (?)	Basalt	black, weathers black, vesicular	30'
	Rhyolite	lavander, weathers tan to brown, partly vesicular	10'
Paleocene (?)	Red Rock	conglomerate with pebbles of quartzite and limestone, lenses of tan and salt & pepper sandstone	2000'+
Upper Cretaceous	Aspen	Porcellainites, bentonites, salt & pepper sandstone, variegated shales	3440'
	Bear River	brown sandstones (some calcareous), gray shales	365'
Lower Cretaceous	Kootenai	conglomerate marker beds, salt and pepper sandstones, limestones and shales	1080'
Upper Jurassic	Morrison	variegated siltstones and claystones, sandstones and limestones	300'
	Reardon	gray-brown, öolitic limestone	60'
Middle Jurassic	Sawtooth	calcareous siltstones, calcareous shales with interbedded gray limestone	200'
Lower Triassic	Thaynes	gray-brown limestone, calcareous sandstones and shales, chert nodules	1940'
	Woodside	red to brown sandstone, dolomite and siltstone	115'
	Dinwoody	dark gray shale, dark brown sandstone, light gray limestone	190'
Permian	Phosphoria	phosphatic shales, chert beds, gray to brown limestone, sandstone, dolomite	420'
Middle Pennsylvanian	Tensleep	white to tan quartzitic sandstone, weathers black	2970'
Lower Pennsylvanian Upper Mississippian	Amsden	gray crystalline and argillaceous limestones interbedded with gray calcareous shale	2020'
Lower Mississippian	Madison	Blue-gray fossiliferous limestone massive.	1000'+

Mississippian system

Madison limestone: A. C. Peale named the Madison formation from outcrops of massive jaspery limestone, light bluish-gray massive limestone and dark-colored compact laminated limestone found in the Madison Range in the central part of the Threeforks quadrangle, Montana. (1893, p.33). In the type section, this formation rests on Devonian Threeforks shale and is overlain by the Quadrant formation. R. H. Hamblin and L. L. Sloss have proposed a new type area located at Logan, Montana (1942, p.305). Peale described the Madison as a formation but now many geologists classify it as a group.

The only Madison found in the thesis area forms the sole of the Medicine Lodge thrust. Here it appears as a massive blue-gray limestone and represents part of the Mission Canyon or upper member of the Madison. It contains abundant fossils but they are poorly preserved.

The true thickness of the Madison cannot be determined in this area since the base of it is a thrust contact and the formation is unconformably overlain by Pliocene rhyolites. There are at least 1,000 feet of Madison exposed in Middle Creek Butte. Just west of this area, Adam (1948, p.11) found as much as 2,000 feet of Madison exposed in the thrust sheet. About 20 miles west of the overthrust in the Nicholia Creek Basin, Kupsch estimates a total of 3,000 feet of Madison (1948, p.22).

Pennsylvanian system

Amsden formation: The name Amsden was applied to a group of red shales, white limestones, and cherty, sandy limestones exposed in the Amsden branch of the Tongue River in Wyoming. N. H. Darton gave the name to the formation (1904, p.379), but he thought it was Mississippian in age on the basis of megoscopic fossils collected from its lower beds. Subsequent studies of the microfauna have shown that most of the Amsden is of Lower Pennsylvania age. The diagnostic Amsden fusilinid is a genus known as Millerella.

The Amsden can be divided into three members in Wyoming and most of Montana. The upper and lower members consist of limestones and shales; whereas, the middle member is the Darwin sandstone. Only the upper member is exposed in the thesis area; however, E. G. Lipp (1948, p.15) measured 2,022 feet of Amsden on Sheep Creek about nine miles west of this area.

The upper Amsden in the thesis area is almost entirely gray crystalline and argillaceous limestones interbedded with gray calcareous shales.

Some of the lower beds mapped as Amsden may be equivalent to the Brazer formation which is recognized farther south to overlie the Madison limestone and underlie the Amsden (Foster, 1947, p.1555). Branson applied the name "Sacajawea member" to the lower member, and in central Wyoming he considers it to be a separate formation of Mississippian age. Branson reports a disconformity between the Darwin and Sacajawea members in central Wyoming, and thus places the Mississippian-Pennsylvanian boundary at this point (1935, p. 391).

The Amsden is conformably overlain by the Tensleep formation.

Tensleep sandstone: The term Tensleep was first applied by N. H. Darton (1904, pp.394-401) to a formation of White sandstone which is exposed in the walls of the lower canyon of Tensleep Creek. Here it underlies the Chugwater formation and overlies the Amsden formation. It seems advisable to use the name Tensleep in this part of Montana rather than Quadrant, since the Quadrant of Montana contains both the limestones and shales of the Amsden formation and the sandstones of the Tensleep formation.

The Tensleep in the thesis area is highly resistant and is composed, for the most part, of a dense, massive sandstone. The lower part of the formation is cross-bedded and somewhat dolomitic. The sandstones become more dolomitic upward in the section until the uppermost part of the formation is reached, where limestones with thin, interbedded chert layers appear. The sandstones are light in color and weather to various shades of tan, red, purple and white.

The formation weathers into a very coarse talus composed of angular blocks up to several feet in diameter. The talus makes the unit very distinct to the observer since the freshly weathered blocks appear as long white ribbons flowing down the mountain side and prevents vegetation from growing on the slopes. Lichen growth changes the talus color to black.

The Tensleep in this area makes up the backbone of the Lima Peaks. A composite measured section in the Lima Peaks shows 2,970 feet of almost entirely sandstones (Dillon, 1949, p.25).

The Tensleep is unconformably overlain by the Phosphoria formation of Permian age.

Permian system

Phosphoria formation: The Phosphoria formation was named by Richards and Mansfield from exposures near Meade Peak, Idaho, in Phosphoria Gulch (1912, p.686).

The Phosphoria formation found in the thesis area is located on the flanks of the Lima Peaks. Compared to the Tensleep, it is a non-resistant formation; therefore, its presence is indicated by a marked change of slope. A good exposure occurs on the south flank of the Lima Peaks on a ridge between two tributaries of Deep Creek.

The lowest member of the Phosphoria is an eight foot bed of phosphatic shale that forms a grassy slope in the thesis area. Immediately above this is a 35 foot bed of chert. The rest of the formation consists of limestones, sandstones and dolomites, generally gray and brown in color and is capped by a 70 foot layer of blue-black phosphatic shale. The total thickness of the formation is 417 feet.

The upper portion of the Phosphoria is fossiliferous. The name "upper *Productus* limestone" has been given by some workers to the limestone unit of the Rex chert member which contains an abundant fauna of *Productus*, *Pustula*, and *Composita* (Mansfield, 1927, pp.78 and 25). In the thesis area the Rex chert member is not well defined; however, the *Productus* limestone is a marker bed of chert and limestone.

An erosional unconformity separates the Phosphoria from the overlying Triassic Dinwoody formation.

Triassic system

Dinwoody formation: The name Dinwoody was applied by Blackwelder to outcrops of greenish-gray shales and thin, dense sandstones in Dinwoody Canyon in the Wind River Range of Wyoming (1918, pp.425-426).

There is a distinct lithologic break at the Phosphoria-Dinwoody contact in the thesis area. The black phosphatic shale of the uppermost Phosphoria bed is overlain by a red-brown weathering shale of the Dinwoody.

The Dinwoody is only 190 feet thick in this area and consists of dark gray shales, dark brown sandstones and light gray limestones. The most distinctive member of this formation is a one-foot bed of brown sandstone which weathers into blocks where it is exposed. Some poorly preserved fossils were found in this member but they could not be identified other than that they appeared to be brachiopods.

The Dinwoody is basal Triassic in age (Newell and Kummel, 1941, pp.204-208). The characteristic Lingula zone of the Dinwoody was not observed in the thesis area; however, Lingulas were observed in the Thaynes limestones on Little Sheep Creek (Dillon, p.34).

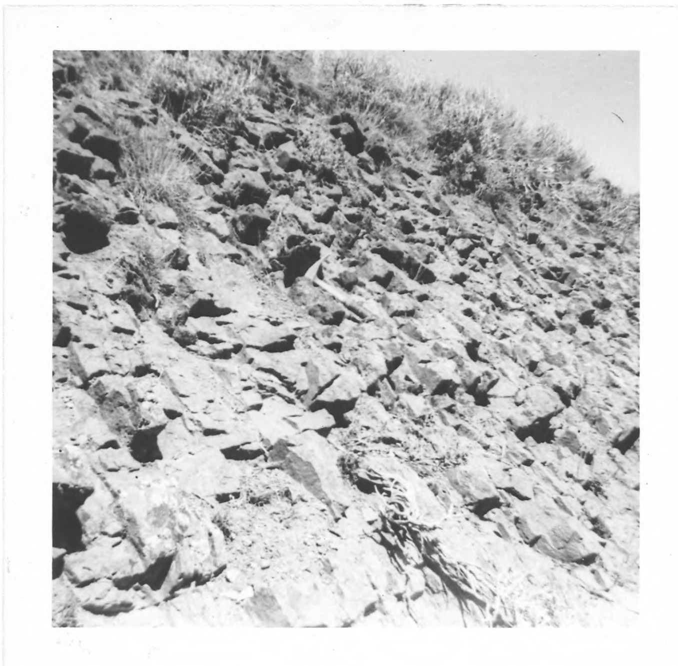

Plate 2. Block weathering characteristic of a Dinwoody sandstone bed.

Woodside: The Woodside was named by Boutwell (1907, p.446) from a formation consisting of dark red shale exposed in Woodside Gulch, Park City District, Utah. It is lower Triassic in age. Newell and Kummel believe that the Dinwoody is a time equivalent of the lower Woodside of the type area.

The Woodside section is very thin in the thesis area, consisting of 116 feet of poorly exposed pink and brown sandstones, pink sandy dolomite, red to brown calcareous siltstone, and gray crystalline limestone.

Thaynes: Boutwell gave the name Thaynes to exposures found in Thaynes Canyon, Park City District, Utah (1907, p.448). The name was later applied in Idaho and Wyoming to the strata from the base of the Meekoceras limestone up to the Ankareh shale (Kummel, 1943, p.316).

The Thaynes is the most important Triassic formation in this area. It has a thickness of 1,940 feet compared with the 300 foot total thickness of the Woodside and Dinwoody.

The lowest unit of the Thaynes is a gray-brown crystalline limestone containing some sandy dolomite. It contains the Meekoceras fauna which Kummel has designated as the basal unit of the Thaynes.

These ammonites are limited to eight feet of poorly bedded limestone within the 270 foot limestone basal unit. The rest of the unit contains numerous, poorly preserved brachiopods and pelecypods.

Above the Meekoceras limestone are nearly 600 feet of nondescript calcareous sandstones and shales. These beds are capped by a 12 foot gray-brown dolomite marker bed, easily distinguished because it weathers to a light color.

The 100 foot limestone unit found above the dolomite was formerly thought to represent the top of the Dinwoody (Lipp, 1948, p.27) since the 250 feet of calcareous sandstone above it resembles the Woodside formation of Jackson, Wyoming area. The sandstone is easily weathered, to form a brown sandy soil, but a few of the more resistant beds form small ridges. Earlier field work in this area had placed the base of the Thaynes at the bottom of the Pentacrinus limestone which overlies the aforementioned sandstone. The limestone is a conspicuous cliff-maker and contains numerous Pentacrinus columnals. The top unit of the Thaynes is another limestone, the base of which contains chert nodules.

The Thaynes formation is lower Triassic in age (Kummel, 1943, p.326). It is separated by an erosional unconformity from the Jurassic Sawtooth formation.

Plate 3. Resistant, _Pentacrinus_ limestone of the Thaynes formation, near Deep Creek.

Jurassic system

Sawtooth formation: Sawtooth is a name applied to exposures found in the Sawtooth Range of Montana by W. A. Cobbon (1945, p.1270).

The Sawtooth is a non-resistant formation that forms a characteristic yellow-brown soil between the upper Thaynes limestones and the öolitic limestones of the Reardon. 200 feet of Sawtooth are found in the thesis area consisting of a brown siltstone member at the base; a middle member composed of calcareous shales with a few interbedded light gray limestones; and an upper member of brown calcareous siltstone. The middle member is very fossiliferous, containing *Placunopsis* aff., *Lycetti*, *Ostrea stringilecula*, *Pentacrinus asteriscus*, *Coniopygus zitteli*, *Aviculopecten*, *Pleuromya weberensis*, *Serpula*, *Lima*, and *Camptonecten*.

This formation is middle Jurassic in age (Imlay and others, 1948). It has a conformable contact with the Reardon.

Reardon formation: The Reardon was named by W. A. Cobban from exposures of calcareous gray shales and gray limestones found in Reardon Gulch, Sweetgrass Arch, Montana (1945, p.1277).

Plate 4. Vertical ridges of the Reardon formation, south of Deep Creek. Lima Peaks in the background.

In the thesis area the Reardon is composed entirely of gray-brown öolitic limestone. This formation is only 60 feet thick but is very prominent because it is highly resistant to erosion and has an almost vertical dip. The ridge formed by the Reardon has as much as 50 feet of relief in some places.

The age of the Reardon formation is lower upper Jurassic (Imlay and others, 1948). This formation is conformable with the Morrison which lies above it.

<u>Morrison formation</u>: Above the Reardon lies a 300 foot covered interval that probably represents the Morrison formation. There is also a possibility that the lowest few feet of this covered zone represent the Swift formation. However, since no more than 16 feet of Swift have ever been found in southwestern Montana (Imlay and others, 1948), it seems advisable to call the whole interval Morrison until additional evidence is found.

The Morrison is a non-marine formation of upper Jurassic age. Where it crops out at Indian Creek, Madison County, Montana, the Morrison is composed of varicolored siltstones and claystones, with some sandstone and limestone (Imlay and others, 1948).

The name Morrison was applied by G. H. Eldridge to fresh-water marls found near Morrison, Colorado (1896, p.60).

The Morrison is unconformably overlain by the basal conglomerate bed of the Kootenai formation.

Cretaceous system

Kootenai formation: The name Kootenai was first used by J. W. Dawson (1885, p.2). However, Dawson's Kootenai probably included the Morrison formation. Fisher (1909, pp.28-35) used the name of Kootenai for a coal-bearing series found at Great Falls, Montana. Here it was underlain by Morrison and overlain by the Colorado shale.

A total of 1,080 feet of Kootenai were measured in the thesis area by Dillon and McUsic. The basal conglomerate of the Kootenai is widespread throughout Montana.(Bevan, 1929, p.444) and makes an excellent marker bed. In the area of this report, the conglomerate bed is almost 50 feet thick and contains a large number of chert pebbles. A thin conglomerate bed can be found about 300 feet higher in the section. This one is also a distinct marker bed and probably correlates with the medial conglomerate of the Kootenai mentioned by Deiss as occuring in the Sawtooth Range of central Montana (1943, pp.1143-1144).

Limestones are found in the middle of the formation that contain a great number of gastropods. These beds are almost coquinas in character and are good marker beds for the Kootenai of this part of Montana. The Kootenai also contains calcareous shales which are often covered by a very distinctive red clay soil.

A very interesting lithologic change takes place with the onset of the Cretaceous, and from this time on, salt and pepper sandstones are found. The Kootenai is of lowest Cretaceous age and contains the first of these salt and pepper sandstones.

The Bear River formation conformably overlies the Kootenai in this area.

Bear River formation: The Bear River was named from exposures found near Bear River City, Wyoming by Hayden (1869, p.91).

The Bear River formation can be divided into two members in the thesis area: the lower member is a non-calcareous sandstone, and the upper member consists of calcareous sandstones and shales. The total thickness of the formation is 365 feet.

Some geologists have classified the lower member as a separate formation, called the Dakota. However, such a division does not seem to be necessary in this area. The "Dakota" member is a resistant,

Plate 5. Talus of the Bear River "Dakota" member, near Deep Creek.

non-calcareous sandstone that weathers to a rather coarse talus. This talus differs from the Tensleep talus in that it is a darker brown in color and breaks into smaller blocks.

The upper member of the Bear River is non-resistant and forms gentle slopes below the "Dakota" talus in this area. It consists of alternating shales and calcareous salt and pepper sandstones. Near the top of the member is a conquina of fresh-water pelecypods, including Unio douglassi.

The age of the Bear River is lowest upper Cretaceous. It has a conformable contact with the overlying Aspen formation.

Aspen formation: A. C. Veatch applied the name Aspen to a series of black and gray shales exposed near Aspen Station, Uinta County, Wyoming (1907, p.56).

The Aspen section of the thesis area is very thick. Dillon and McUsic (1948, p.62) measured 3,440 feet of it. In some parts of the area, thrust faulting and high-angle faulting cause a repetition of beds and thus make the Aspen seem even thicker than it really is.

In this area the Aspen is composed of porcellanites, bentonites, and brightly colored salt and pepper sandstones and shales. Many fossil plants can

Plate 6. A "bentonite hill" in the Aspen, south of the South Paint Pot

be found in the few fresh-water limestones present, including *Podozamites lanceolatus*, *Hicoria*, *Cornus forchhomeri*, and *Platanus platanoides*.

The bentonite beds are known locally as "Paint Pots" because of their bright, variegated colors. They have a typical badlands appearance and are very difficult to cross during wet periods. Numerous fragments of dinosaur bones are found in the bentonite beds near the top of the formation.

Most of the porcellainites are light gray to green in color but a few are white to pink. These porcellainites are typical of the Aspen formation and it is largely because of their presence that the name Aspen was applied here rather than the name Mowry.

The Aspen is upper Cretaceous in age and is separated from the overlying Red Rock conglomerate by an angular unconformity.

Tertiary system

Red Rock conglomerate: The name Red Rock was tentatively given to a thick coarse conglomerate by Professor Eardley and will be used here even though future writings may refer to it as the Beaverhead conglomerate. The formation covers an extensive area south of Lima, Montana. To date no diagnostic fossils have been found, so the age cannot be exactly determined; however, it is known to be post-Aspen and pre-thrust faulting. Benner (1948, p.35) states that it is unconformably overlain by the upper Eocene Sage Creek formation, making it approximately Paleocene in age.

The Red Rock conglomerate is composed almost entirely of conglomerates but there are some lenses of tan sandstone and salt and pepper sandstone. The conglomerates are composed of boulders and pebbles of quartzite in their second or third stage of erosion, as evidenced by their high polish, and limestone pebbles and boulders, some of which are rounded and others roughly angular.

The conglomerate found in the Tendoy thrust sheet is composed almost entirely of well-rounded pebbles, cobbles, and boulders of quartzite, most of which are of pre-Cambrian Beltian age. Most of the stones have been highly fractured and shattered. The shattering is probably due to orogenic forces associated with the late Laramide orogeny, coupled with the fact that the conglomerate does not have an abundance of cementing material. The fractures have been cemented with some secondary material, often calcite, which serves to hold the stones together until they receive a blow. The jar of rolling down the mountain side is enough to break them into highly angular fragments. This can be seen in the talus below the conglomerate exposures. The color of the quartzite ranges from purple, red and pink to white.

The quartzitic conglomerate of the Tendoy thrust sheet holds up the Continental divide. North of the divide it has a sedimentary contact (angular unconformity) with the Aspen formation. South of the divide it is unconformably overlain by Pliocene rhyolites and by Madison limestone of the Medicine Lodge thrust sheet.

North of the Tendoy thrust sheet, the conglomerate is composed of very angular boulders and pebbles of limestone, massive formations of chert, and lenses of tan sandstone. One of these lenses is over 200 feet thick. The limestones are generally gray in color and are probably derived from the Madison limestone.

The source of these sediments was probably a rapidly uplifted highland to the southwest. The evidence for this assumption is the fact that the sediments become finer as one goes eastward. A huge boulder of Kinnikinick quartzite (Ordovician), at least 12 feet on each side, was found near the west fork of Indian Creek; this is proof of the great floods that must have occured during the deposition of the conglomerate.

Bannock Pass rhyolitic lavas: Kirkham (1927, p.33) described volcanics at Bannock Pass as a series of late Tertiary lavas. Scholten (1948, p.33) named them the Bannock Pass rhyolitic lavas in his thesis area. He describes these lavas as being felsitic with glassy phenocrysts. A microscopic analysis made by Scholten showed that the phenocrysts make up about 8% of the rock and the groundmass is cryptocrystalline. The minerals which make up the rock are potassium feldspar, albite-plagioclase, quartz, some amphibole and biotite, with very little pyroxene, magnetite, and apatite. The groundmass is made up of almost 100% quartz and potassium feldspar which alters to limonite and kaolinite.

The lavas have a lavander color on a fresh surface and weather tan to black; many are vesicular.

The source of the lavas is not known. Kirkham (1927, p.37) believes they belong to the widespread lava sheets which flowed westward from Yellowstone National Park. He believes they covered over 1,000 square miles at one time. They are probably Pliocene in age.

These rhyolites were found only in the extreme southwest and southeast corners of the thesis area. South of the area of this report, the rhyolites are found over an extensive area but are, for the most part, covered by a thick series of basalts flows. The rhyolites are only a few feet thick in the thesis area but they become much thicker to the south.

Snake River basalts: The basalts, which overlie the Bannock Pass rhyolites south of the thesis area, apparently had a tongue extending up the Junction and Beaver Creek valleys almost to Lima. Some of the remnants of this lava tongue now form buttes in the northern part of the area of this report.

Kirkham (1931, pp.193-240) says the basalts are of Pleistocene and Pliocene age. They are black on a fresh surface and weather to a black color. All of the basalts in the thesis area are vesicular.

Quaternary system

Alluvium: Recent flood plain deposits are found in the northern part of the area in the valleys of Junction and Beaver Creeks. This veneer of alluvium masks the axis of the Lima anticline in many places.

STRUCTURAL GEOLOGY

Regional structures

In the broadest terms, this area is located at the boundary of the eastern shelf and the Cordilleran geosyncline. The whole area of southwestern Montana and eastern Idaho was depressed during Mesozoic and Paleozoic times, resulting in the deposition of over 18,000 feet of sediments.

During the late Cretaceous, the Laramide orogeny caused the sediments to be folded, thrusted and faulted. The general trend of the Laramide structures is northwest with overturning and overthrusting to the northeast. These trends are lost under the Snake River downwarp but reappear again on the south side of that structure and extend on into northwestern Wyoming.

The Snake River downwarp is a great sag in the earth's crust that is noted all the way from the Yellowstone Plateau to Oregon. It lies directly south of the thesis area with some of its associated lavas extending into the area. This great structure has been adequately described by Kirkham, (1931, pp.456-482).

Laramide structures

Early Laramide cross-folding: Early in the Laramide period of orogeny, the section of southwestern Montana was subjected to compressional forces that folded the strata into northeast trending folds. The folds trend roughly at right angles to the later folding and thrusting and it is for that reason that they are referred to here as cross folds.

Only one of the early Laramide structures has been found in the thesis area. This structure is found in the Lima Peaks region and is referred to as the Sawmill Creek anticline. Part of the anticline is found in the Tendoy thrust sheet; apparently the major part of the northwest flank of the structure is located under the thrust sheet. The visible part of the anticline shows overturned beds on the northwest flank dipping about 85° to the southwest, and a succession of upper Paleozoic and Mesozoic formations from Carboniferous Amsden to Cretaceous Aspen, dipping 45° to 75° to the southeast on the southeast flank. The Tertiary Red Rock conglomerate masks any evidence of an adjacent syncline to the southeast.

Other cross folds have been found near the area covered by this report. W. L. Adam (1948, p.42) reports several small northeast trending folds just to the west of the thesis area. Wallace (1948, p.36) mapped the northeast trending Little Water syncline about fifteen miles northwest of the Lima Peaks. The Snowcrest range located 40 miles east of the thesis area is a major northeastward trending structure.

Medicine Lodge thrust and related folding: The Medicine Lodge thrust is located in the southwest corner of the thesis area. It strikes northwest from the junction of Irving Creek and Bull Pen Creek and has been traced by Kupsch, Wallace, Cummins, Davis, Bowers and others to a point west of Armstead, Montana. Immediately west of the area, the structure was called the Beaverhead thrust by Adam (1949, p.43). Still farther to the northwest in the Tendoy Mountains, Lipp (1948, p.39) referred to it as the Tendoy thrust. However, as work has progressed in this region, it has become evident that there are at least three thrusts to contend with, and the University of Michigan students who did thesis work in Montana, recently have decided on the following nomenclature. The thrust lying farthest east is, for the most part, in the Tendoy Mountains and thus the name Tendoy thrust seems appropriate. The thrust lying farthest west is within the Beaverhead range and thus will be called the Beaverhead thrust. The thrust lying between these two was first recognized by V.R.D. Kirkham who applied the

Plate 7. Folds in the Red Rock conglomerate, near Bull Pen Creek.

name Medicine Lodge to it. It is the Medicine Lodge thrust that passes through the southwest corner of the mapped area.

The thrust plunges under late Tertiary lavas as it is traced to the southeast from the junction of Irving Creek and Bull Pen Creek. It emerges from beneath the lava cover near Middle Creek where the Madison limestone of the thrust sheet holds up Middle Creek Butte. South of the area mapped by the author, the thrust again plunges beneath the Snake River lavas and is lost.

Kirkham (1927, p.27) thinks that this thrust may be a northwest extension of the great Bannock overthrust which is found south of the Snake River lava plain. The Bannock thrust plunges under the lava with no evidence of dying out and with a general strike of about N20W. Projecting this strike to the north side of the lava plain brings it out very near to where the Medicine Lodge thrust emerges from the lava.

Everywhere the Medicine Lodge thrust has been mapped in Idaho, Madison limestone of Lower Mississippian age has been thrust over Red Rock conglomerate, which is probably Paleocene in age. This, of course, dates the thrust as post-Paleocene. In the thesis area, rhyolites of Pliocene age lie unconformably on the thrust contact; thus, we can say the thrusting was pre-Pliocene. In areas farther north, Basin beds of upper Eocene age are not involved in the thrusting, thus indicating a lower Eocene or late Paleocene age for the thrust.

In Idaho, only Madison limestone is found in the thrust sheet; however, farther to the northwest, in Montana, the Threeforks formation of Devonian age, Ordovician Kinnikinick, and Cambrian Flathead quartzite are found in the thrust sheet.

Kirkham (1927, p.26) estimated the vertical throw of the thrust as at least 10,000 feet and the horizontal overthrust several times that much. There is no evidence in the thesis area as to the amount of overthrust or vertical throw. Farther west in the Nicolia Creek area, Scholten* found what appeared to be the top of a sheared-off anticline which had apparently been carried a distance of ten miles by the thrust sheet.

The thrusting came from the southwest and in the process of overriding the Red Rock conglomerate, caused a series of northwest trending folds to develop in the conglomerate. A syncline flanked by two anti-clines can be seen on the west side of Bull Pen Creek valley. These folds trend northwest-southeast and pitch to the southeast.

*Personal communication.

Tendoy thrust and related folding and faulting: The Tendoy thrust was named from the Tendoy mountains, where it originates (Adam, 1949, p.45). This thrust is apparently the same age as the Medicine Lodge and Beaverhead thrusts, since it overrides the Red Rock conglomerate of probable Paleocene age just as the others do. The thrust can be traced as far north as Big Sheep Creek; it dies out as it is traced into the eastern part of the thesis area.

In the area of this report, the Tendoy thrust trends east to southeast. The thrust sheet contains the previously described Sawmill anticline (p.38) so that tracing the thrust contact from the Lima Peaks eastward shows progressively younger formations truncated along the thrust front. These formations include all the Paleozoic and Mesozoic strata of this area from lower Mississippian Madison (just west of this thesis area) through upper Cretaceous Aspen. The thrust overrides Red Rock conglomerate in the western part of the thesis area; whereas in the eastern part, Aspen is thrust over Aspen.

The amount of vertical throw and horizontal overthrust is unknown other than the thrust appears to have the smallest displacement and the highest thrust angle of the three thrusts found in this region.*

*Personal communication - A. J. Eardley.

Plate 8. Tendoy thrust contact of the Tensleep and Red Rock formations on the north side of the Lima Peaks.

The strata in the thrust sheet were greatly deformed by the thrustal movement. Twisted, overturned beds and local high-angle faulting were observed in the Lima Peaks area of the thrust sheet. A small syncline, trending northwest, was observed in the Aspen formation of the thrust sheet. This structure pitches southeast.

Lima anticline: Directly north of the Tendoy thrust sheet, a broad anticlinal structure has been mapped by Professor A. J. Eardley. The anticline trends roughly northwest and is traceable to the town of Lima.

The pre-Laramide strata have been arched with dips of 30°- 45° from the anticlinal crest. The core of the structure is the Upper Cretaceous Aspen formation. Many minor folds are observed in the outcrops along Junction Creek and Crooked Run; it is probable that these folds die out at depth into one large arch.*

The age of the folding is not known exactly. It could have occured during the mid-Laramide period of orogeny which folded the Red Rock conglomerate in places (Step 5 in Post-Jurassic history). More likely, it occured during the Late Laramide period of thrusting (Step 6), since the trend of the anticline and of the thrust is appoximately parallel.

*Personal communication - A. J. Eardley.

Post-Laramide high-angle faulting

No post-Laramide structures were found in the thesis area; however, such structures have been found in adjacent areas and they will be briefly described here. Cummins (1948, p.37) mentions four high-angle faults striking northwesterly to form a graben (Muddy Creek Basin), a horst (Tendoy Mountains), and a tilted fault block (Red Rock Basin). To the west of the thesis area, Adam (1949, p.47) mapped high-angle faults which produced the Red Rock Basin and the Medicine Lodge Basin. All of the downfaulted areas are associated with the accumulation of Tertiary sediments and are referred to as Tertiary basins.

POST-JURASSIC HISTORY OF SOUTHWESTERN MONTANA

The following sequence of events was worked out at a meeting attended by Dr. A. J. Eardley and students of the University of Michigan who did field work in southwestern Montana during the summer of 1948. Those steps marked with an asterisk indicate that the author has elaborated on the original statement because of pertinent data from the Red Peaks area.

1. Uplift (probably orogenic) of the Cordilleran geanticline and deposition of Kootenai clastics; conglomerate generally at the base.

* 2. Uplift (probably orogenic and lasting through most of Upper Cretaceous) of the Cordilleran geanticline and deposition of the Colorado group clastics. The Bear River and Aspen formations were deposited in the thesis area at this time.

* 3. Early Laramide orogeny to form northeast trending folds. Snowcrest range is prominent element. The Sawmill anticline of the thesis area was developed at this time.

* 4. Deposition of the Red Rock conglomerate. The position of the highland was possibly to the 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. The conglomerates of the thesis area become finer to the east until the formation is almost entirely represented by salt and pepper sandstones near Corral Creek.

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 Tendoy (from north of Sheep Canyon to Middle Creek), Medicine Lodge (from Medicine Lodge Pass, Idaho-Montana line to Armstead and beyond), and Beaverhead (pre-Cambrian, pink granite gneiss sheet and klippen in Medicine Lodge Valley west of Armstead). The Tendoy thrust dies out in the thesis area; the last four miles of the thrust has Aspen thrust over Aspen. The Medicine Lodge thrust continues on into Idaho until it plunges beneath Snake River lavas just south of the thesis area. Probably the Lima anticline developed at this time.

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 the Absaroka Range. Started in the late Eocene. Volcanism of superior magnitude also took place in the Coast Range region of Oregon and Washington at this time. It resulted in the damming of drainage ways and abundant ash and dust falls. Alluviation of great intermontane valleys of southwestern Montana was heavy. Deposition of the 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 notknown.

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

12. Erosion to an extensive surface of moderate relief. In places the pre-Sage Creek surfaces may have been re-exhumed and became co-extensive with this post-Blacktail surface. It is present now in the 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 the Ruby Basin.

* 15. Volcanism in Idaho with one tongue of basalt extending up the Junction and Beaver Creek Valleys into Montana. The rhyolites of the thesis area were extruded followed by extrusions of basalts.

16. Regional uplift, in places possibly more block-faulting, and erosion of extensive pediments Those on the northwest side of the Snowcrest range were most extensively and perfectly developed. Pediments on basin beds of 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.

17. Third episode of block-faulting and alluviation in places. Gentle uplift in places and

dissection of pediments. Two episodes of glaciation in the Beaverheads, probably one before dissection, and one after.

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

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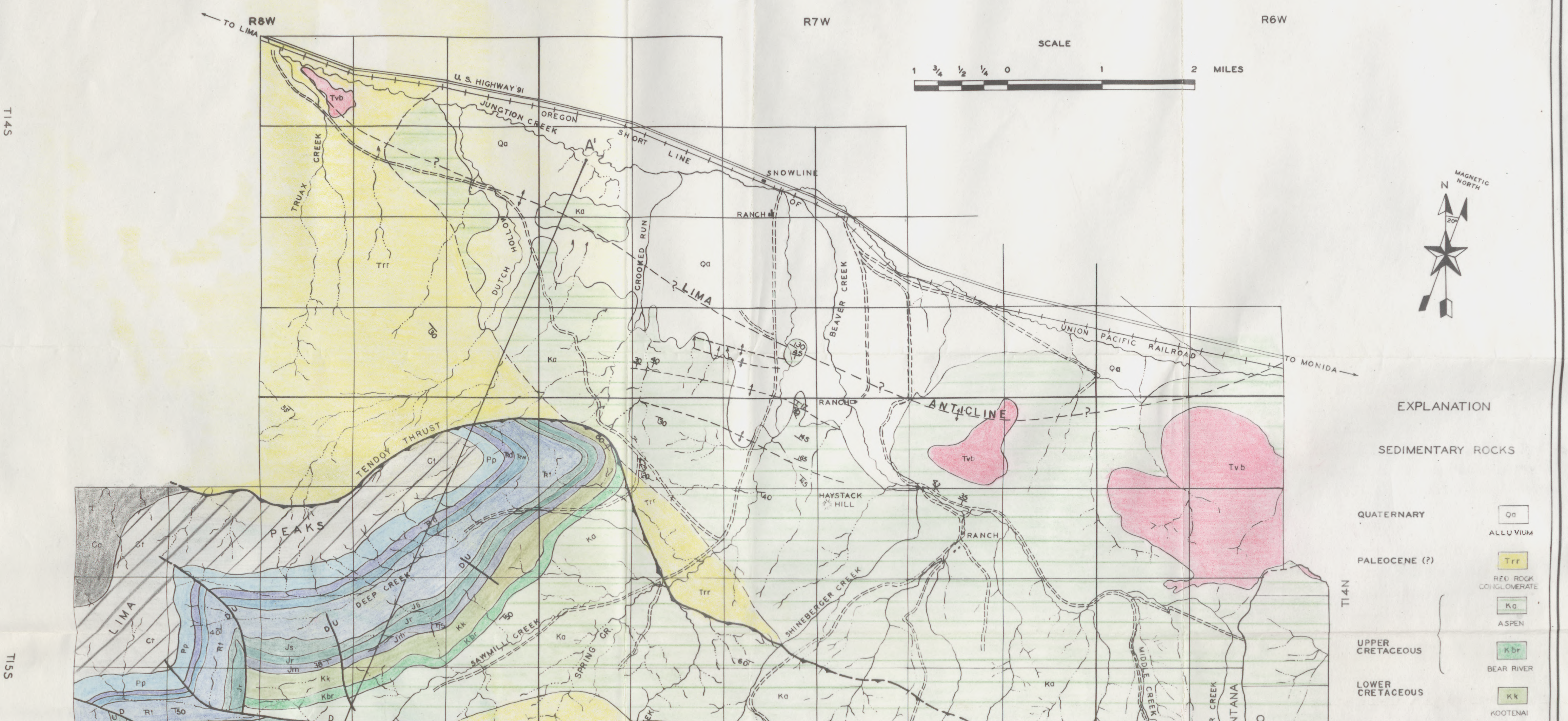
GEOLOGY OF THE RED PEAKS AREA

BEAVERHEAD COUNTY MONTANA & CLARK COUNTY IDAHO

BY J.M. DREXLER E. KILDAL & J.M. McUSIC

AUGUST 1948

COMPILED BY RADIAL LINE ASSEMBLY OF AERIAL PHOTOGRAPHS EXCEPT IN SOUTHEAST PART OF MAP WHERE FOREST SERVICE MAP WAS USED



GEOLOGIC CROSS SECTION ALONG A-A'

SCALE SAME AS MAP SCALE