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

By James M. McUsic

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ABSTRACT

The area described in this report is located in southern Beaverhead County, Montana, and northern Clark County, Idaho. Paleozoic rocks which are present are of Mississippian, Pennsylvanian, and Permian age, and include the Madison, Amsden, Tensleep, and Phosphoria formations. A thick section of Mesozoic strata is also present, including the Triassic Dinwoody, Woodside, and Thaynes formations, the Jurassic Sawtooth, Rierdon, Swift, and Morrison formations, and the Cretaceous Kootenai, Bear River, and Aspen formations. The Paleocene Red Rock conglomerate, Pliocene volcanic rocks, and Recent alluvium make up the Cenozoic rocks in the area. Laramide structures trending northeasterly and northwesterly occur, and include the Sawmill Creek and Lima anticlines, and the Tendoy and Medicine Lodge overthrusts. A geologic history of southwestern Montana is included in the report.

INTRODUCTION

Purpose

The aim of this report is to describe the geology of an area in southwestern Montana and northeastern Idaho which was mapped by the author and his associates during the summer of 1948. The associates were Edward L. Dillon, graduate student at the University of Illinois, who, with the author, mapped the northwestern quarter of the area, and James M. Drexler and Edwin Kildall, graduate students at the University of Michigan, who mapped the remainder. The field work included mapping the contacts of the formations present, determining the structural relationships, and measuring stratigraphic sections wherever possible. Mapping was done directly on aerial photographs, and the final map was produced by the radial line assembly method, using the Multiscope.

Location

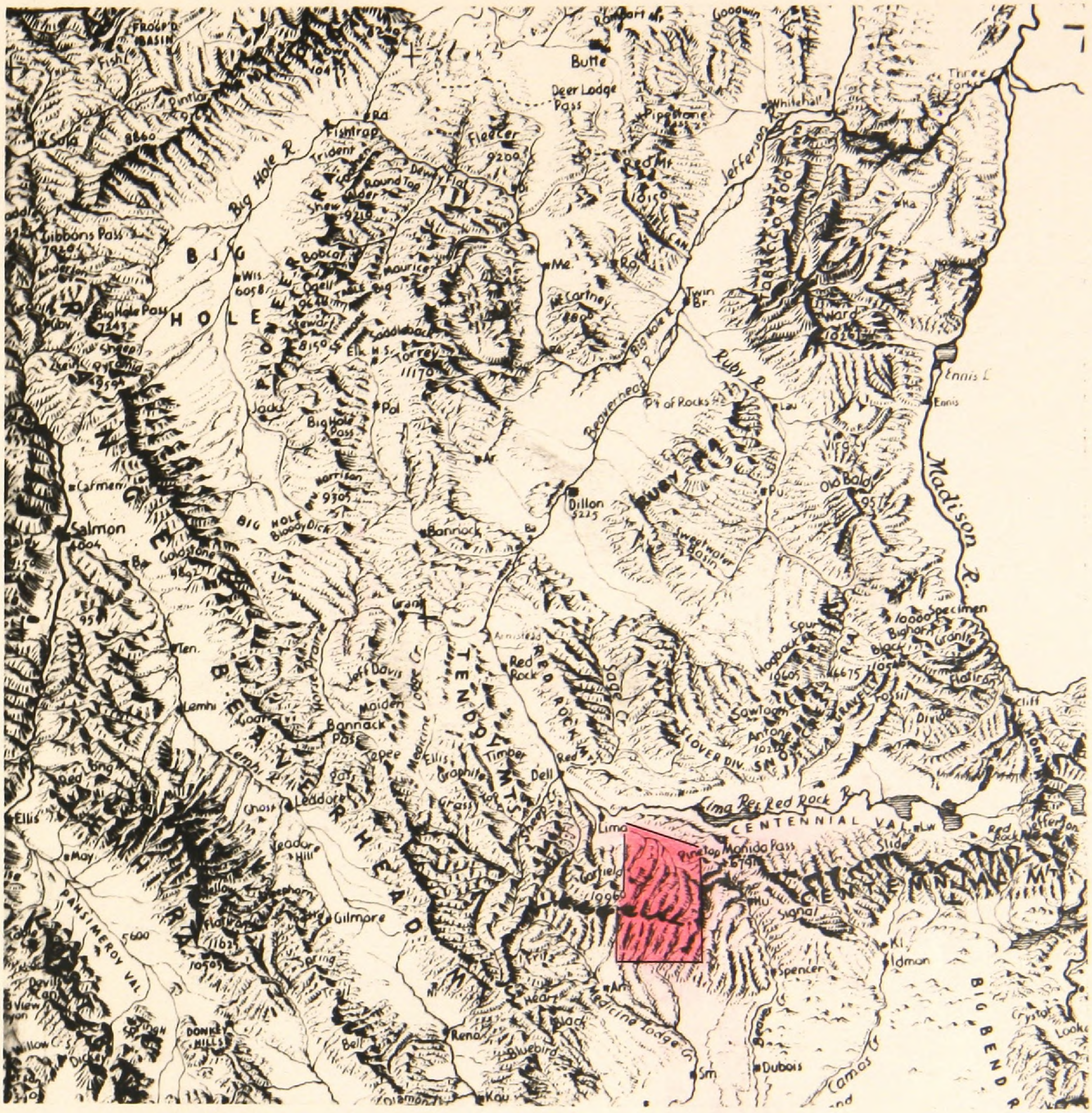
The area described in the report is located in southern Beaverhead County, Montana, and northern Clark County, Idaho, on both sides of the Continental Divide, which forms the state boundary in the region (see index map, page 3). Much of it is included within the boundaries of Beaverhead and Targhee National Forests. The areal boundaries are as follows: U.S. Highway 91 on the north; Modoc Creek in Montana and Corral Creek in Idaho on the east; the township line between T12N and T13N, Idaho, on the south; and Irving Creek in Idaho and a line extending north from the Red Conglomerate Peaks to the vicinity of the town of Lima in Montana, on the west. The entire area can be included within the boundaries of 44°25' to 44°40' N Latitude, and 112°20' to 112°40' W Longitude. All or part of the following ten townships, comprising approximately 180 square miles, are included: in Montana, T14S, R 6,7,8 W; T15S, R 6, 7, 8 W; in Idaho, T13N, R 33, 34 35 E; T14N, R35E.

Topography

The area has 3,800 feet of relief, the highest point of which is in the Red Conglomerate Peaks (10,113') along the Divide, and the lowest, an elevation of 6,265' near Lima, Montana.

Two eastward-trending mountain ranges are the most prominent topographic features in the area. In Montana, the Lima Peaks extend from the western boundary to the headwaters region of Crooked Run (see fig. 2, p.18). They have an average elevation

Plate II



INDEX MAP

of about 9,000 feet, gradually increase in elevation toward the west, and reach a maximum of 10,961 feet (Garfield Mountain) just to the west of the area of this report. The Peaks are an imposing group of mountains, being composed of a resistant red-brown sandstone which weathers into a coarse talus and supports little or no vegetation, especially on the upper slopes. The other range is the Red Peaks, located along the Montana-Idaho boundary, and which may be considered an extension of the Beaverhead Range. The Red Peaks have an average elevation of about 9,000 feet, with Knob Mountain and the Red Conglomerate Peaks extending several hundred feet higher (see fig. 7, p.38). The drainage divide of this range is the Continental Divide in the region; streams in the Montana part of the area drain into the Missouri River system, whereas those in Idaho drain into the Snake-Columbia River system. As their name implies, the peaks are composed of a coarse, reddish Tertiary conglomerate which weathers into unusual forms, with a rugged, picturesque topography resulting.

A conspicuous hogback ridge, trending west and formed by steeply dipping Mesozoic strata, is present between the valleys of Deep and Sawmill Creeks in Montana. Middle Creek Butte, composed of a massive Carboniferous limestone formation, and located in the extreme southern part of the Idaho area, is another topographic feature worth mentioning.

Drainage

The Montana area is drained by Junction and Beaver Creeks and their numerous tributaries. Beaver Creek flows into Junction Creek, which enters the Red Rock River near the town of Lima. The waters eventually reach the upper course of the Missouri River in northeastern Montana. In the Idaho area, Irving, Eidie, Middle, and Indian Creeks drain southward into Medicine Lodge Creek, which flows into the Snake River.

Due to the semi-aridity of the region (average rainfall is 13 inches per year) the stream integration is incomplete; there are a number of intermittent streams which do not connect with the perennial creeks but end abruptly where the slope flattens. The dry climate is also responsible for the prominence of limestone strata as ridge formers, the restriction of wooded areas to the north slopes of hills and ridges, and the general paucity of vegetation except in the creek bottoms.

Accessibility

Ranch roads, passable during the summer except immediately after heavy showers, permit most of the area to be reached by automobile or truck (see geologic map in pocket). In Montana, one road leads from U.S. Highway 91, near Lima, south to Deep Creek, with a branch leading to the junction of Deep and Sawmill Creeks. A similar road leads from Snowline (on the highway) south along the east bank of Beaver Creek to Shineberger and Swamp Creeks. Good horse or foot trails exist in the areas not otherwise accessible; one which is worthy of mention is Forest Service trail #40, which follows Deep Creek to its head and then crosses the drainage divide to the head of Little Sheep Creek, west of the author's area. The Idaho region is reached by a good motor road which follows Medicine Lodge Creek north from the Dubois-Arco road; dirt roads lead up the various tributaries from the main road.

Previous Study in the Area

Prior to the summer of 1947, very little geologic or topographic work had been done in the general region of this report. No topographic maps covering the author's area have ever been made. U.S. Forest Survey maps of Beaverhead and Targhee National Forests were used as base maps. R. V. D. Kirkham, of the Idaho Bureau of Mines and Geology, made a geologic reconnaissance of Clark and adjacent counties in 1925; a report of his findings was published by the Bureau in 1927 (22). E. S. Perry and U. M. Sahinen of the Montana School of Mines made a brief reconnaissance of part of southwestern Montana in 1946 (30). Copies of their unpublished map were made available to the author's party and others. Beginning in 1947, the department of geology of the University of Michigan instituted a program of detailed geological mapping in southern Montana, under the direction of Dr. A. J. Eardley, as part of their graduate thesis work plan. The work of the author and his associates was a part of the program.

Acknowledgments

The author is indebted to Dr. A. J. Eardley, who supervised the field work, preparation of the final map, and writing of the report itself. Edward L. Dillon was an able and enthusiastic co-worker in the field, and James M. Drexler and Edwin Kildall worked with the author in preparing the final map. Robert Scholten, in whose doctoral area the author worked, aided in the solution of many of the geologic problems encountered, and William Roth, of Carleton College, assisted during the latter part of the summer with the field and camp work.

STRATIGRAPHY

Introduction

Rocks ranging in age from Mississippian to Recent crop out in the area of this report. Every period in the upper Paleozoic and Mesozoic eras is represented by at least one formation. The formations are summarized in the stratigraphic column (page 9).

The Paleozoic era is represented by the Mississippian Madison limestone, the Amsden formation (believed to be partly Mississippian and partly Pennsylvanian in age), the Pennsylvanian Tensleep formation, and the Permian Phosphoria formation. All of these formations except the Madison crop out in stratigraphic succession in the Sawmill Creek anticline area in Montana (see geologic map in pocket). In the author's area, the Madison occurs only in the thrust sheet of the Medicine Lodge thrust in Idaho; however, this formation and older ones are present in the Lima Peaks region in Montana, immediately west of the area of this report, and have been described by other workers (1, 2). The Paleozoic strata present measure about 6,500 feet in thickness.

STRATIGRAPHIC COLUMN

Age	Formation	Thickness
Quaternary	Alluvium	----
Pliocene (?)	Rhyolite flows	----
	Basalt flows	----
Paleocene (?)	Red Rock conglomerate	2,000' (est.)
Upper Cretaceous	Aspen formation	3,437'
	Bear River formation	365'
Lower Cretaceous	Kootenai formation	1,080'
Jurassic	Swift and Morrison fms. (?)	300'
	Rierdon formation	62'
	Sawtooth formation	198'
Triassic	Thaynes formation	1,941'
	Woodside formation	117'
	Dinwoody formation	189'
Permian	Phosphoria formation	417'
Pennsylvanian	Tensleep sandstone	2,970'
Mississippian-Pennsylvanian	Amsden formation	2,022'
Mississippian	Madison limestone	1,000' (est.)

Mesozoic rocks include the Triassic Dinwoody, Woodside and Thaynes formations, the Jurassic Sawtooth, Rierdon, Swift (?), and Morrison (?) formations, and the Cretaceous Kootenai, Bear River, and Aspen formations. These rocks crop out in succession in the Sawmill Creek area, as a continuation of the Paleozoic sequence described above. The high angle of dip and the lack of vegetative cover made measurement of beds in this area relatively easy, and good sections were obtained of most formations. Some 7,800 feet of Mesozoic rocks were measured.

Cenozoic strata include the Red Rock formation, a thick pebble- to boulder-conglomerate of probable Paleocene age, rhyolitic and basaltic lava flows of probable Pliocene age, and Quaternary alluvium.

A complete description of the stratigraphy in the northwest part of the area of this report, including detailed sections and attempted correlations with other regions, is included in the thesis of the author's co-worker, E. L. Dillon (15), and should be consulted if more specific information is desired. Credit should also be given to Dillon for the identification of the fossils described; such faunal study resulted in the redrawing of several formational boundaries.

Mississippian system

Madison formation The Madison formation was named by A. C. Peale from outcrops in the Madison Range, near Three Forks, Montana, where it rests on the Devonian Three Forks limestone and is overlain by the Quadrant formation (29). The Madison was later divided in northern Montana into two distinct members, the lower (Lodgepole) unit consisting of a very fossiliferous, thin-bedded limestone-shale sequence, and the upper (Mission Canyon) unit, which is a massive, less fossiliferous marine limestone (11). In the area of this report, the Madison forms the thrust sheet of the Medicine Lodge thrust in Idaho. Since only a massive, grayish limestone was observed, the Mission Canyon member is apparently the only one present in the area. The thickness was estimated at 1,000 feet in Middle Creek Butte, where the massive, homogeneous character of the formation is quite apparent. It is of lower Mississippian age, and is normally overlain by the Amsden formation.

Pennsylvanian system

Amsden formation The Mississippian-Pennsylvanian boundary in the area is transitional, and its exact position is the subject of much debate. The age of the Amsden formation is important in determining this time boundary; it is now generally believed that the lower Amsden beds represent Mississippian deposition, whereas the upper part of the formation is of Pennsylvanian age.

N. H. Darton originally applied the name Amsden to a group of red shales, white limestones and cherty, sandy limestones exposed along the Amsden branch of the Tongue River in Wyoming (12). He considered the formation to be Mississippian in age, on the basis of fossils found in the lower beds. Subsequent study of fusilinids from the formation show most of it to be lower Pennsylvanian in age. The diagnostic fusilinid genus is Millerella, a lower Pennsylvanian form.

The Amsden can be divided into three members in Wyoming and most of Montana, the upper and lower units being composed of interbedded limestone and shale, separated by an intermediate member, the Darwin sandstone.

A complete section of the Amsden did not occur in the author's area; for this reason, a section measured by E. G. Lipp (25) in the Tendoy range, about 15 miles to the west, was studied. Lipp did not divide the formation into its three members, but Dillon (15) believes such a division possible, on the basis of comparison with the section reported by H. Foster (17) in western Wyoming. The upper member is composed of 655 feet of alternating gray-brown shales and cherty limestone beds. The Darwin member consists of 144 feet of thin- to thick-bedded tan sandstone, and the lower unit is made up of 1,223 feet of argillaceous and crystalline limestone interbedded with gray calcareous shale. The total thickness is 2,022 feet.

In the region of this report, the Amsden apparently conformably overlies the Madison formation. In western Wyoming, the Brazer formation of middle Mississippian age is recognized as overlying the Madison and underlying the Amsden (17). C. P. Ross, in describing an area 40 miles to the southwest, states that the Brazer overlies the Milligan formation, which is the Idaho equivalent of the Madison, but does not mention the Amsden (32).

C. C. Branson reported a disconformity existing between the lower Amsden (which he called the "Sacajawea member") and the Darwin sandstone in central Wyoming, and places the Mississippian-Pennsylvanian boundary at that level (6).

The Amsden formation is conformably overlain by the Tensleep formation.

Tensleep formation The Tensleep formation was named by N. H. Darton from white sandstone outcrops along Tensleep Creek, Wyoming (12). The name Quadrant has been previously used by workers in the region to designate the formation. However, since the original Quadrant section, as described by A. C. Peale (29) and W. H. Weed (37), included the limestone-shale sequence now known as the Amsden, as well as the typical Pennsylvanian sandstones (34), it is felt that the Wyoming name is more appropriate. The formation is of lower Pennsylvanian age.

In the general region of this report, the Tensleep is composed essentially of highly resistant, dense, tan to white sandstone. The upper part is dolomitic, and toward the top of the formation limestones with interbedded chert layers appear. The lowermost beds are also dolomitic, with cross-bedded structure. The Lima Peaks are composed of this massive sandstone, which weathers into a coarse, angular talus, upon which no vegetation will take hold (see fig. 8, p.38).

It was impossible to measure the complete Tensleep section in the author's area, due to the difficulties encountered on the talus-covered slopes. E. G. Lipp, at the location mentioned above, measured a thickness of 2,970 feet (25). A thickness of 2,800 feet has been reported by Carl Moritz of the Phillips Oil Company in Little Sheep Creek, immediately to the west (personal communication).

Permian system

Phosphoria formation The Phosphoria formation was named by H. W. Richards and G. R. Mansfield from outcrops in Phosphoria Gulch, near Meade Park, Idaho (31). It is a comparatively non-resistant formation in the author's area, and appears as a distinct break in slope on the southeastern flank of the Lima Peaks. The formation was 417 feet thick where measured, and included the following units: a phosphatic shale near the top, underlain by cherty, and in places fossiliferous, limestone, a distinct chert zone below the limestone, and a ten foot grassy covered interval at the bottom, above the Tensleep formation. The uppermost bed of phosphatic shale is essentially the same as the upper boundary of the formation established by Condit, Finch and Pardee in the Three Forks, Montana, region (10). Some of the underlying limestone beds are quite fossiliferous, containing siliceous representatives of the genera *Composita* and *Pustula*. The Rex Chert member, which G. R. Mansfield describes in his original report (26), is not a distinctive unit in the area of this report. Assuming that the lowermost covered interval is underlain by phosphate rock, the formational boundary agrees very well with that established by D. D. Condit, who states that the lowermost bed of the

Phosphoria is a non-resistant layer of phosphate rock, overlain by a cherty quartzite containing scattered phosphate granules (9). Dillon (15) discovered microscopic black grains in the chert zone of the author's section mentioned above, which may correspond to Condit's granules.

The exact age of the Phosphoria is in dispute. Some workers place it in the middle Permian (27), while others consider at least the lower part to be lower Permian (18).

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

Triassic system

Dillon's revision Important revisions were made in the Triassic section, which changed the formational boundaries from those previously established by workers in the Lima area. Earlier geologists, such as E. G. Lipp (25), had differentiated the Dinwoody, Woodside, and Thaynes formations on the basis of lithologic appearance, the Dinwoody being an alternation of gray crystalline limestones and shales, the Woodside being composed of non-resistant brown siltstones and impure limestones, and the Thaynes as being above the Woodside and marked by limestones containing *Pentacrinus* columnals. However, Dillon (15) states that ammonites from the limestone near the base of the so-called "Dinwoody" have been identified by Dr. B. Kummel of the University of Illinois as specimens from the "Meekoceras limestone" which marks the base of the Thaynes formation (24). Consequently, most of the 2,247 feet of Triassic exposed in the area is definitely in the Thaynes formation.

Dinwoody formation The Dinwoody was named by Blackwelder from outcrops of gray-green shales and thin dense sandstones found in Dinwoody Canyon in the Wind River Range, Wyoming (4). In his description, the uppermost Phosphoria bed is overlain by a red-brown shale bed which forms a distinct lithologic break. In the author's area, a dark-gray shale marks the base of the formation. Dark brown sandstone and light gray limestone are also present in the formation, which has a thickness of 189 feet (see fig. 1, p. 18). The formation is basal Triassic (28).

Woodside formation Conformably overlying the Dinwoody is the Woodside formation, named by J. M. Boutwell from an exposure of dark red shale in Woodside Gulch, Park City District, Utah (5). In the area of this report, the Woodside consists of 117 feet of thin-bedded pink and brown sandstones, pink sandy dolomite, and red to brown calcareous siltstones (all poorly exposed) below the "Meekoceras limestone" base of the Thaynes and above the typical Dinwoody shales and sandstones. The lithology agrees

Figure 1. Outcrop of sandstone unit of Dinwoody formation north of Deep Creek, showing blocky weathering.

Figure 2. Vertical ridges of oolitic limestone of Rierdon formation, south of Deep Creek. Lima Peaks in background.

substantially with a description of the formation by V. J. Kennedy near Jackson, Wyoming (21). The formation is lower Triassic in age.

<u>Thaynes formation</u> The Thaynes was named by J. M. Boutwell from outcrops in Thaynes Canyon, Park City District, Utah (5). The formation name was later carried into Idaho and Wyoming, where it was defined as the strata from the base of the <u>Meekoceras</u> limestone to the base of the Ankareh shale (24). A section 1,941 feet thick was measured in the author's area. The basal unit of the formation is a gray-brown crystalline limestone containing some sandy dolomite. This unit contains the narrow (nine feet) <u>Meekoceras</u> bed which has been established by Kummel as the base of the formation. Besides <u>Meekoceras sp.</u>, another ammonite, <u>Clypites</u> sp., was identified by Dr. Kummel, and a number of other unidentifiable forms were found in the thin bed. Above the <u>Meekoceras</u> zone lies nearly 600 feet of calcareous sandstones, shales and thin-bedded limestones, overlain by a prominent gray-brown dolomite layer. The limestone bed immediately above the dolomite was thought by earlier workers to be the top of the Dinwoody formation, and the 250 feet above the limestone unit was mapped as Woodside (25). The resemblance of this 250-foot section to the calcareous sandstones of the Woodside near Jackson, Wyoming (21),

was probably the reason for such a division. The sandstone easily weathers to a brown, sandy soil, with a few of the more resistant layers forming small ridges.

Above the calcareous sandstones occurs the so-called "*Pentacrinus* limestone", a resistant unit which was formerly regarded as the base of the Thaynes in this region. As the name implies, *Pentacrinus* columnals are very abundant in this unit. Several hundred feet of thin-bedded crystalline limestones and calcareous sandstones occur above the *Pentacrinus* zone. The top of the section is marked by a cherty limestone unit, making a distinct lithologic break with the overlying siltstones of the Jurassic Sawtooth formation.

The Thaynes is lower Triassic in age (24), and is unconformably overlain by the Jurassic Sawtooth formation.

Jurassic system

Sawtooth formation Two Jurassic formations, the Sawtooth and Rierdon, definitely outcrop in the author's area, and Dillon (15) has shown by correlation that two others (Swift and Morrison) may be present, although not exposed. Some 560 feet of Jurassic sediments are present.

The Sawtooth formation in the area of this report consists of 198 feet of non-resistant brown calcareous shales, siltstones, and thin-bedded limestones which weather into a characteristic yellow-brown soil between the upper Thaynes limestones and the oolitic limestones of the overlying Rierdon. The formation is quite fossiliferous, and Dillon (15) has identified species of the following genera: _Ostrea_, _Placunopsis_, _Gryphea_, _Pentacrinus_, _Goniopygus_, _Serpula_, _Aviculopecten_, _Pleuromya_, _Lima_, and _Camptonectes_.

W. A. Cobban (8) named the Sawtooth from exposures in the Sawtooth Range of Montana. He recognized three members in the Sweetgrass Arch district, Montana: a lower light gray, fine-grained sandstone member, an intermediate dark gray calcareous shale containing some nodular limestone, and an upper member of highly calcareous siltstone and sandy limestone. These members can be recognized in the section measured in the author's area. The Sawtooth is considered to be of middle Jurassic age (20), and is the approximate equivalent of the lower part of the Twin Creek formation of western Wyoming.

Rierdon formation Overlying the Sawtooth is the Rierdon formation, which in the author's area consists of 62 feet of very resistant oolitic limestone, in places forming cliffs and ridges as high as 50 feet (see fig. 2, p. 18), and some 300 feet of covered interval which may represent the Swift and Morrison formations (described below). The Rierdon was named by W. A. Cobban, from outcrops of calcareous gray shale and gray limestone in Rierdon Gulch, Sweetgrass Arch district, Montana (8). In the author's area, the formation (excluding the unknown covered zone) consists of oolitic limestone entirely, with variations only in the thickness of bedding. No fossils were found in the Rierdon, although an abundance are reported in the area of the type section. The age of the formation is considered to be upper Jurassic (20).

<u>Swift and Morrison formations</u> Between the oolitic limestone outcrops of the Rierdon and the basal conglomerate of the Cretaceous Kootenai lies a covered unit, some 300 feet thick, with a light brown soil visible throughout. This interval may represent the Swift and Morrison formations, and was so mapped in the field.

The Swift was named by Cobban from outcrops near the Swift reservoir, Montana (8). The formation represents the upper part of the Ellis group, whose lower members are the Sawtooth and Rierdon. It is composed of flaggy sandstones and non-calcareous shales, and is present throughout Montana, varying in thickness from three to 234 feet. In Little Water Canyon in the Tendoy range (20 miles northwest of the area of this report), the Swift is ten feet thick, and in Madison county (50 miles to the northeast) it is 16 feet thick. It is a marine formation, and rests with small unconformity on the Rierdon in these areas.

The non-marine Morrison formation overlies conformably the Swift in most of Montana. It is 375 feet thick on Indian Creek in Madison County, and consists of varigated siltstones and claystones, with some interbedded sandstone and limestone (20). The basal Kootenai conglomerate overlies the Morrison in that area. The age of the Swift is upper Jurassic, and the age of the Morrison is in dispute, probably being upper Jurassic as well.

Cretaceous system

Kootenai formation An excellent exposure of the Cretaceous section was found in the area of this report. Some 5,000 feet of Upper and Lower Cretaceous rocks are present, which consist of the Kootenai, Bear River, and Aspen formations. The Aspen makes up the greater part of the section.

The Kootenai was named by J. W. Dawson (13), and rests unconformably on the Jurassic Morrison formation. It is of Lower Cretaceous age. The basal conglomeratic sandstone of the formation is persistent, and has been reported at various localities in Montana (3). Above the conglomerate lies some 300 feet of coarse-grained sandstone and sandy shales, topped by a thin conglomeratic sandstone and sandy shales, topped by a thin conglomeratic sandstone which probably represents a minor diastem. This layer apparently correlates with the medial Kootenai conglomerate mentioned by C. Deiss in the Sawtooth range of central Montana (14). The central part of the formation consists of numerous limestone units interbedded with some calcareous shales. Some of the limestone strata contain small gastropods in prolific numbers, forming a coquina-like rock. These "gastropod limestones" are typical of the Kootenai in this part of Montana. Species of _Viviparus_ and _Campeloma_ were identified by Dillon (15). The upper 150 feet of the formation consists primarily of gray to brown calcareous sandstone containing some interbedded shale and a third thin conglomerate bed, which may correlate with a similar bed found by Deiss in the upper-middle part of the Kootenai (14). A total thickness of 1,080 feet was measured, which compares closely with Deiss' 1,100 feet in the Rierdon Gulch section.

Bear River formation Conformably overlying the Kootenai is the Bear River formation, originally named by F. V. Hayden from an outcrop near Bear River City, Wyoming (19). A section 365 feet thick was measured in the area of this report, the lower 180 feet consisting of an arkosic "salt and pepper" sandstone, and the remainder of calcareous shales and sandstones. The lower part has been classified as a separate formation, the Dakota, by some geologists in the area, although the term is more appropriate to eastern Wyoming outcrops. This "Dakota" member is a resistant sandstone, weathering to a coarse talus reminiscent of Tensleep talus at first glance; the former is finer grained, and contains sub-angular grains of ferro-magnesian minerals as well as quartz, thus giving the "salt and pepper" appearance to the rock (see fig. 3., p. 26). The upper part of the Bear River contains a fresh water coquina, in which species of Unio were found. The formation is Upper Cretaceous, and is overlain by the Aspen formation.

Aspen formation The name Aspen was first applied to a series of black and gray shales exposed near Aspen Station, Uinta County, Wyoming, by A. C. Veatch (36). The term Mowry, of eastern Wyoming origin, has been used by some geologists for the Montana outcrops, but the varigated shales and porcelainite beds resemble the Aspen section more closely (21). A composite section, measuring 3,437 feet in thickness, was taken in the Aspen outcrops near Sawmill Creek in the author's area. About 1,150 feet of the middle of the section is covered by alluvium in the creek valley. Some repetition of beds undoubtedly could be seen in this area if the alluvium were removed,

Figure 3. Coarse sandstone talus of Bear River formation ("Dakota" member) along Deep Creek.

Figure 4. North Paint Pot on Sawmill Creek, showing "badlands" weathering in Aspen formation.

since sharp folding and local faulting is apparent in the exposures west of the creek. The formation consists of many thin beds of varigated shales, porcelainites, "salt and pepper" sandstones, bentonitic clay, and one thin conglomerate bed near the top. The uppermost part of the section is obscured by the alluvium of a tributary of Sawmill Creek.

The origin of the porcelainite and bentonite beds is not definitely known; several theories have been advanced, all of them pre-supposing a fall of volcanic ash. E. Dobrovolney examined the porcelainite microscopically, and found it to be made up of unweathered particles of volcanic dust and glass (16). In the author's area, a volcanic breccia which had weathered to a porcelainite-like surface made up one of the thin beds in the Aspen. Dillon reported that the breccia contains angular grains of quartz, plagioclase feldspar, sanidine and large fragments of carbon; the latter may represent the carbonized remains of plants (15). H. L. Foster has suggested that volcanic ash falling in sea water may alter to bentonite, while that falling in lakes may alter to porcelainite (17). W. W. Rubey advances the theory that the deposition in sea water of a volcanic ash of high silica content, with the subsequent decomposition of the ash and precipitation of silica by decaying organic matter will produce porcelainite (33).

Identifiable fossil plant leaves were found in a thin lithographic limestone unit of the Aspen (see fig. 5, p. 30). One gymnosperm, Podozamites lanceolatus, and three angiosperms, Hicoria, Cornus forchhameri, and Platanus platanoides were identified by Dillon (15). Fossil plant leaves were first reported from the Aspen by A. A. Weymouth from a locality near Kemmerer, Wyoming, and they have been found in many other localities since (7). Several carbonized tree trunks, up to one foot in diameter, were found in a bentonite bed above the strata containing the plant leaves. The trunks were apparently carbonized by a fall of hot volcanic ash which later altered to bentonite.

One of the most unusual topographic features in the author's area is the "badlands" landscape found in the Aspen formation on both sides of Sawmill Creek (see fig. 4, p. 26). The bentonite beds are easily eroded, and the sudden mountain showers have cut intricate gullies into the strata. The hard porcelainite layers resist erosion, and form many little ridges between the eroded gullies. Slumping of large masses of bentonite contribute to the jumbled nature of the terrain. Near the obscured upper part of the section, several small hills of bentonite (up to ten feet high) rise out of the flat valley floor; their presence is, at least, partially due to the swelling nature of bentonite when wet.

Numerous vertebrate bone fragments were found near these hills, and an attempt is now being made to identify them.

The Aspen is of Upper Cretaceous age. The Frontier formation, which overlies the Aspen in most of Wyoming and Montana, is not present in this area.

Tertiary system

Red Rock conglomerate Lying with angular unconformity on older sediments in the general region of Lima is the Red Rock conglomerate, named from outcrops along the Red Rock River, several miles north of the author's area. No fossils have been found to date in this formation, so the exact age is unknown: however, it is known to be younger than the early Laramide period of folding, and older than the late Laramide thrust faulting (see Geologic History below). Benner states it is unconformably overlain by the upper Eocene Sage Creek formation, so it is generally considered Paleocene in age (2).

The Red Rock is a boulder and pebble conglomerate, its texture varying considerably from place to place. Quartzite and limestone pebbles are present, the quartzite probably being of pre-Cambrian Beltian age, whereas the limestone is thought to have been derived from the Mississippian Madison formation. The quartzite

-Photograph by T. Beard

Figure 5. Specimen of fossil plant leaves, Aspen formation.

Figure 6. Outcrop of Red Rock conglomerate near U. S. Highway 91.

pebbles have evidently passed through more than one stage of erosion as shown by the fact that they are well rounded and possess a high polish. The color of the quartzite may be purple, pink, or white. The limestone pebbles may be angular or well-rounded, and are generally gray in color. The cementing material varies both in abundance and color, being red, brown or white; it is generally calcareous. In some localities, sandstone lenses are present in the formation in variable thicknesses and lateral extent.

The lithologic variation of the Red Rock is well illustrated within the area of this report. The formation occurs in two places: north of the Lima Peaks in Montana to the northern boundary, and in the Red Peaks area along the Continental Divide. In the first location, the conglomerate is on the underthrust side of the Tendoy thrust, and forms a highland area north of the Lima Peaks proper. Near the thrust trace, the formation is composed of angular to sub-angular pebbles and cobbles of limestone and quartzite, with limestone predominating; the cement is red and calcareous, and many thin brown sandstone lenses are present. As the conglomerate is traced northward, the pebbles show a greater variation in size (many are boulders), limestone pebbles are present almost exclusively, and the sandstone lenses, although fewer in number, are of greater thickness (see fig. 6, p. 30). One lens south of U. S. Highway 91 near Lima was about 200 feet thick, but of limited extent. Along Junction Creek, where a sedimentary contact exists between the Red Rock and the Cretaceous Aspen formation, the Red Rock is finer textured, and is composed principally of coarse-grained sandstone with pebble-conglomerate lenses present.

Along the Continental Divide, where the formation holds up the Red Peaks, quartzite pebbles and cobbles predominate (see fig. 7, p. 38). On the south side of the Divide, where the Red Rock has been overthrust by the Medicine Lodge thrust, many of the pebbles have been fractured (apparently by the weight of the overlying thrust sheet) and recemented with secondary calcite. Cementing material is scarce in this part of the formation, and the pebbles and cobbles are in contact with each other. North of the Divide, cementing material is more abundant, and sandstone lenses up to five feet thick appear.

As the Red Rock is traced down the north slope of the Peaks toward the Aspen contact, the texture becomes finer, with conglomeratic phases, just as it did north of the Tendoy thrust, as described above. This fact would seem to indicate periods of gentle uplift at the beginning of Red Rock times, followed by more abrupt action later, when the main mass of conglomerate was deposited. However, little can be known about the conditions of deposition of this thick terrestial deposit until it has been more thoroughly studied over a wide area. Dr. Eardley estimates that the formation is 2,000 feet thick near Lima (personal communication).

Volcanic rocks Lava flows of both rhyolitic and basaltic character are present in the area of this report. In Idaho, rhyolitic lavas are observed near the Medicine Lodge thrust contact, which is overlapped by the flows in places. The rock is lavender-colored on a fresh surface, weathering brown. It is only a few feet thick. The texture is felsitic and vesicular, with small phenocrysts of feldspar present. R. Scholten described the rock in the Nicolia Creek area, about fifteen miles to the west (35). He called them the "Bannock Pass rhyolitic lavas", and upon making a petrographic examination found that they contain potassium feldspar, albite, quartz, amphibole, biotite, and small amounts of pyroxene, magnetite and apatite. R. V. D. Kirkham, in his report (22), refers to the rocks as "late Tertiary lavas", and believes that they are a part of the widespread lava sheets which spread westward from the Yellowstone Park area at that time. Later workers, such as Benner (2), have assumed their age to be Pliocene.

In the Montana area, a few remnants of basalt flows occur as caprock on buttes composed of Red Rock conglomerate. The basalt is steel gray to black in color, felsitic and vesicular in texture, and contains small phenocrysts of olivine. Kirkham believes the rock to be of Pleistocene or Pliocene age (22). H. H. Krusekopf found similar basalts overlying the lower Pliocene Muddy Basin formation, and concluded that the flows were Pliocene in age (23). The source of the lavas is not definitely known.

Quaternary system

Alluvium Stream alluvium is present in all the valley bottoms in the area, and is thickest and most widespread in the valley of Junction Creek, south of U. S. Highway 91, where hay is grown on irrigated land.

STRUCTURE

Introduction

Two periods of major deformation are apparent in the area of this report. A northeast trending overturned anticline was produced during the first period. At a later time, two northwest trending thrust faults of extensive magnitude were formed, as well as several folds of the same general trend. The two periods are apparently of early and late Laramide age (see Geologic History below).

Early Laramide Structures

Sawmill Creek anticline In the western part of the Montana area, an anticlinal structure composed of the normal sequence of Paleozoic and Mesozoic rocks occurs. The beds strike generally northeast and dip toward the southeast. As the formations are traced along strike toward the northeast, the dips increase from 45° to 90°; the strike then veers toward the northwest for a short distance, with the strata overturned as much as 60°. The structure is then sheared off by a thrust fault, and no longer traceable. Since the entire sequence of formations from the Carboniferous Amsden to the

Cretaceous Aspen are exposed, the anticline must have been of considerable proportions. The high angle of dip and the complete succession enabled the author and his associate to measure most of the formations with comparative ease.

Other northeast trending structures have been found in near-by areas. W. L. Adam (1) found several small synclines with such a trend immediately to the west of the author's area, and the Snowcrest Range, located 40 miles to the east, shows similar folding.

The age of the orogeny which formed the folds is assumed to be early Laramide (late Cretaceous), since all of the Mesozoic formations are involved, and since later Laramide thrusting is apparent which cuts the folds.

Late Laramide Structures

Tendoy thrust   An overthrust is observed in the Montana area, which trends east to south-east from the western boundary, and apparently dies out toward the east. This thrust was first mapped by W. L. Adam (1) and R. Benner (2) in the area immediately to the west, along what was originally thought to be a sedimentary contact. It is traceable as far as the Tendoy Mountains, 20 miles to the west. It should not be confused with the Tendoy thrust mapped by H. Krusekopf (23) and E. G. Lipp (25), which is now called the Medicine Lodge thrust (see explanation below). The thrust sheet in the author's area is composed of the sheared-off anticline described above, which is thrust northward over the Tertiary Red Rock conglomerate except toward the eastern end of the thrust, where it overrides the Cretaceous Aspen formation (see fig. 8, p. 38). Considerable distortion of the strata and local high-angle faulting is apparent in the thrust sheet. The horizontal and vertical extent of thrust movement is unknown, although it must have been of considerable magnitude. The age of the Tendoy thrust is considered to be the same as the other southeast trending overthrusts in the region (upper Paleocene or lower Eocene); an explanation of this age determination is given under the description of the Medicine Lodge thrust.

<u>Lima anticline</u> North of the Tendoy thrust, the Mesozoic and Paleozoic formations have been arched upward into a broad fold, trending southeast to east. This structure has been named the Lima anticline by Dr. A. J. Eardley, who originally mapped it, and from whose unpublished map was obtained the information concerning the structure's trend. The anticline is traceable north-westward to the town of Lima. The core of the fold is the Cretaceous Aspen formation; dips from the anticlinal crest range from 30° to 45°. Many minor folds are observed in the Cretaceous

Figure 7. The Red Conglomerate Peaks and Knob Mountain, showing the uniform southward dip of the Red Rock conglomerate.

Figure 8. Thrust contact of Tensleep and Red Rock formations, north side of Lima Peaks. Tendoy thrust.

outcrops along Junction Creek and Crooked Run; it is Dr. Eardley's opinion that these folds die out at depth into one broad arch. The age of the folding is not known exactly, but probably occurred during the period of overthrusting, since the trends of the thrusts and of the anticline are approximately parallel.

A small syncline of similar trend is present in the Aspen formation near the eastern end of the Tendoy thrust. The structure pitches toward the northwest.

Medicine Lodge thrust Another overthrust is found in the southeast corner of the Idaho area. From the junction of Irving and Bull Pen Creeks, the thrust trends in a northwesterly direction for about 75 miles to the region west of Dillon, Montana. The thrust was referred to as the Beaverhead thrust by W. L. Adam (1) and R. Benner (2) in the area to the west. Farther to the north-west, in the Tendoy Mountains, E. G. Lipp (25) referred to the same thrust as the Tendoy thrust. At the present time, it is apparent that at least three overthrusts are present in the region, and to avoid further confusion the following names have been adopted: Tendoy will be applied to the thrust lying farthest north, which crosses the Montana part of the author's area; Beaverhead will be applied to the southern-most thrust, lying for the most part in the Beaverhead Mountains, and not present in the area of this report; and the name Medicine Lodge will be given to the thrust present between the two others, from the name applied to it by V. R. D. Kirkham, who first studied it (22).

The Medicine Lodge thrust disappears beneath late Tertiary lava flows as it is traced southeast from the junction of Irving and Bull Pen Creeks. It emerges from beneath the lava near Middle Creek, where Middle Creek Butte is formed by the Mississippian Madison formation of the thrust sheet. South of the area of this report, the thrust sheet again is covered by the Snake River lava flows and is lost.

Kirkham believes that the Medicine Lodge thrust may be a northern extension of the Bannock overthrust, which appears on the south side of the Snake River lava plain. If the trend of the Bannock thrust is projected to the north side of the plain, it comes very close to the location where the Medicine Lodge thrust disappears beneath the lava. Since the Bannock thrust plunges beneath the flows with no evidence of dying out, it seems reasonable to conclude that it reappears again north of the plain.

Wherever the Medicine Lodge thrust has been mapped in Idaho, the Mississippian Madison limestone has been thrust over Red Rock conglomerate of probable

Paleocene age, making the thrusting post-Paleocene. The rhyolitic lavas overlying the thrust trace in the area of this report are regarded as Pliocene; in adjacent areas, Oligocene and late Eocene beds such as the Sage Creek formation overlie the thrust (2). Therefore, the thrusting took place in Eocene times.

Only Madison limestone is found in the thrust sheet in Idaho; however, farther to the northwest in Montana, Devonian, Ordovician and Cambrian formations are present.

Kirkham estimated that the vertical throw of the thrust is at least 10,000 feet, and the horizontal overthrust several times that much. No evidence was recognized in the area of this report which would indicate the magnitude of thrust movement.

The thrusting was toward the northeast, and in the process of overriding the Red Rock conglomerate, the thrust produced several northwest trending folds in that formation. A syncline with two flanking anticlines is observed in the conglomerate on the west side of Bull Pen Creek. The folds pitch to the southeast.

GEOLOGIC HISTORY OF SOUTHWESTERN MONTANA*

Recent	Continuation of block faulting at front of Tendoy range.
Pleistocene	Third episode of block faulting and alluviation in places. Gentle uplift in some areas and dissection of pediments. Two episodes of glaciation in the Beaverhead range, probably one before dissection and one after.
Pliocene	Regional uplift, in places possibly more block faulting, and erosion of extensive pediments; those on the northwest side of the Snowcrest Range are 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 and Sweetwater Creeks, downfaulting was so extensive that alluvial aprons were deposited along the base of the fault scarps.
	Deposition of lower Pliocene Madison Valley beds.
Miocene	Deposition of upper Miocene Madison Valley beds.
	Second episode of block faulting.
	Erosion to extensive surface of moderate relief. In places the pre-Sage Creek surface may have been re-exumed and become co-extensive with this post-Blacktail surface, which is now present in summit areas of the Blacktail Range, where lower Miocene basalts and tuffaceous beds are gently beveled.

*Developed at a general meeting of University of Michigan workers in the region, 1949.

Miocene (cont'd.)	Early episode of block faulting. Volcanism broke out at north end of Blacktail Range and extensively in Snake River valley, Yellowstone Park and Columbia Plateau. Deposition of lower Miocene Blacktain Deer beds and associated basalts, tuffs, and agglomerates in upper Sage Creek area, along northwest flank of Snowcrest Range and in Ruby Basin.
Oligocene	Continued volcanism nearby and deposition of Cook Ranch beds in middle Oligocene time, on Sage Creek beds. Contact between beds is obscure, and extent of erosion is unknown.
	Local gentle deformation and erosion in early Oligocene.
Eocene	Volcanism broke out in nearby regions, focussing in Yellowstone Park and Absaroka Range (began in late Eocene). Volcanism of superior magnitude also in the Coast Range region of Oregon and Washington at this time, resulting in damming of drainage ways and abundant ash and dust falls. Heavy alluviation of great intermontane valleys in southwestern Montana. Deposition of Sage Creek formation (late Eocene) in southwestern Montana, and other formations of equivalent age elsewhere over a wide region.
	Long episode of erosion and possibly some additional crustal movements during lower, middle, and early upper Eocene times, which resulted in great intermontane valleys.
Paleocene	*Late Laramide orogeny; formation of three thrust sheets athwart the northeast trending folds. Thrusts strike northerly and northwesterly and contain elements of the northeasterly trending folds. All thrusts override the Red Rock conglomerate. Thrusts from east to west are: Tendoy (north of Sheep Creek Canyon), Medicine Lodge (from Medicine Lodge Pass, Idaho-Montana line,

*Events observed in the area of this report.

Paleocene (cont'd.)	north to Armstead and beyond), and Beaverhead (pre-Cambrian pink granite gneiss thrust sheet and klippen in Medicine Lodge valley west of Armstead). In area of this report, Lima anticline probably formed at this time.
	Mid-Laramide orogeny; second episode of northeast folding resulting in upturning of Red Rock conglomerate along the Snowcrest Range and folding of the formation in other places.
	*Deposition of Red Rock conglomerate. Position of highland from which sediments came was possibly to southwest in Idaho, but its 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.
Upper Cretaceous	*Early Laramide orogeny, producing northeast trending folds; the Snowcrest Range is a prominent element. Sawmill Creek anticline probably formed in the author's area at this time.
	*Uplift (probably orogenic and lasting through most of the upper Cretaceous) of the Cordilleran geanticline, and deposition of Colorado group clastics (such as the Bear River and Aspen formations).
Lower Cretaceous	*Uplift (probably orogenic) of Cordilleran geanticline and deposition of the Kootenai clastics, generally conglomeratic at the base.
Early Mesozoic and Paleozoic	*More or less continuous deposition of Mesozoic and Paleozoic formations in fluctuating seas on the eastern shelf area of the Rocky Mountain trough.

*Events observed in the area of this report.

BIBLIOGRAPHY

1. Adam, W. L., Geology of the Lima Peaks Area, Beaverhead County, Montana, and Clark County, Idaho, Master's thesis, Univ. of Mich., 1949.

2. Benner, R., Geology of the Lima Peaks Area of the Tendoy Mountains, Beaverhead County, Montana, and Clark County, Idaho, Master's thesis, Univ. of Mich., 1948.

3. Bevan, A., "Rocky Mountain Front in Montana", GSA Bull., vol. 40, no. 2, 1929.

4. Blackwelder, E., "Geological Formations of western Wyoming", Wash. Acad. Sci. Journ., vol. 8, 1918.

5. Boutwell, J. M., "Stratigraphy and Structure of the Park City Mining District, Utah", Journ. Geol., vol. 15, 1907.

6. Branson, C. C., "Carboniferous Stratigraphy of Wyoming", GSA Proc., 1935.

7. Brown, R. W., "Fossil Plants from the Aspen shales of Wyoming", U. S. Natl. Museums Proc., vol. 82, 1934.

8. Cobban, W. A., "Marine Jurassic Formations of Sweetgrass Arch, Montana", AAPG Bull., vol. 29, no. 9, 1945.

9. Condit, D. D., Relations of Late Paleozoic and Early Mesozoic Formations of Southwestern Montana and Adjacent Parts of Wyoming, USGS Prof. Paper 120, 1919.

10. Condit, D. D., Finch, E. H., and Pardee, J. T., Phosphate Rock in the Three Forks-Yellowstone Park Region, Montana, USGS Bull. 795-796, 1928.

11. Collier, A. J., and Cathcart, S. H., "Possibilities of Finding Oil in Laccolithic Domes south of the Little Rocky Mountains, Montana", Contributions to Economic Geology, USGS Bull. 736F, 1922.

12. Darton, N. H., "Comparison of the Stratigraphy of the Black Hills, Bighorn Mountains, and Rocky Mountain Front Range", GSA Bull., vol. 15, 1904.

13. Dawson, J. W., "On the Mesozoic Floras of the Rocky Mountain Region of Canada", Science, vol. 5, 1885.

14. Deiss, C., "Structure of the Central Part of the Sawtooth Range, Montana", GSA Bull., vol. 54, 1943.

15. Dillon, E. L., Stratigraphy of an Area near Lima, Montana, Master's thesis, Univ. of Ill., 1949.

16. Dobrovolney, E., "Jurassic and Cretaceous Strata of the Camp Davis Area, Wyoming", Papers, Mich. Acad. Sci., Arts and Letters, vol. 26, 1941.

17. Foster, H. L., "Paleozoic and Mesozoic Stratigraphy of the northern Gros Ventre Mountains and Mount Leidy Highlands, Teton County, Wyoming", AAPG Bull., vol. 31, no. 9, 1947.

18. Frenzel, H., and Mundorff, M., "Fusilinidea from the Phosphoria Formation of Montana", Journ. Paleon., vol. 16, no. 6, 1942.

19. Hayden, F. V., Preliminary Field Reports, Third Annual Report, USGS, 1883.

20. Imlay, R. W., Gardner, L. S., Rogers, C. P., and Hadley, M. D., Marine Jurassic Formations of Montana, USGS Oil and Gas Investigations Prelim. Chart 32, 1948.

21. Kennedy, V. J., Stratigraphy of the Upper Horse Creek Arch, Teton County, Wyoming, Master's thesis, Univ. of Ill., 1947.

22. Kirkham, R. V. D., A Geologic Reconnaissance of Clark and Jefferson, and parts of Butte, Custer, Fremont, Lemhi, and Madison Counties, Idaho, Idaho Bureau of Mines and Geology, 1927.

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

24. Kummel, B., "The Thaynes Formation, Bear Lake Valley, Idaho", Am. Journ. Sci., vol. 241, 1943.

25. Lipp, E. G., Geology of an Area East of Sheep Canyon, near Dell, Beaverhead County, Montana, Master's thesis, Univ. of Mich., 1948.

26. Mansfield, G. R., Geography, Geology, and Mineral Resources of Part of Southeastern Idaho, USGS Prof. Paper 152, 1927.

27. Miller, A. K., and Cline, L. M., "The Aphalopods of the Phosphoria Formation of the Northwestern United States", Journ. Paleon., vol. 8, no. 3, 1934.

28. Newell, N. D., and Kummel, B., "Permo-Triassic Boundary in Idaho, Montana, and Wyoming", Am. Journ. Sci., vol. 239, 1941.

29. Peale, A. C., The Paleozoic Section in the Vicinity of Three Forks, Montana, USGS Bull. 110, 1893.

30. Perry, E. S., and Sahinen, U. M., Geological Reconnaissance Map of a Portion of Southwestern Montana, Montana Bureau of Mines and Geology, 1946, unpublished.

31. Richards, H. W. and Mansfield, G. R., "The Bannock Overthrust", Journ. Geol., vol. 20, 1912.

32. Ross, C. P., "Geology of the Borah Peak Quadrangle, Idaho", GSA Bull., vol. 31, no. 9, 1947.

33. Rubey, W. W., "Origin of the Siliceous Mowry Shale of the Black Hills Region", USGS Prof. Paper 154-D, 1929.

34. Scott, H. W., "Some Carboniferous Stratigraphy in Montana and northwestern Wyoming", Journ. Geol., vol. 43, no. 8, 1935.

35. Scholten, R., Geology of Part of the Beaverhead Mountains and Nicholia Creek Basin, Beaverhead County, Montana, and Clark County, Idaho, Master's thesis, Univ. of Mich., 1948.

36. Veatch, A. C., Geography and Geology of a Portion of Southwestern Wyoming, USGS Prof. Paper 66, 1907.

37. Weed, W. H., Yellowstone National Park Folio, USGS, Geologic Atlas of the United States, folio 30, 1896.

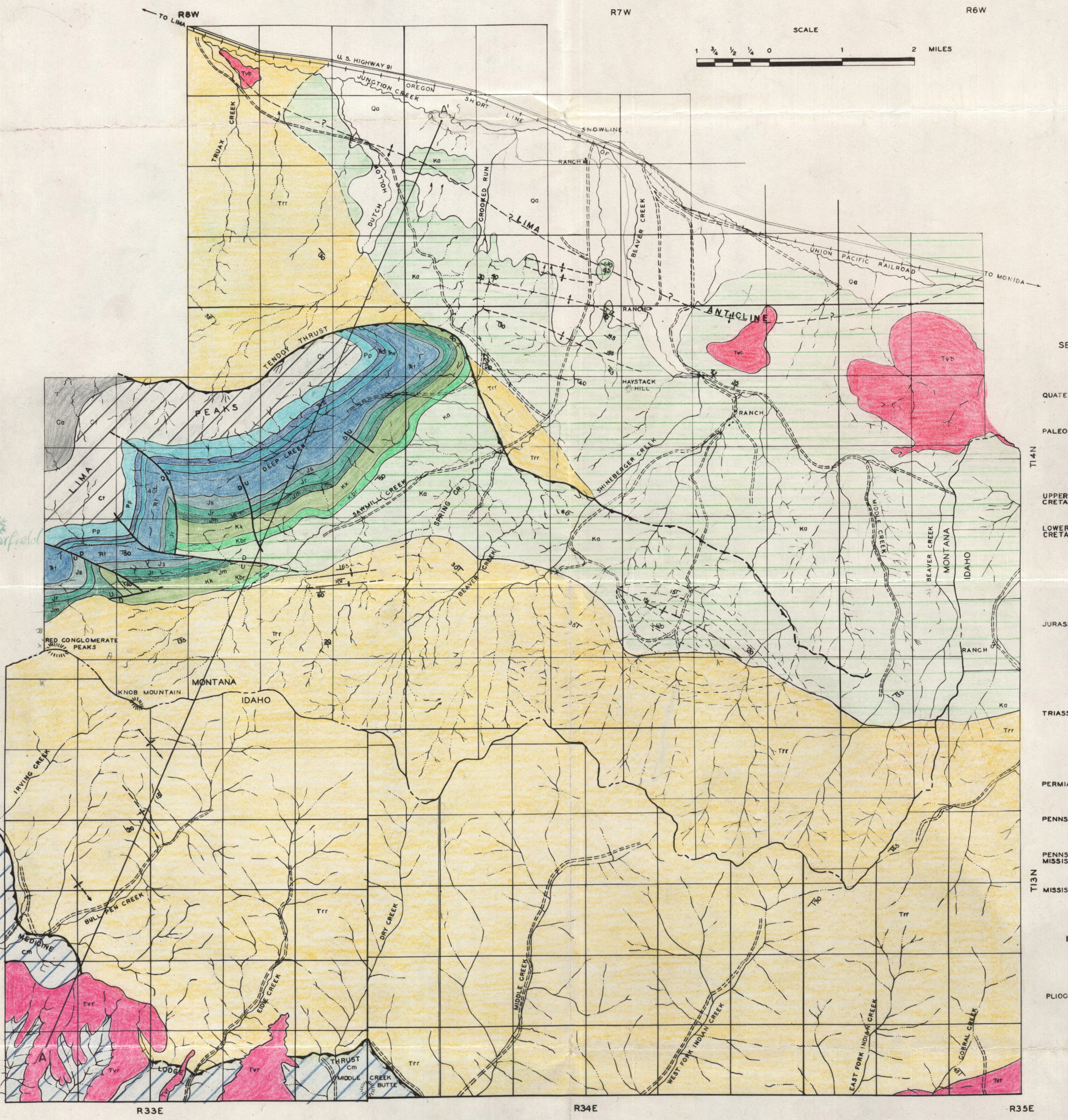
GEOLOGY OF THE RED PEAKS AREA

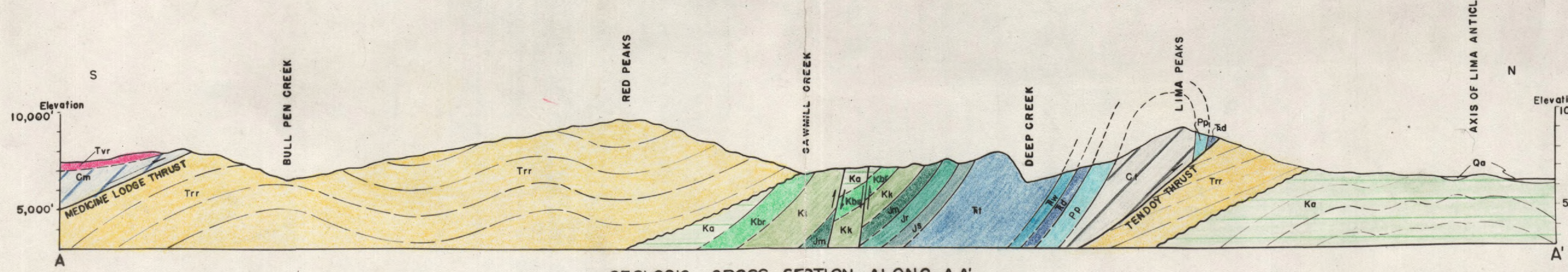
BEAVERHEAD COUNTY MONTANA & CLARK COUNTY IDAHO

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