The Geology
of the Lima Peaks Area,
Beaverhead County, Montana and
Clark County, Idaho

by

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Submitted in partial fulfillment of the requirements for the degree of Master of Science in Geology at the University of Michigan, 1948.

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ABSTRACT

The area of the Lima Peaks was mapped during the summer of 1948 by the author and Richard Benner, graduate students of the University of Michigan. It covers approximately 80 square miles, and is located in Beaverhead County of southwestern Montana, and Clark County, Idaho.

The area is part of the shelf zone just east of the Rocky Mountain geosyncline. The oldest rocks that outcrop in the area are Mississippian in age, and all younger periods are represented by formations common to the general region of the Rocky Mountains. The thesis area lies just within the western limit of Mesozoic strata. The Paleozoic and Mesozoic formations are mostly marine, whereas the Tertiary formations consist of a Paleocene orogenic conglomerate, Oligocene and Miocene basaltic and rhyolitic lava flows, and Miocene fresh water limestones.

The main Laramide structures trend northwest-southeast, and are probably a continuation of the Wyoming Laramide structures. Two thrust sheets occur in the thesis area, and both have brought Mississippian rocks eastward over the Tertiary Red Rock conglomerate. There is some evidence of early Laramide cross-folding along axes running northeast to southwest. A series of high angle block faults also runs northwest to southeast through the area. These are the

same Mid-Tertiary faults that run from Utah and Wyoming into eastern Idaho under the Snake River lavas and appear again in Montana.

The thesis area is located within Fenneman's Northern Rocky Mountain Physiographic Province. In contrast with the rest of the province, some of the mountains in the Lima Peaks area have a definite north-south alignment. The central highlands are an uplifted horst block, and the basins on the north and south are grabens. The block faulting is thought to be Miocene. Three erosion surfaces have been discovered within the area. They stand at elevations of 6,000 to 6,200, 6,700 to 7,000, and 7,500 to 8,500 feet above sea level.

After Raisz

Index map of thesis area

INTRODUCTION

Location and description of the area

The area of the Lima Peaks was mapped during the summer of 1948 by the author and Richard W. Benner, graduate students of the University of Michigan. It includes approximately 80 square miles, and is located mainly in Beaverhead County of southwestern Montana, but extends southward into Clark County, Idaho. It is bounded on the north by the Red Rock Basin near Lima, on the west by Little Sheep Creek and a southward extention of its west fork, on the south in Idaho by Divide, Medicine Lodge, and Irving Creeks, and on the east by a line through Alder Creek, Montana to Irving Creek. Parts of six townships are contained in the area. These are 14 S. and 15 S., R 8 W., and R 9 W., in Montana, and T 13 N., R 32 E., and R 33 E., in Idaho.

The most prominent features of the area are the centrally located Lima Peaks, from which this thesis takes its name. These peaks are a distinctive and colorful group of mountains of reddish sandstone, whose upper slopes are bare of vegetation, and which rise from three to five thousand feet above the surrounding stream valleys and the Red Rock Basin. The major peak of this group, Mount Garfield, is 10,961 feet high. Immediately adjacent to the southeast is another group of slightly lower but much more rugged mountains referred to as the Red Conglomerate Peaks. These two groups of mountains, along with lower ridges, are a part of the Beaverhead Range, which passes east-west through the area. The drainage divide of the range is both the Continental Divide and the Montana-Idaho state line.

Bordering the mountains are the Red Rock Basin in Montana to the north, and the South Medicine Lodge Basin in Idaho to the south. The two basins are essentially similar in that they are believed to be downfaulted blocks adjacent to the relatively uplifted blocks in the Beaverhead and Tendoy Mountains between them.

The part of the area contained in Montana is drained mainly by the three branches of Little Sheep Creek, and by Birch Creek. These two streams flow northward into the Red Rock River near the town of Dell, about five miles north of Lima. Passable roads along the three forks of Little Sheep Creek reach to almost all parts of the area north of the Continental Divide. In Idaho, the area is drained by Divide Creek, Warm Creek, and Irving Creek and their tributaries. These creeks flow southward into South Medicine Lodge Creek, the master stream of the basin. A good road from Dubois, Idaho enters the area from the south and proceeds onward to Bannock Pass on the Divide. Another road branches off from this one and runs up Irving Creek Valley to the base of the Red Conglomerate Peaks.

Previous study of the Area

Little previous work has been done in the immediate vicinity of the Lima Peaks. Professors E.S. Perry and U.N. Sahinen of the Montana School of Mines made a reconnaissance map of this part of southwestern Montana in 1946, but it has not been published. During the summer of 1947 the Department of Geology of the University of Michigan instituted a program of mapping the geology of the hitherto unmapped portion of southwestern Montana. Field work was done in areas adjacent to the Lima Peaks by graduate students Robert Scholten, Walter Kupsch, Henry Krusekopf, Stewart Wallace, Edward Lipp, and Robert Becker. Richard Benner and the author assisted Kupsch and Scholten during the latter part of the summer.

Acknowledgements

The author is indebted to Professor A.J. Eardley of the University of Michigan for his supervision of the field work, the construction of the geologic map and cross section, and the writing of the report. The author is also indebted to Richard Benner, graduate student of the University, with whom the author collaborated in doing the mapping and the preparation of the map and cross section. Further credit is due Robert Scholten, within whose Ph.D. thesis area the author's area is located, and who furnished the author with information pertaining to problems of age relationships and structures based on knowledge obtained in the adjoining area during the summer of 1947. Use was made of the reconnaissance map of Professors Perry and Sahinen for information as to the presence of certain formations. Helpful suggestions and information was also given the author by graduate students Dean Cummins and William Smith, and by L.L. Sloss and Carl Moritz of the Phillips Petroleum Company.

STRATIGRAPHY

Introduction

A fairly complete column of Upper Paleozoic, Mesozoic, and Cenozoic sedimentary rocks is present in the Lima Peaks area. Also present are Tertiary extrusive volcanic rocks in the form of rhyolites and basalts. No rocks older in age than lower Mississippian occur in the area. However, some have been mapped in other parts of the Beaverhead Mountains immediately to the south and west, and are briefly discussed below. The thesis area lies just within the western limit of Mesozoic outcrops in this region. According to C.P. Ross (1947, P.1126) this boundary, in Montana, trends roughly along 113° W. Longitude which passes through the southeastern part of the Beaverhead Mountains.

The measured sections included in this report are, with a few exceptions, the result of field work done during the summer of 1947 by the six graduate students mentioned previously. Since these sections are located close to the area of the report, and are, for the most part, better exposures than those in the thesis area, it was felt that there would be little to gain by repeating their work. The Triassic section was, however, measured in the thesis area by the author and his co-worker Richard Benner, and the information obtained included in this report.

Stratigraphic Column

Lima Peaks Area, Montana

Age	Formation	Thickness
Quaternary	Alluvium	Variable
Pleistocene	Gravels	100'
Miocene (?)	Volcanic rhyolites	300'
Miocene (?)	Basin limestones	400'
Oligocene	Volcanic basalts	300'
Paleocene	Red Rock conglomerate	2000' ≠
Lower Cretaceous	Kootenai fm.	1078'
Jurassic	Rierdon fm.	100'
Jurassic	Sawtooth fm.	200'
Lower Triassic	Thaynes fm.	410'
Lower Triassic	Woodside fm.	558'
Lower Triassic	Dinwoody fm.	763'
Permian	Phosphoria fm.	650'
Pennsylvanian	Quadrant quartzite	3000'
Miss-Penn.	Amsden fm.	1500'
Mississippian	Madison limestone	2000'

With the exception of the three Lower Triassic formations, the thicknessess are approximated.

Pre-Mississippian rocks in adjoining areas

Pre-Cambrian. No pre-Cambrian rocks have been found in the vicinity of the Lima Peaks. William Vaughan (1948, p.9) describes rocks of the pre-Cambrian age outcropping in the northeast part of the Elk River Canyon in the Gravely Range fifty miles to the east. He states that they consist of schists, and gray-white, dense, fine grained quartzites similar to pre-Beltian rocks exposed near Pony, Montana. The thickness is unknown.

Flathead quartzite. The Flathead quartzite of middle-Cambrian age is not exposed in the thesis area. However, it does occur as the bottom unit in the Beaverhead thrust sheet at the head of the west fork of Little Sheep Creek about two miles to the west. Here the Flathead is a red to brown well bedded quartzite that has been thrust over the Tertiary Red Rock conglomerate and considerably broken. Kupsch (1948, p.13) gives a minimum thickness of 900 feet to the formation in this region of Montana. He attributes the reddish color to included particles of hematite.

The type locality of the Flathead quartzite is near Flathead Pass at Three Forks, Montana. The formation was first named by A.C. Peale (1893, P.20).

Kinnikinic quartzite. Scholten has mapped as Kinnikinic an almost pure white, in places pink banded, quartzite in Four Eyes Canyon near the west fork of Little Sheep Creek. He assigns a thickness of approximately 800 feet to the Kinnikinic (1948, p.16).

The Kinnikinic quartzite of Ordovician age was first named by C.P. Ross (1934, p.947), the type locality being near Kinnikinic Creek in the western part of the Bayhorse quadrangle in Idaho.

Three Forks formation. The Three Forks formation where exposed in the upper part of Four Eyes Canyon above the Ordovician Kinnikinic is a soft, slope forming, calcareous shale that is mainly yellow to gray in color with brown included masses. At the base of the formation is a purplish, cherty shale. The thickness of the Three Forks is estimated by Scholten (1948, p.18) to be approximately 600 feet.

The name Three Forks was given by A.C. Peale (1918, p.29) to a formation of Upper Devonian age exposed at Three Forks, Montana.

Mississippian system

Madison limestone. The Madison limestone of upper Kinderhookian age and Osage age was first named by A.C. Peale (1893,p.33), who located the type section in the Madison Range of the Three Forks quadrangle, Montana. However, L.L. Sloss and R.H. Hamblin believe that the section is not a satisfactory one, and propose a new type section located at Logan, Montana (1942, p.305). The Madison was first described as a formation, but now is considered by many to be better classified as a group.

The Mississippian limestones of southwestern Montana and eastern Idaho have all been mapped as Madison by the field parties of the University of Michigan. The Lodgepole and Mission Canyon members have not been differentiated, the problem requiring more detailed stratigraphic study. The major difference between the two members is a lithologic one, the Lodgepole being massive, whereas the Mission Canyon is thin bedded.

The Madison limestone is found in two parts of the area. In both places it occurs as the bottom unit of a thrust sheet; and, therefore, the base is not exposed. In the northern part of the area the Madison is thrust over the Red Rock conglomerate of Paleocene age. It is conformably overlain by the Amsden formation of upper Mississippian and lower Pennsylvanian age. The Madison limestone here is a thin bedded, dark grey limestone containing calcite inclusions. Fossils are present, but are poorly preserved. The beds are highly contorted. The thickness of the Madison in this part ofthe area depends upon the position of the thrust plane which slices at an acute angle through the formation. As a result, the Madison ranges in thickness from 1000 to 2000 feet and the maximum figure is nearer the true thickness.

In the southern part of the area the Madison formation forms a long ridge of high hills that crosses the area from east to west just south of the Montana-Idaho state line. The Continental Divide runs along these hills for several miles.

Here more than 2000 feet of Madison is exposed as the remnant of a second thrust sheet which also lies on top of the Red Rock conglomerate. Further east the Madison rests on top of the Cretaceous Kootenai formation. The Madison is unconformably overlain by Tertiary limestones and gravels. How much Madison existed before the thrusting and erosion and deposition of the Tertiary beds is not known. Kupsch and Scholten (Personal communication) estimate more than 3000 feet and possibly as much as 10,000 feet of Madison limestone exists in the part of the Beaverhead Mountains west of Nicholia Creek Basin, about 20 miles to the west of the overthrust. They have made the only detailed measurements of the Madison to date in this region. Their partial section of 900 feet is included below.

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

12.	Limestone, medium to dark gray, thin bedded, bands of dark chert, cliff forming ---------------------	350'
II.	Limestone, dark gray, weathers differentially in light gray to tan, laminated in gray colors, bedding of intermediate thickness, scattered chert nodules, crinoid stems and large cup corals, bryozoa, gastropods, crinoids decrease, corals increase in quantity in higher parts of the unit ----------------------	200'

10.	Limestone, light to medium gray, massive, strongly jointed, almost entirely built up of fossils, mainly crinoids, calcite veins, chert layers -------------	60'
9.	Limestone, medium gray, weathers to tan and light gray, bedding of intermediate thickness, strongly jointed, calcite veins, chert layers, few fossils -	30'
8.	Limestone, light gray, weathers white, massive, no chert, completely built up of crinoid stems -------	30'
7.	Limestone, light gray, laminations in gray colors, cliff forming, calcite veins, chert, very fossiliferous, crinoid stems, corals, bryozoa, brachiopods	50'
6.	Limestone, gray, thin bedded, slope forming, chert nodules, calcite veins ----------------------------	15'
5.	Limestone, dark gray to black, fan-like laminations, breccia layers, regular chert beds, calcite veins, fossiliferous -------------------------------------	100'
4.	Limestone, gray, weathers pink, laminations in brown and red colors, massive, chert nodules, calcite veins, corals ---	30'
3.	Limestone, dark gray, thin bedded, chert and calcite, fossiliferous -------------------------------------	25'
2.	Shale, brown, and sandstone, violet-pink ----------	30'
1.	Limestone, dark gray, breccia with sandstone fragments, rusty brown, few fossils, some lenses of recrystalized crinoid stems ------------------------------	60'
	Total thickness	980'

Pennsylvanian System

<u>Amsden formation</u>. The Amsden formation was named by N.H. Darton (1904, p.379) who described the type locality on Amsden Creek west of Dayton, Wyoming. This formation is now known to contain beds of both Mississippian and Pennsylvanian age. Ruth Bachrach (1946, p.71) tentatively places the period boundary at the base of the Darwin sandstone member, all units below being considered upper Mississippian in age. C.C. Branson (1937, p.650) proposes the name Sacajawea for the Mississippian Amsden beds, restricting the name Amsden to the units of lower Pennsylvanian age. However, Bachrach states that the term Sacajawea has not been generally accepted because the Mississippian strata do not comprise a mapable unit.

The Amsden formation of the thesis area contains gray limestone beds, dolomites, red shales, some thin sandstone units, and a gypsum bed. The Darwin sandstone member, which is present in northwestern Wyoming, does not occur in the area of the Lima Peaks. The gypsum bed, which is about 100 feet thick, contains both the massive and the fibrous varieties of the mineral. The color is predominately white, but shades of pink, yellow, and gray are also found. The outcrop occurs approximately two miles above the Forest Service campground on the road along the east fork of Little Sheep Creek in section I, T 15 S., R 9 W. The deposit has been mined intermittantly.

The exact contact of the Amsden with the overlying Quadrant quartzite is a matter of doubt in certain places in the area due to the thick cover of talus blocks of the Quadrant. Also, the sandstones and dolomites of the Amsden seem to grade into those of the Quadrant formation. The author, however, considers the contact to be between the first of a regular succession of sandstone beds and the underlying dolomite layer. The sandstones form inconspicuous ledges, while the dolomites are usually found as grass covered slopes containing pieces of dolomite. The Amsden occurs throughout the area mainly as grass covered slopes containing scattered outcrops that do not form conspicuous ledges. Therefore the thickness of the formation was approximated as being 1500± feet. The Amsden is conformable on the Madison.

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

29.	Limestone, dark gray, weathering to light gray, fine grained --	2'
28.	Sandstone, light tan, friable --------------------------	6'
27.	Limestone, dark gray, weathering to light gray, fine grained --	8'
26.	Covered interval --	58'

25. Limestone, dark gray, weathering to light gray, massive, dense -- 10'

24. Covered interval ---------------------------------- 139'

23. Limestone, gray, weathering to buff, crystalline, well bedded, contains numerous thin bands of dark chert ---- 43'

22. Shale, gray, grading upward into brown, upper part of bed is covered --------------------------------------- 389'

21. Sandstone, light brown, thin bedded, calcareous, bedding planes well developed, weathers in places to a reddish purple -- 120'

20. Sandstone, tan, weathers to a rusty brown, massive, and friable -- 24'

19. Covered interval ---------------------------------- 269'

18. Limestone, gray, finely crystalline, contains numerous organic fragments --------------------------------- 12'

17. Limestone, dark gray, weathers to buff, argillaceous, thin bedded, some interbedded chert ------------------ 38'

16. Limestone, gray-brown, weathering to buff, finely crystalline, fossiliferous ---------------------------- 62'

15. Shale, gray, thin bedded, calcareous, containing numerous pelecypods ----------------------------------- 80'

14. Sandstone, light tan, weathering to orange buff, hard, quartzitic -- 3'

13. Shales, gray, calcareous, thin bedded ---------------- 29'

12. Limestone, dark gray, weathering to buff, crystalline, containing productids ------------------------------ 21'

II. Shales and limestones, gray, alternating and grading upward into brownish and buff colored beds ------------ 106'

10. Limestones and shales, argillaceous, dark gray, weather to light tan, thin bedded, calcareous, contain fragments of gypsum -- 245'

9.	Limestone, medium gray, medium grained, highly fractured	29'
8.	Shale, dark gray, weathering to light gray, calcareous, thin bedded with some interbedded argillaceous limestone	67'
7.	Limestone, light to medium gray, weathers to buff, finely crystalline, highly fractured, fractures filled with secondary calcite ------------------------------------	14'
6.	Shale, dark gray, weathering to light gray, calcareous, thin bedded, some interbedded argillaceous limestones -	43'
5.	Limestone, gray, thin bedded, argillaceous ------------	67'
4.	Limestone, buff, thin bedded, silty ------------------	10'
3.	Limestone, dark gray, fine grained, petroliferous odor--	4'
2.	Shale, gray, weathering to lighter gray, thin bedded, calcareous, contains pelecypods ----------------------	86'
1.	Limestone, dark gray, weathering to buff, dense, compact	46'
	Total thickness	2022'

Quadrant quartzite. A.C. Peale first named the Quadrant (1893, p. 32). He applied the name to beds lying between the Mississippian Madison formation and the Upper Jurassic Ellis group on Quadrant Mountain in the Three Forks quadrangle of Montana. W.H. Wood (1896, p.5), D D. Condit (1918, p.111), and H.W. Scott (1935, p.1038) have used the name to represent strata of different ages. The name, as used in this paper, applies to those beds of Pennsylvanian age lying above the Amsden formation and below the Permian Phosphoria formation.

As such, it is approximately equivalent to the Tennsleep formation of Wyoming and Montana.

The Quadrant formation of the Lima Peaks area consists of white, tan, gray, pink, and dark red sandstones and quartzites. The sandstones are resistant, medium grained, and sub-rounded. The quartzites are very hard, fine grained, and massive. These sandstones and quartzites form the backbone of most of the high country in the central part of the thesis area. Many of the higher ridges and all of the Lima Peaks are made up of these beds, which in many places, are covered with thick slopes of talus blocks. These talus slopes are very conspicuous, and are typical of outcrops of the Quadrant in Montana. The Peaks themselves are colorful, and consist of mostly the pink and darker hued quartzites and sandstones. Lamminations are abundant, and because they are white, pink, and red, they are very contrasting. The slopes of the Peaks are void of vegetation, which makes the colors stand out from great distances away. The lower Quadrant ridges are covered in most places with thick forests of pines. The underlying Amsden formation and the overlying Phosphoria formation seem to be bare of trees, and have only grasses and sagebrush on their slopes. Thus the trees are a guide in locating the approximate contacts of the Quadrant with the other two formations.

W.H. Scott (1935,p.1011) states that the Quadrant of Western Montana is disconformable upon the Amsden. Dip readings in the thesis area lend support to this statement, although the evidence is far from being conclusive enough to definitely determine the exact nature of the contact without further study. According to Professor Eardley (personal communication) the Amsden is missing entirely in the area near Armstead, about 25 miles to the north. Professor Eardley states that here the eastern facies of the Quadrant rests directly upon the Madison formation.

The Quadrant formation in the area of the Lima Peaks is estimated by the author to be 3,000 feet thick. No section was measured; but one measured the previous summer is included below.

Section of Quadrant formation measured by Krusekopf, Becker, and Lipp in E. 1/2, section 35, T.13 S., R.10 W., in Hidden Pasture Canyon.

12. Sandstone, dark gray, massive, calcareous cement	26.3'
11. Covered interval, dolomite and chert layers ---	280.9'
10. Limestone, more pitted than before, otherwise similar to unit 8 ----------------------------	8.8'
9. Dolomite ----------------------------------	15.5'
8. Limestone, gray to light tan, weathers white to tan, finely crystalline, dense, slightly pitted	5.0'
7. Dolomite, white to light gray, dense at base, sandy, chert at top ------------------------	54.9'
6. Sandstone, white, soft, easily weathered, forms rolling slopes ----------------------------	131.0'

5.	Sandstone, (first exposure), white to light gray, weathers to brownish tan, dense, becomes light tan near top ------	1724.9'
4.	Sandstone, dark tan, weathers to yellowish tan, friable, massive, many black lichens covered talus slope near top --	913.6'
3.	Sandstone, light tan, weathers to light gray, friable, massive, interbedded with two inch layers of more quartzitic and slightly dolomitic near the center. Also another member of quartzitic, slightly dolomitic sandstone near top --------------------------------------	109.4'
2.	Sandstone, quartzitic, very dense, gray to buff, weathers to tan, thinly bedded with 3 inch shaly sandstone layers --	5.0'
1.	Sandstone, white to buff, weathers to light gray, mottled slightly reddish, friable, fine well sorted sand, becomes more dense near top, massive, cross bedded --	43.8'
	Total thickness	3319.1'

Permian System

Phosphoria formation. The Phosphoria formation was named by R.W. Richards and G.R. Mansfield (1912, p.684) for exposures in Phosphoria Gulch near Meade, Idaho. In the Lima Peaks area the formation consists of interbedded gray dolomites, limestones, shales, and some siltstones and sandstones. The Rex chert member, as a distinct and thick unit is not present; however, cherty beds near the top may correspond to it. The author and Richard Benner found a bed of pisolitic phosphorite in a prospect trench on the west side of the middle fork of Little

Sheep Creek about one mile above the junction. This bed, only a few feet thick, is dark gray to black in color, and similar to phosphorite in the Phosphoria formation of Wyoming. Probably the phosphatic shales and limestones occur, but are not exposed.

The Phosphoria conformably overlays the Quadrant formation, and is in turn conformably overlain by the Lower Triassic Dinwoody formation. It is more resistant than the Dinwoody, and so stands out as cliffs or ledges on top of the Quadrant and below the grassy slopes formed by the Dinwoody. The formation is very fossiliferous, but no time was spent in collecting, other than picking up specimens while mapping the extent of the formation.

The author estimates the thickness of the Phosphoria formation in the Lima Peaks area to be approximately 650± feet.

Phosphoria section measured in section 35, T. 13 S., R. 10 W. by Krusekopf, Becker, Lipp.

20. Limestone, tan to medium gray, weathers gray, very hard, fine grained, crystalline, mottled white with calcite, partly covered	10.0'
19. Dolomite, gray, weathers gray to reddish brown, cherty, massive, hard, fractured	191.6'
18. Covered interval	88.0'

17.	Sandstone, mostly covered by small angular blocks of brown sandstone ----------------------------------	66.0'
16.	Limestone, gray, weathers to yellow tan, massive, hard ---	15.7'
15.	Shale, gray to buff, mostly covered ---------------	31.6'
14.	Siltstone, red, slightly calcareous, massive at bottom and top, thin bedded in between, forms small cliffs ---	45.1'
13.	Limestone, yellow-tan, fine grained, thin bedded to massive --	10.0'
12.	Dolomite, dark gray, weathers to light gray, contains large bluish chert nodules ---------------------	8.4'
11.	Sandstone, light gray to white, weathers buff to light gray, calcareous, shows faint color banding -	6.3'
10.	Dolomite, light gray, arenaceous, massive, highly fractured, contains some chert nodules -----------	92.6'
9.	Covered interval -------------------------------	11.7'
8.	Bedded chert, gray-green -----------------------	.8'
7.	Limestone, dark gray-green, weathers gray, arenaceous, hard, massive, interbedded thin chert layers ------	6.0'
6.	Limestone, gray, interbedded with chert layers 2 to 8" thick; chert is light to dark gray; near top chert disappears and concretions are present -----------	76.3'
5.	Dolomite, light gray, abundant dark chert ---------	12.5'
4.	Covered interval --------------------------------	8.4'
3.	Sandstone, light gray, fine grained, calcareous near base, hard, massive, contains calcite stringers ---	44.5'
2.	Limestone, light gray, fine grained, hard, massive, contains large dark gray chert nodules -----------	71.6'
1.	Dolomite, gray to buff, weathers light gray, very fine grained, sandy -----------------------------	5.0'
	Total thickness	802.1'

TRIASSIC SYSTEM

Dinwoody formation. The lower Triassic Dinwoody formation was named by Blackwelder (1918 p.425) for outcrops in Dinwoody Canyon in the Wind River Range of Wyoming. Previous nomenclature of Montana Triassic beds places all of them in the Woodside formation. However, on the basis of mapping done in southwestern Montana during the summer of 1947, it is believed that three distinct and mappable units occur. They correspond roughly to the Dinwoody, Woodside, and Thaynes formations of western Wyoming, and so the names have been tentatively applied to them.

The Dinwoody in the thesis area is characterized by tan to gray limestones and siltstones that weather chocolate brown. The outcrops are not conspicuous, being few in number; and the formation is mostly represented by grassy slopes.

Dinwoody section measured in SE. corner section 32 T. 14 S., R. 9 W. in gully on west side of Little Sheep Creek 1/2 mile south of Two Spring Gulch by William Adam and Richard Benner.

14. Sandstone, light tan to gray, calcareous, weathers chocolate brown ------------------------------- 4'

13. Sandstone, light gray to tan, no change upon weathering, calcareous, thin bedded with two 4" beds of sandy limestone, gray in color ------- 4'

12. Limestone, gray, weathers dark brown, arenaceous, thin bedded ------------------------------------ 2'

11.	Sandstone, light gray to tan, weathers same color, calcareous, thin bedded ----------------------------	3'
10.	Limestone, gray, weathers chocolate brown, arenaceous, thin bedded ------------------------------	1'
9.	Sandstone, grayish white, friable, thin bedded, calcareous ---------------------------------------	3'
8.	Limestone, gray, weathers chocolate brown, arenaceous, thin bedded ------------------------------	5'
7.	Sandstone, light gray to tan, thin bedded, calcareous ---	2'
6.	Covered ---	3'
5.	Limestone, gray, weathers to dark brown, arenaceous, thin bedded ------------------------------	2'
4.	Covered ---	2'
3.	Limestone, white to gray, weathers blue-gray, sandy	4'
2.	Limestone, gray, weathers to chocolate brown, thin bedded, arenaceous, contains lingula -------------	78'
1.	Covered interval between the last outcrop of the Phosphoria and the first outcrop of the Dinwoody containing float of chocolate brown and gray limestones and siltstones -------------------------	650'
	Total thickness	763'

Woodside formation. The Woodside formation of Lower Triassic age was named by J.M. Boutwell (1907, p.446) for exposures in Woodside Gulch, Park City, Utah. The Woodside in the thesis area forms reddish brown and white to tan slopes containing few outcrops. The slopes are covered with talus from the underlying beds. The formation consists of gray to brown limestones, siltstones, sandstones, and shales. These beds weather to a dark brown to red color which gives the distinctive appearance to the slopes. The Woodside seems to be conformable on the Dinwoody, and is itself conformably overlain by the Thaynes formation. No fossils were found in the Woodside. The measured thickness of the formation is 558 feet.

Woodside section measured above measured section of Dinwoody at same locality - SE. corner section 32 T. 14 S., R. 9 W. by William Adam and R. Benner.

15.	Slope of tan soils (shale?) --------------------	110'
14.	Slope of red soils, small pieces of red limestone in float, unknown whether color is stain or not --	50'
13.	Limestone, mottled gray to brown, weathers gray, rusty color in places due probably to stain from above, massive, forms ledge --------------------	5'
12.	Slope, reddish brown limestone float, very small pieces, almost soil ---------------------------	35'
11.	Limestone, mottled gray and brown, weathers gray, stained brown in places, forms ledge ------------	10'
10.	Siltstone, greenish gray, soft, very shaley, slightly calcareous ---------------------------	20'
9.	Slope, red limestone in float ------------------	55'
8.	Siltstone, gray, calcareous, massive -----------	2'
7.	Siltstone, light gray, very friable, calcareous, forms white to tan slopes ---------------------	10'
6.	Siltstone, white to gray, weathers tan, calcareous, fine bedded, 3" shale beds included ------------	15'

5. Slope, red soils with some patches of white soil - 70'

4. Sandstone, greenish gray, weathers brown forming reddish brown slopes, very calcareous, fine grained 35'

3. Same as bed 4 only very slightly calcareous ------ 20'

2. Sandstone, gray, weathers to reddish brown slopes, calcareous -- 10'

1. Sandstone, gray, weathers to white slope, non-calcareous -- 11'

Total thickness 558'

<u>Thaynes formation</u>. The Thaynes was named by J.M. Boutwell for beds in Thaynes Canyon, Park City, Utah. Found in northern Utah, eastern Idaho, and western Wyoming, the formation has now been tentatively extended into southwestern Montana. The Thaynes of the Lima Peaks area consists of tan to gray limestones and siltstones that form prominent cliffs that stand out above the red slopes of the Woodside formation. The section where measured does not represent the total thickness of the Thaynes due to the overriding Beaverhead thrust sheet. There is an interval of about 200 feet of grassy slope between the uppermost outcrop of the Thaynes and the bottom of the Amsden in the overlying thrust. This covered interval, if included in the Thaynes, would make the section here approximately equal in thickness to the section measured in 1947 by Krusekopf,

Wallace, Lipp, and Becker.

Pentacrinus asteriscus occurs in bed number 12 in about the same position as in the 1947 section mentioned above. The variety found in the Thaynes is characteristic of it, and helps distinguish the beds from the overlying Jurassic beds that contain a different variety of the fossil.

Thaynes section measured in SW. corner of section 19 T.15 S., R. 9 W. in cliff on west side of west fork of Little Sheep Creek by W.L. Adam and R.W. Benner.

13.	Covered interval between top outcrop of Thaynes and bottom layer of the Amsden ----------------------	200'
12.	Talus slope, brown shaley limestone, thin bedded, contains Pentacrinus asterisus in two foot ledge at top --	30'
11.	Limestone, brown, weathers chocolate brown, shaley, thin bedded, contains Pentacrinus, forms ledge ---	1'
10.	Talus slope, brown shaley limestone, thin bedded -	20'
9.	Limestone, white to gray mottled with brown, weathers blue-gray to brown, fine grained, calcite inclusions, forms ledge -------------------------------------	40'
8.	Limestone, brown, weathers chocolate brown, shaley, thin bedded, forms ledge -------------------------	15'
7.	Limestone, white to gray, weathers blue-gray to brown, calcite inclusions, forms ledge -----------	8'
6.	Limestone, tan, weathers yellow tan, silty, fine grained, laminated -------------------------------	7'

5.	Siltstone, gray, shaley, calcareous --------------	25'
4.	Limestone, gray, weathers brown, forms massive ledge	8'
3.	Siltstone, slope containing thin weathered ledges, tan, very friable ----------------------------------	30'
2.	Siltstone, gray, weathers brown, calcareous, forms ledge, lower 4 feet shaley, upper 2 feet massive --	6'
1.	Limestone, gray, weathers to tan slope, silty -----	20'
	Total thickness	410'

JURASSIC SYSTEM

Sawtooth formation. The Jurassic Ellis group of Montana is divided into the Sawtooth, Rierdon, and Swift formations. The first two and possibly the third are present in the Lima Peaks area. The Sawtooth formation was named by W.A. Cobban (1945 p.1274) for outcrops in Rierdon Gulch in the Sawtooth Range of Montana. In the thesis area the formation consists of tan to gray silt-stones, shales, and limestones. These beds are not very resistant, and for the most part, form grassy slopes blanketed with talus from scattered outcrops. The formation is approximately 200 feet thick.

Sawtooth section measured in S. 1/2 section 22, T. 13 S., R. 10 W. By Krusekopf and Wallace.

3. Shale, light gray to buff, slabby and thin bedded,

calcareous, not the top of the formation? --------	105.5'
2. Siltstone, buff, weathers to a speckled appearance	64.2'
1. Covered interval ---------------------------------	82.6'
Total thickness	252.3'

Rierdon formation. The Rierdon formation was named by W.A. Cobban (1945 p.1277). The type section is in Rierdon Gulch in the Sawtooth Mountains of Montana. Wallace (1948,p.27) describes the formation in his area as being calcareous shales interbedded with oolitic limestones. Only the oolitic limestones outcrop in the Lima Peaks area, although grassy slopes above and below the limestone bed probably represent the shales. The limestone is light brown, weathers to a light gray, and is fairly resistant. It forms a ledge 8 feet thick. The total thickness of the formation is not more than 100 feet, the exact contacts being obscured by grassy slopes.

Rierdon section measured in W. 1/2 section 10,
T. 13 S., R. 10 W. by Krusekopf and Wallace.

4. Covered interval --------------------------------	78'
3. Oolitic limestone, gray to buff, massive --------	10'
2. Shale, light brown, calcareous ------------------	20'
1. Olitic limestone, gray to buff, massive ---------	8'
Total thickness	116'

Swift formation. The author and his field associate did not recognize the Swift formation in the thesis area. However, L.L. Sloss (personal communication) believes that the formation may very well be present, and is represented by grassy slopes above the outcrops of the oolitic limestone of the Rierdon formation, and below the first outcrops of the salt and pepper sandstones of the lower Cretaceous Kootenai formation.

CRETACEOUS SYSTEM

Kootenai formation. The Kootenai formation of lower Cretaceous age was first described by J.W. Dawson (1885 p.531) from exposures in southern Alberta. It was named by G.M. Dawson (1885 p.162). The Kootenai is of continental origin. In the Lima Peaks area it consists of a basal conglomerate, salt and pepper sandstones, shales, and fresh water limestones containing gastropods.

The basal conglomerate is made up of a matrix of coarse sand grains which contain pebbles of sandstone and limestone up to one-half inch in diameter. The composite color is grayish, the individual pebbles being of various colors. The unit is massive and resistant, forming ledges that weather into huge rounded individual boulders. The salt and pepper sandstones are fairly light in color, ranging from white to gray.

A greenish tinge is given to some of the sands by the inclusion of grains of glauconite. The gastropod limestone strata are in the upper part of the formation, and form a good marker bed. They are almost pure white in color, weathering to tan to white slopes that are very easily seen in the field. A large part of the beds is composed of the shells of fresh water gastropods. Rounded and highly polished pebbles that may be gastroliths were found in the Kootenai formation.

All units above the Rierdon formation and below the Red Rock Conglomerate were mapped as Kootenai. However, subsequent field work in the adjoining areas has shown that the upper Cretaceous Mowry and Mesa Verde formations overlie the Kootenai, and so must be present in the thesis area. These formations were found in the Sawmill Creek area immediately to the southeast (professor Eardley, personal communication), indicating that the estimated thickness of 2000 feet for the Kootenai formation probably represents also other younger Cretaceous units.

Measured section Kootenai fm.

Measured August, 1948, by J.M. McUsic, W. Roth, and E.L. Dillon. Section measured along tributary of Sawmill Creek southward from 1/4 SE 1/4 Sec. 14, T. 15 S., R. 8 W. Dip 35° S., Strike S. 50° W.

55. Covered, brown soil ------------------------------ 46.0'

54. Sandstone, light brown, weathers brown, calcareous, salt and pepper, fine grained, bedded 1"-4", cross bedded -- 22.6'

53. Covered, red brown soil ------------------------ 42.3'

52. Sandstone, light gray, weathers light gray, calcareous, fine grained, very friable, thin bedded to 6", cross bedded ------------------------------- 19.5'

51. Covered, brown soil ---------------------------- 27.6'

50. Conglomerate, red brown, weathers red brown, limestone pebbles, pebbles crystalline, rounded, 1/2"-2" diameter, with calcareous cement ------------- 4.5'

49. Covered, red brown soil ------------------------ 15.0'

48. Sandstone, gray, weathers red brown, fine grained, calcareous -- 5.2'

47. Covered, red brown soil ------------------------ 37.6'

46. Sandstone, white, weathers gray, fine grained, calcareous -- 0.5'

45. Covered, red brown soil ------------------------ 57.4'

44. Limestone, gray, weathers gray, finely crystalline, small high spired gastropods --------------------- 5.7'

43. Covered, limestone float ----------------------- 4.9'

42. Limestone, gray-brown, weathers light brown, finely crystalline, bedded 1" -------------------------- 2.2'

41. Covered, limestone float ----------------------- 8.2'

40. Limestone, gray, weathers light brown, Viviparus montanensis, Campeloma harlowtonensis ------------ 1.0'

39. Shale, gray, calcareous ------------------------ 5.7'

38. Limestone, shaly, gray, weathers gray brown, finely crystalline, poorly bedded ---------------------- 3.2'

37. Covered, brown soil ---------------------------- 31.4'

36. Limestone, gray, crystalline, poorly bedded 1"-7", numerous small high spired gastropods ----------- 22.1'

35. Covered, brown sandy soil --------------------- 94.3'

34. Sandstone, light brown, weathers light brown, calcareous, fine grained, thin bedded, cross bedded 12.3'

33. Covered, red soil, probably red shale ----------- 68.3'

32. Limestone, red gray, weathers red brown, sandy, finely crystalline, abundant limonite staining, massive, fossiliferous ------------------------ 0.9'

31. Covered, red soil ----------------------------- 3.9'

30. Limestone, gray, weathers red brown, finely crystalline, sandy ---------------------------- 2.6'

29. Covered, red soil ----------------------------- 14.3'

28. Sandstone, gray, weathers light gray, fine grained, salt and pepper, slightly calcareous, thin bedded, cross bedded ------------------------------- 9.2'

27. Covered, red soil ----------------------------- 9.6'

26. Limestone, gray, weathers light brown, arenaceous, crystalline ---------------------------------- 3.0'

25. Covered, probably shale ----------------------- 5.4'

24. Shale, gray, calcareous ----------------------- 6.0'

23. Limestone, gray, weathers light brown, finely crystalline, calcite crystals and veins, hard --- 1.1'

22. Covered, calcareous brown soil ---------------- 3.4'

21. Limestone, gray, lithographic, massive ---------- 1.5'

20. Shale, limey, gray --------------------------- 6.6'

19. Limestone, gray, lithographic, fossiliferous, small fossil fragments ------------------------------ 2.5'

18. Limestone, gray, lithographic, bedded 3" -------- 3.0'

17. Limestone, gray, lithographic, bedded 6"-8" ----- 2.5'

16. Limestone, gray,lithographic, splintery fracture, bedded 2"-4" ---------------------------------- 11.0'

15. Limestone, gray, weathers gray, finely crystalline, bedded 8"-12" ---------------------------------- 4.0'

14. Covered, red brown soil ---------------------- 57.9'

13. Shale, red gray, slightly calcareous ----------- 12.6'

12. Limestone, gray, weathers red brown, brown mottling, poorly bedded ---------------------------------- 4.2!

11. Shale, red, noncalcareous ---------------------- 3.9'

10. Shale, gray, noncalcareous --------------------- 13.5'

9. Covered, light brown soil ---------------------- 52.4'

8. Sandstone, light gray, weathers light gray, medium grained, arkosic, calcareous, conglomeratic, pebbles 0.1"-0.5" in diameter, well rounded, composed of chert, sandstone, and quartzite. The sandstone is poorly sorted, mostly quartz, with grains rounded and showing characteristics of aqueous history -- 1.0'

7. Shale, gray, calcareous ----------------------- 13.4'

6. Covered, brown soil, probably thin bedded limestone or shale ------------------------------------- 112.0'

5. Sandstone, white, weahters light gray, very calcareous, bedded thin to 8", mostly clear quartz grains, subangular, with few biotite particles -- 4.3'

4. Covered, brown soil, probably shale ------------- 5.0'

3. Sandstone, gray, weathers red brown, coarse grained, arkosic, massive, cross bedded, sub-angular grains 15.9'

2. Covered, red soil ------------------------------- 106.0'

1. Sandstone, brown, weathers dark brown to gray, very conglomeratic in lenses, arkosic, bedded 3"-3', massive, cross-bedded, breaks into large blocks 47.6'

Total thickness 1079.5'

Tertiary system

<u>Red Rock conglomerate</u>. The name Red Rock has been tentatively given by Professor Eardley to a coarse, oregenic deposit of probable Paleocene age that exists in southwestern Montana in the vicinity of the Lima Peaks. Just east of Dell, Montana this conglomerate is unconformably overlain by the upper Eocene Sage Creek formation. There is evidence that it post-dates the earliest Laramide movements in southwestern Montana, and pre-dates the main thrusting that occurred in this region during the latter part of the Laramide oregeny. Thus, a Paleocene or lower Eocene age is suggested but no fossils have yet been found.

In the major part of the thesis area the conglomerate consists of rounded cobbles of all sizes up to two feet in diameter embedded in a sandy matrix that is slightly calcareous. This cementing material ranges from tan to dark red in color due to the presence of iron oxides, and gives a distinctive reddish appearance to the formation when viewed from a distance. The subangular to subrounded shapes of the boulders indicate a source not very far from the area of deposition, probably a highland to the west uplifted in early Laramide movements. The boulders are of two kinds, those coming from the blue-gray limestones of the Mississippian system, and those of quartzitic composition, which appear to be Beltian but may in part have been derived from the Cambrian and Ordovician quartzites and from the Quadrant quartzitic sandstones of Pennsylvanian age.

The Red Rock conglomerate is consolidated, and is resistant enough to form the second group of high peaks in the thesis area. These are the Red Conglomerate Peaks which form the Continental Divide in the southeastern part of the area in T. 15 S., R. 8 W. Immediately to the south of the peaks, and stratigraphicly above them, the Red Rock changes into a sandstone with a salt and pepper appearance that greatly resembles that of the Kootenai formation of Lower Cretaceous age. The two are so similar, that on the basis of lithology alone, it is impossible to differentiate between them. According to Scholten (personal communication), in the area to the south between the Lima Peaks and the Snake River lava plains, the conglomerate disappears entirely, and the Red Rock formation is wholly made up of these salt and pepper sandstones. These sandstones have a pinkish to tanish hue, and are quite hard. Close observation will reveal that they contain grains of a greenish material that is probably glauconite and red to pink porcellainite.

No measured section of the Red Rock has as yet been obtained. The author and Richard Benner estimate the thickness to be as much as 3,000 feet. In the northern part of the area it unconformably overlies the Mississippian Madison limestone as evidenced by the islands of Madison that protrude through the Red Rock to the surface. Along the Continental Divide it unconformably lies on top of the Kootenai (?) formation. In both parts of the area it is itself overridden by the two Laramide thrust sheets that are present in the Beaverhead Mountains.

Volcanic basalts. A small patch of basaltic lavas lies on top of the Red Rock conglomerate in the northern part of the thesis area. It is 300 feet thick, covers an area of approximately one acre, and is located along the course of Birch Creek three miles south of Lima, Montana. This remnant is the only outcrop of basaltic lava in the thesis area, although there are many such outcrops scattered throughout Beaverhead County.

The basalt is similar in many respects to basalts found to the east and south of Lima where they also lie on top of the Red Rock conglomerate, and are in some places interbedded with the Sage Creek formation. For this reason a temporary age of Upper Eocene or Lower Oligocene has been given to these lavas.

The basalts are dark gray in color, weathering to a rusty brown. They are fairly heavy, indicating a high specific gravity. The texture of the groundmass is felsitic. There are only a few phenocrysts of minute size contained in the rocks. The upper part of the outcrop is highly vesicular, and has been weathered to a reddish color.

Basin beds of the South Medicine Lodge Creek area. The South Medicine Lodge Basin of Idaho in the southern part of the thesis area contains a group of basin beds made up of fresh water limestones and rhyolitic lavas. They represent an extention of the upper units of the Nicholia Creek Basin Beds, mapped by Scholten (1948, p.27) and Kupsch in 1947. Scholten tentatively places their age as Miocene or Pliocene on the basis of vertebrate evidence found in them. However, it is the belief of Professor Eardley (personal communication) they may be equivalent to the Sage Creek Basin Beds outcropping in Beaverhead County to the east of Dell, and to which an upper Eocene or lower Miocene age has been assigned. The Nicholia Creek beds are similar to the lake beds described by A.C. Peale (1893), and to which he first applied the name Bozeman Lake Beds. V.R.D. Kirkham mapped 1000 feet of basin beds made up of shale, lignite, sandstone, and conglomerate, at the head of Medicine Lodge Creek, Idaho. He considered them to be Miocene or Pliocene in age (1927, p.23-26). According to Scholten (1948, p.33) the Nicholia Creek beds lie on the eroded surface of the Challis (?) volcanics which are Oligocene in age. Thus, conflicting evidence is presented for the age of these beds; and further study is necessary to determine their true age.

In the area of this report only the upper part of the limestones and the overlying rhyolites are present. The limestones unconformably overlie the Madison formation of the Beaverhead thrust. The rhyolites lie on top of the limestones in this particular area, although a few miles to the west, the two are interbedded. The rhyolites are in turn unconformably overlain by gravels of Pleistocene (?) age. About 400 feet of limestones are present, the base of them not being exposed. The rhyolites are about 100 feet thick.

The limestone beds are a fresh water lake deposit, as is evidenced by fresh water type gastropods found in them. These fossils are not diagnostic, and so do not aid in establishing the age of the beds. The limestones also contain plant fragments and twigs. The limestones are a pure white to tan and gray in color, and weather to a gray. They are cavernous, and pitted on eroded surfaces. They contain a system of joints that strike east-west. Scholten describes the beds as a tufa deposit, (1948,p.31).

The rhyolites are porous, light gray to pink in color, and weather to a tan to brown color. They are somewhat vesicular, and are pitted on weathered surfaces. They contain small phenocrysts up to one-eight inch in size, and which are not very numerous. The groundmass is felsitic. The rhyolites are fairly soft, and when weathered, tend to crumble. Their source is unknown. Kirkham (1927,p.37) mentions two possible sources for Tertiary lavas similar to these in north-central Idaho. He believes that these flows occurred in widespread sheets covering many square miles. He believes that a large part of the Tertiary lavas of this region owe their origin to the great sheets extending westward from the Yellowstone Park area.

Pleistocene gravels. Lying unconformably on top of the rhyolitic lavas of the South Medicine Lodge Basin are patches of mainly unconsolidated gravels of Pleistocene age. These gravels are composed for the most part of boulders and pebbles of Mississippian limestones embedded in a sandy matrix. There are some quartzite boulders. Locally this material is consolidated into beds of conglomerate, which outcrop in ledges as much as 5 feet thick along the slopes of intermittent stream gullies on the east side of the basin. The overall color of these beds is brown. They dip gently to the southwest away from the ridge of Madison limestone which forms the eastern wall of this part of the basin. The thickness of the gravels is estimated to be up to 100 feet. They probably represent a fanglomerate spread out from the highlands to the east.

Quaternary system

Alluvium. Deposits of alluvium occur along the major stream valleys throughout the thesis area. The valleys of the three branches of Little Sheep Creek, of Birch Creek, South Medicine Lodge Creek, Irving Creek, Warm Creek, and Divide Creek have a thin veneer of pebbles, sand, and silt deposited in historic times by the waters of the streams. The Red Rock Basin in the northern part of the area also has a cover of alluvium on its floor, and along the edges beneath the side slopes. The Red Rock River and other streams which enter the valley brought in part of this material. The rest has been laid down as radiating fans into the valley from the mouths of intermittant stream gullies which drain the highlands that border the basin.

STRUCTURAL GEOLOGY

Laramide structures

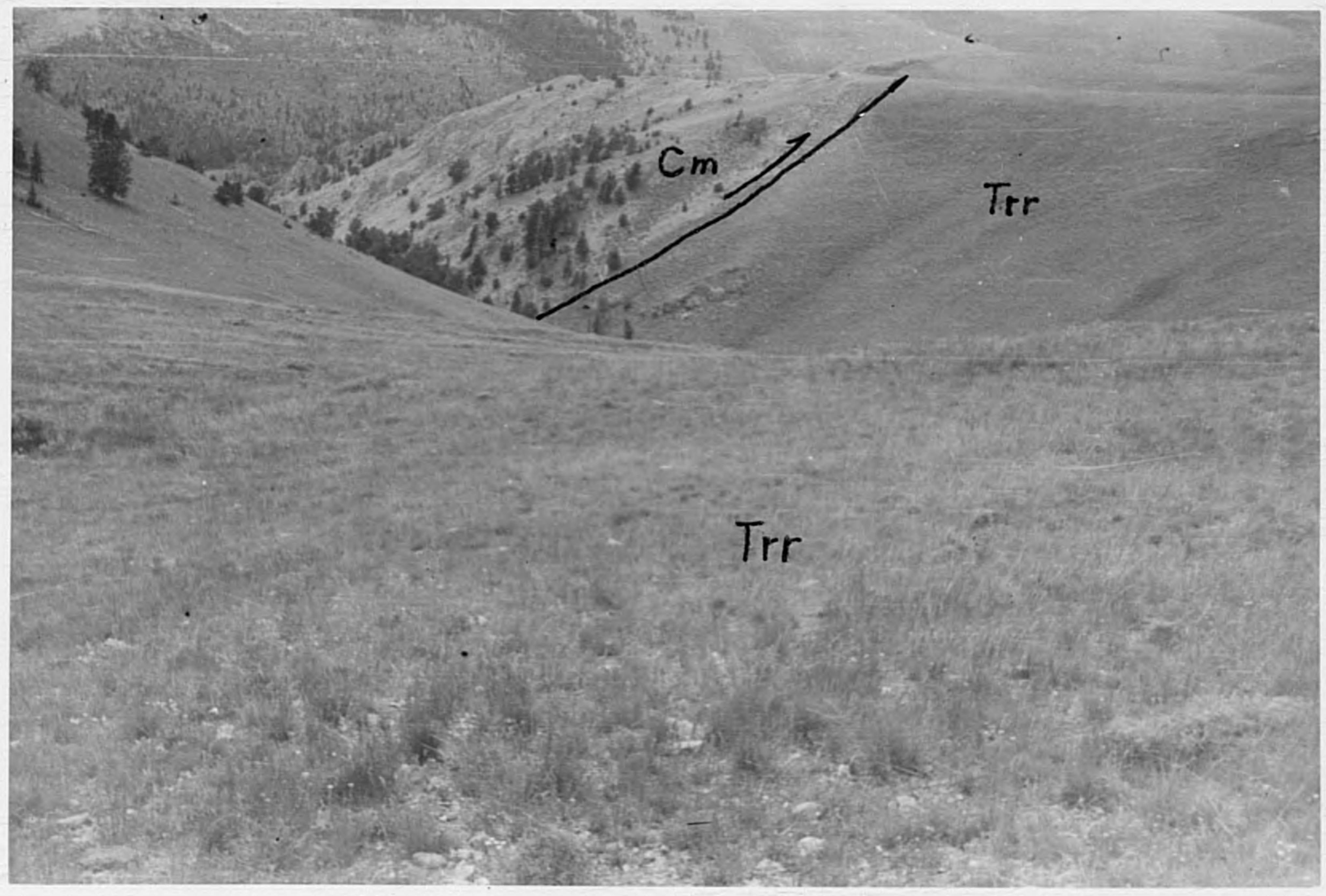
<u>Early Laramide cross-folding</u>. Within the thesis area several folds trend approximately northeast-southwest, and predate the main overthrusting. Fifteen miles to the northwest of the Lima Peaks isthe Little Water syncline (Wallace, 1948, p.36) which trends northeastward. Immediately southwest of Mt. Garfield is a small downfolded structure in Upper Paleozoic and Mesozoic beds which also extends northeastward. Still another northwest-southeast fold is found on the eastern edge of the Lima Peaks area near the head of Sawmill Creek. This is the Sawmill Creek moncline, which is downthrown on the southeast side. Since these folds trend almost normal to the thrust traces they are called cross-folds.

Uplift along northeast-southwest lines also took place in the Snowcrest Range 40 miles east of the Lima Peaks, evidently at the same time that the cross-folds were formed in this area. The two movements have been correlated by the fact that the Red Rock conglomerate, which was laid down unconformably in both areas, has been involved in the northeast folding, and is overridden by the later thrust sheets. The exact time that the folding took place is not known. However, it must have been in the

Upper Cretaceous or the Lower Paleocene before the uplift to the west occurred that furnished the material for the deposition of the Red Rock conglomerate in Paleocene time.

Later Laramide thrusting: The main Laramide structures within the thesis area are two thrust sheets that have been carried an unknown distance to the east. These thrusts occurred after Paleocene time, as they override the Red Rock conglomerate. Their age is probably Eocene because of the fact that in Oligocene time great extrusions of lavas occurred under which at least one thrust, the Beaverhead, disappears in the Snake River plains to the south. The Beaverhead thrust was first mapped by Kirkham (1927,p.26-29). He named it the Medicine Lodge overthrust, and stated that it rose from under the Snake River lava plains, and ran northward through Medicine Lodge Basin into Montana possibly as far as Dillon.

The Beaverhead thrust sheet crosses the southern part of the thesis area from northwest to southeast. The thrust front is cut out by a fault in section 4 of T. 3 N., R. 32 E., which brings basin limestones in contact with the underlying Red Rock conglomerate. This was brought about by the uplift of the thrust sheet, and the erosion of it to expose the Red Rock. From this point the thrust runs



View of Beaverhead thrust front

In section 35 T. 15 N., R. 9 W. Foreground is part of Continental Divide. Looking west toward Bannock Pass. Tributary of Warm Creek at top of picture.

eastward, and crosses the Continental Divide one mile to the east. From here it bends southward, and again crosses the Divide in section 2 of the same township. Beyond this point the thrust trends southeast, and can be traced along the steep northern slope of the ridge immediately south of the left fork of Irving Creek. It crosses Irving Creek just south of the junction of the two forks, and passes out of the area in the direction of the Snake River plains.

In the thesis area the exposed part of the Beaverhead thrust is composed of only one formation, the Madison limestone of Mississippian age. Basin faulting has uplifted the thrust sheet, and beds that originally overlay the Madison and were included in the sheet have been eroded off. Now the Madison is unconformably overlain by Pleistocene gravels over most of the southern part of the area. In the southwestern part it is in contact with the Miocene basin limestones. The plane of the thrust in areas adjacent to this cuts through lower formations, such as the Cambrian Flathead quartzite, the Ordovician Kinnikinick, and the Devonian Three Forks formation. There is one formation underlying the thrust throughout the area. This is the Red Rock conglomerate.

The underlying Red Rock is itself part of another thrust sheet in the thesis area named the Tendoy thrust. What is referred to in this paper as the Beaverhead thrust is the continuation of the thrust mapped between Little Sheep and Big Sheep Creeks in the summer of 1947 by Lipp and Becker, and named by them the Tendoy thrust. During the summer of 1948 the author and Richard Benner mapped a second thrust in the northern part of the thesis area along what was originally supposed to be a sedimentary contact. To this second thrust the name Tendoy has been given, because so far, it has been traced only through the area of the Tendoy Mountains. The first mentioned thrust, however, passes mostly through the Beaverhead Mountains and only part of the Tendoys. Because of the location of the two thrust sheets, Professor Eardley believed that the name Beaverhead was a more appropriate name for the thrust in the southern section of the thesis area.

The Tendoy thrust has been traced from at least as far north as Big Sheep Creek, across the area between Big Sheep and Little Sheep Creeks, and into the thesis area just north of the junction of the three branches of Little Sheep Creek. From this point, the thrust front makes several swings, but trends in a more or less south-easterly direction across the area. It passes out of the area through sections 4 and 9 of T. 15 S., R. 8 W., along the base of the Lima Peaks on their northern side. The plance of the Tendoy thrust cuts two formations, the Madison limestone, and the Upper Mississippian and Lower

Pennsylvanian Amsden formation. The Tendoy thrust sheet includes all of the formations listed in the column on page 8 from the Madison limestone through the Red Rock conglomerate. The Red Rock is also the formation that underlies the thrust throughout its length. Thus the Red Rock conglomerate is the formation that is overridden by both thrust sheets, and is itself included as the top part of the forward thrust sheet.

The Madison limestone, which is the bottom unit in both thrusts, is intensely folded, overturned, and sheared. Just north of the junction of the three forks of Little Sheep Creek the Madison is well exposed in the valley walls. Here, within a distance of a few feet, dip readings from 30° to 90° were obtained, and the great deformation of the beds can be clearly seen.

The lateral extent of the overthrusting of these sheets is not known. However, Kirkham (1927, p.26) believes that the vertical throw of the Beaverhead or Medicine Lodge thrust may be more than 10,000 feet, and that the lateral movement is several times as much.

Post-Laramide structures.

<u>High angle block faulting</u>. The series of block faults

mentioned on page 39 were responsible for the formation of Medicine Lodge and Red Rock Basins. The fault on the west side of the Red Rock Basin has been traced along the east front of the Tendoy Mountains between Big Sheep and Little Sheep Creeks. It exists in the northwest corner of the thesis area, but all evidences of it are lost south of Little Sheep Creek. However, it must have continued on to the south beyond the thesis area. In the northwestern part of the area the fault line is marked by a very recent scarp approximately 15 feet high, which forms the contact between the uplifted Red Rock conglomerate and the basin alluvium. In places the scarp cuts across alluvial fans that emerge from the intermittant stream gullies of the front of the Tendoy Mountains. This is evidence of recent movement along the fault line.

In the southern section of the thesis area another zone of normal faults has dropped the Medicine Lodge Basin area in relation to the central highlands. This zone consists of one major basin fault and several short splinters, all of which run northwest to southeast. It is one of the splinter faults that cuts the Beaverhead thrust sheet as mentioned on page 41. The fault line in this part of the area is marked by the contact between the Madison limestone of the thrust sheet and the Miocene basin limestones. East of Warm Creek the trace of the fault is covered by Pleistocene gravels, which lie unconformably on both the Madison and the basin limestones.

Since the fresh water limestones would most likely not be the type of sediments deposited in the basin following the block faulting, it is believed that the deposition of the basin beds occurred first. This would date the faulting as Upper Miocene or Pliocene. It might also support the theory of prior formation of the basin by another agent, before both the deposition of the basin beds and the faulting. This problem will be discussed further in the section on physiography which follows. Also the relation of the faulting to the erosion surfaces produced within the area will be taken up in a special section under Physiography.

Regional features

In northwestern Wyoming the main Laramide structures are a series of thrusts that have been, in most cases, carried to the east. These thrusts have been traced northwestward into eastern Idaho where they disappear beneath the lava plains of the Snake River country. Apparently the same zone of deformation reappears again to the north of the lavas, and is present in southwestern Montana. So the

Beaverhead and Tendoy thrust sheets are believed to belong to this same group of Laramide structures that is present in northwestern Wyoming.

There is evidence in the thesis area of some compression from the north and south during the early part of the Laramide orogeny (p.28). The cross-folds run northeast-southwest at right angles to the main folding. It is not known whether this represents a second general pattern of structures throughout the region of Laramide activity, or merely some locally existant folds. Immediately south of the thesis area is a downwarped area filled with extruded lavas. This is the Snake River downwarp which underlies the so-called lava plains. It extends from the region of the Yellowstone plateau westward into Oregon.

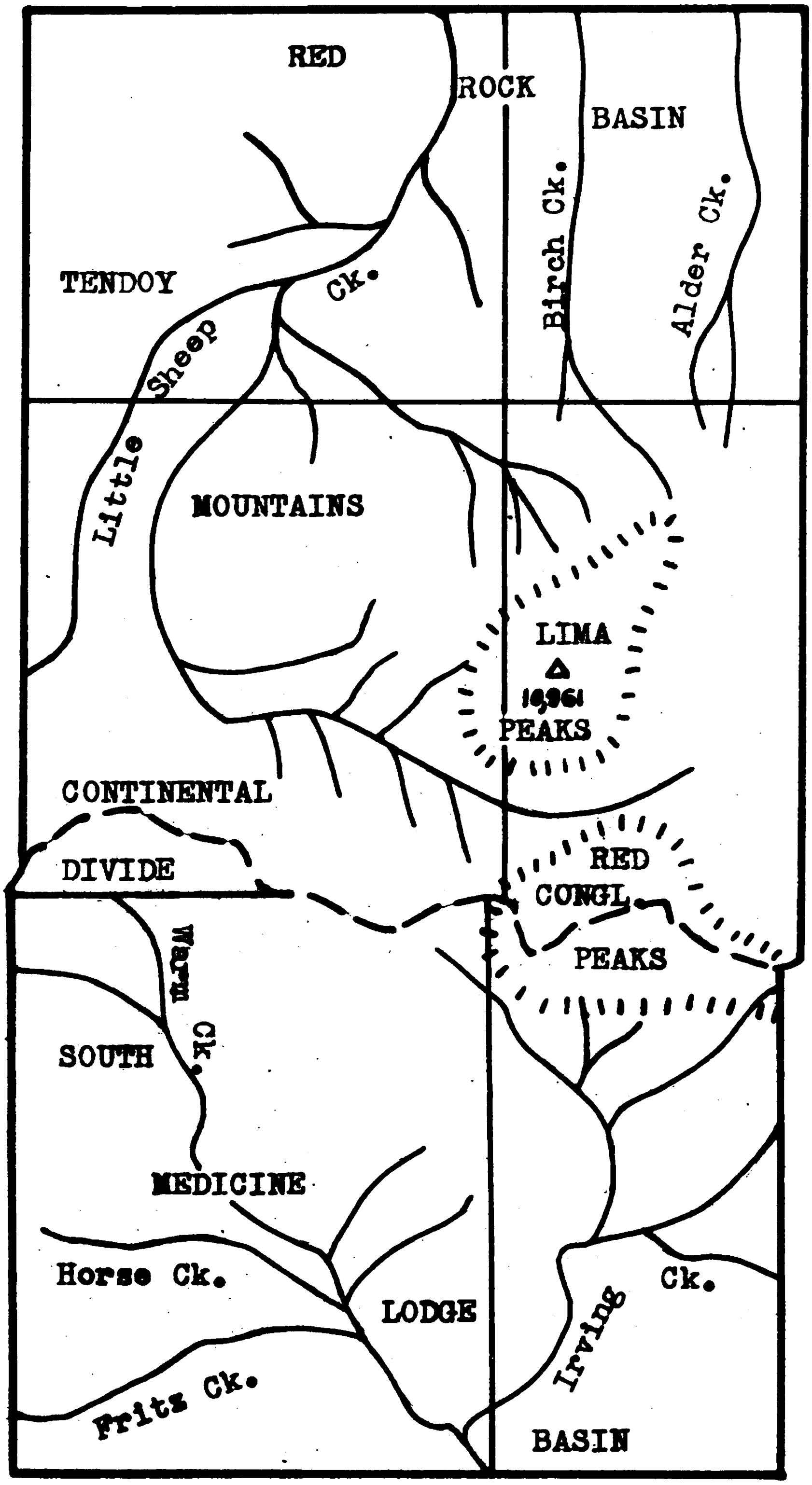
Another group of structures that crosses the thesis area is the series of high angle faults described on page 45. These faults may be part of a rift zone of trenches, which according to Professor Eardley (1947, p.1176) runs from Arizona northward into British Columbia. The creation of these faulted and tilted blocks has resulted in the deposition of clastic sediments eroded from the highlands. Fossils found in the deposits indicate the age of deposition to be Upper Miocene or Lower Pliocene. This would date the faulting as Miocene. However, in some places within the zone, including the area of the Lima Peaks, some faulting has continued until the present time.

PHYSIOGRAPHY

Introduction

The area of the Lima Peaks lies just within the southeastern boundary of Fenneman's Northern Rocky Mountain Physiographic Province. This section of the province is characterized by mountain ranges that are somewhat linear in orientation, which is in contrast with the major portion of the province to the north and west, where there is definitely no regular alignment to the mountain masses. The mountains of the southwestern Montana area are bordered by basins created by faulting of mid-Tertiary age. The approximate north-south alignment of the ranges and basins is similar to the physiography of the Basin and Range Province to the southwest. Thus the term range has been used when speaking of the Beaverhead, Lemhi, and Lost River Mountains of southwestern Montana and eastern Idaho. The term is less applicable to the other mountain masses of the province.

There is a general accordance of the summits of the mountains of the southeastern part of the province, represented by a warped plane varying in elevation, and which Fenneman states (1931, p.187) may be an uplifted erosion surface. This crest level is at its highest altitude in the region of 44° 30' north Latitude along the upwarp of the east west trending Centennial Range, immediately south of the thesis area.



Major physiographic features

of the thesis area.

Physical features

The outstanding physical features of the thesis area are the three groups of mountains and the two basins that border them. Although they have been given different names, these mountain masses are more or less continuous. They are located at the point where the northwest-southeast trending Beaverhead Range meets the Centennial Range, which runs east-west. Of which range they should be considered a part is undetermined.

The Tendoy Mountains extend into the thesis area from the northwest, and vary in height from 7,000 to 9,000 feet. They are in a submature stage of erosion. Their southern end, which is located in the area of this report, is drained by the eastward flowing Little Sheep Creek. Another group of peaks rise approximately 1,500 to 2,000 feet above the general level of the ridges of the Tendoys on their southern end. These are locally called the Lima Peaks. The slopes are bare of vegetation above the 9,000 feet and are covered with huge talus blocks of quadrant quartzite. The peaks are drained on the south and west by the middle and east forks of Little Sheep Creek, on the northern side by Birch and Alder Creeks, and on the east by Sawmill Creek. These streams all flow from the foot of the peaks by circuitous courses into the Red Rock River in the basin to the north.

Immediately to the south of the Lima Peaks lie another group of very rugged mountains named the Conglomerate Peaks. They are slightly lower than the Lima Peaks, but more rugged. They are carved out of the Tertiary Red Rock conglomerate, and the crags, sharp ridgetops, and cliffs present a very similar appearance to alpine topography. The channels of the streams running down from these peaks are filled with large quantities of loose gravel and large boulders that have been eroded out of the conglomerate. Unlike the above mentioned streams, the ones that drain the southern side of the Conglomerate Peaks flow into Irving Creek and thence into South Medicine Lodge Creek. These waters flow eventually into the Snake River and in the end reach the Pacific Ocean by way of the Columbia River. The eastward flowing streams mentioned previously, find their way into the Missouri River and thence to the Gulf of Mexico. Thus the highlands in the central part of the thesis area are the Continental Drainage Divide. The Divide runs from west to east through the area from the Beaverhead Range to the Centennial Range.

In the upper stream valleysbetween the ridges of all of these mountains there are thick clusters of aspens. On the slopes above grow grasses and sagebrush. There are forests of pine also on the slopes and on the ridge tops. The pines seem to grow almost entirely on the outcrops of the Quadrant and the Red Rock formations, whereas the grasses and sagebrush grow on the outcrops of the other Paleozoic and Mesozoic formations. The timberline is close to 9,000 feet which is above most of the ridges of the Tendoys, but leaves over 1,000 feet of bare slope above throughout most of the Lima and Conglomerate Peaks.

The central mountain highlands are bordered on the north and south by two basins. They are the Red Rock Basin of Montana, and the South Medicine Lodge Basin of Idaho. These basins were formed in Mid-Tertiary time by high angle block faulting that uplifted the centrally located uplands in relation to the adjacent areas. The basins lie at approximately 6,000 feet above sea level. They are similar in most respects except in size, the Red Rock Basin being much larger. They both have extensive alluvial fans along their edges. The fans radiate out from the stream gullies of the highlands, and at some points, reach almost to the centers of the basins.

The drainage in the Red Rock Basin is from the highlands to the southwest into the Red Rock River, which runs into the Beaverhead River near Dillon, Montana. The Beaverhead joins the Madison to form the Missouri River at Three Forks, Montana, 200 miles to the northeast. The vegetation cover is predominantly sagebrush. However, aspen trees are found along the stream courses. Also, certain parts of the valleys are used for dry farming by ranchers.

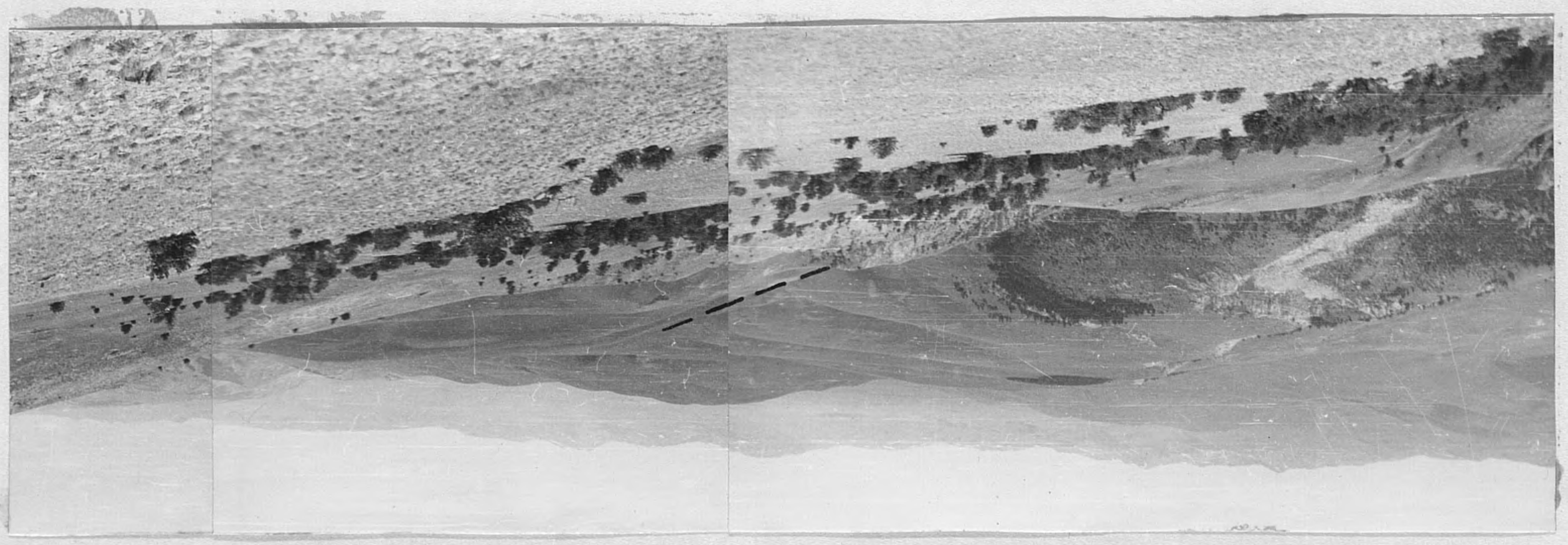
These basins are two of a group of Tertiary basins existing in the northern Rocky Mountains. They have been commonly referred to as "Tertiary Lake Beds". The elevation of the basins varies between 3,000 and 5,000 feet above sea level. According to N.M. Fenneman (1931, p.219) the lower parts of the basins contain Tertiary sediments. The beds may be Oligocene, Miocene, and Pliocene in age. The origin of all basins in western Montana is probably not the same. Some, including the two within the thesis area, were formed by block faulting. Others may be purely erosional features, and some the result of downwarping of a peneplain surface (Pardee, J.T., 1925, p.38). Eliot Blackwelder (1912, p. 410-414) lists four steps in what he considers to be the most logical hypothesis of the origin of most of the basins. He assumes that (1) the basins, however formed, existed before peneplanation of the region took place in Mid-Tertiary time, (2) that they were filled with weak Tertiary sediments, (3) that the peneplain was developed over the entire region regardless of the differences in relative hardness of the rocks, and (4) that differential erosion following uplift reexcavated the basins, while the more resistant highlands were uncovered again. In the case of the Red Rock Basin at least, faulting has occurred in very recent times. On the west side of the basin there is a scarp of perhaps 15 feet that can be traced along the foot of the highlands bordering the basin. This scarp also cuts through the alluvial fans that have spread out from the hills into the basin. Thus, even if this basin were formed by differential erosion, movement has continued to occur along the original fault after the excavation of the basin has taken place.

Erosion surfaces and their relation to the high angle block faulting

Evidence was found within the area described by this paper for the existence of at least three erosion surfaces. The lowest and youngest of the surfaces is the level of the present valleys of the streams, which in the Red Rock and South Medicine Lodge Basins, is between 6,000 and 6,200 feet above sea level. There are remnants of two older surfaces above this altitude. The lower of these is represented by extensive grasslands sloping gently away from the highlands into the basins of Nicholia Creek and Medicine Lodge Creek at elevations between 6,700 and 7,000 feet. Above this, between 7,500 and 8,500 feet there is a general accordance of the gently rolling uplands and the ridgetops of the Tendoy Mountains. This surface is fairly extensive over the western part of the thesis area, although some ridges of the Tendoys rise above it to 9,000 feet.

The exact ages of these different surfaces is unknown, although a few indications were discovered in the field. At one point in the area the middle erosion surface seems to have been established over one of the Miocene high angle faults. This would date the intermediate surface as post-Miocene. The fault is one of several splinter faults along the trend of the main basin zone of faulting on the north side of Medicine Lodge Basin. It is located in section 4 of

T. 3 N., R. 32 E. just south of the Montana-Idaho border. The fault runs approximately east-west up the valley of one of the tributary streams running into Warm Creek. It cuts the Beaverhead Thrust plane, which disappears at this point and brings Miocene basin limestones in contact with Paleocene Red Rock conglomerate. The rolling grasslands into which the stream valley is cut represent the middle erosion surface, which in this part of the area appears to be established over the fault. This is the only place in the area where the relationship between the faults and the erosion surfaces is shown. And the evidence here is not as yet considered conclusive.



View of erosion surface and splinter fault.

Looking west toward the Beaverhead Range. Bannock Pass at left center of picture. Fault along dotted line.

Summary of geologic events

Pleistocene	Rejuvenation of streams, present stream valleys cut into floors of basins. Glaciation of region, no traces in area of the Lima Peaks. Reexcavation of basins, pediment surfaces established.
Pliocene	Baseleveling of area, establishment of erosion surfaces over uplifted and downdropped blocks.
Late Miocene	High angle block faulting, formation of Tendoy horst and Red Rock, Nicholia Creek, and S.Medicine Lodge Basins.
Early Miocene	Extrusion of rhyolitic lavas. Deposition of fresh water limestones in downwarped (?) basins.
Oligocene	Extrusion of basaltic lavas.
Eocene	Shearing and thrusting to the east of the Beaverhead and Tendoy thrusts. Further folding along NW-SE axes, compressive forces from NE to SW.
Paleocene	Erosion of landmass, and deposition of the Red Rock conglomerate. Uplift of a landmass to the west of the Lima Peaks area.
Late Cretaceous	Beginning of Laramide deformation, compressive forces from NW and SE. Folding along axes trending NE to SW. Formation of Little Water syncline and Sawmill Creek monocline.
Early Mesozoic and Paleozoic	More or less continuous deposition of marine Paleozoic and Mesozoic formations in fluctuating seas on eastern edge of Rocky Mountain trough.

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GEOLOGY OF THE

LIMA PEAKS AREA

BEAVERHEAD COUNTY, MONTANA, & CLARK COUNTY, IDAHO

BY WILLIAM L. ADAM & RICHARD W. BENNER

MAP COMPILED BY RADIAL LINE ASSEMBLY
OF AERIAL PHOTOGRAPHS
1948

PL: I

PLATE 2

STRUCTURAL CROSS SECTION ALONG LINE A-B-C

Legend: Cm, Madison ls.; Ca, Amsden fm.; Cq, Quadrant qtzite.; Pmp, Phosphoria fm.; Trd, Dinwoody fm.; Trw, Woodside fm.; Trt, Thaynes fm.; Jst, Sawtooth fm.; Jr, Rierdon fm.; Kk, Kootenai fm.; Trr, Red Rock congl.; Tbl, Basin lss.; Tvb, volcanic basalts; Qal, alluvium.

1 ½ 0 1 2

Scale in miles

Profile and elevations approximated.

WILLIAM L. ADAM & RICHARD W. BENNER