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A Geological Report on South Boulder Canyon and The Mayflower Mine-Renova Areas

B. R. Alto

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MONTANA SCHOOL OF MINES

Butte, Montana

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and

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Submitted to

The Geology Department

Dr. E.S. Perry

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By B.R. Alto

INTRODUCTION

The purpose of this report is to serve as a written explanation of the accompanying geologic maps and columnar section. Also, participation in a geologic field trip and the completion of this report is required for credit in Geology 63 at the Montana School of Mines.

Each year the senior students in mining and geological engineering at the Montana School of Mines spend two weeks in the field where they learn the fundamentals of geologic mapping and related field studies. An additional week is spent at the school where maps are assembled, prints made, and other work is done in preparation for the writing of the report.

This year the field trip was made in the vicinity of Whitehall, Montana during the period 2nd to 13th of September 1947; and the previously mentioned classroom work was done during the week 15th to 20th of September. The town of Whitehall was chosen as the base of operations for the trip. The students were housed at the Green and White Cabins and meals were provided by the Borden Hotel Cafe. Transportation to and from the field was by private automobile.

On the first day of the trip the class was broken up into crews of four members each and some preliminary work was done with the surveying instruments. A pacing course was set up and short traverses were run with alidades and Brunton compasses. Two days of the trip were allotted to a study of the geologic column in South Boulder canyon. The remainder of the time was spent in mapping two areas; the Renova - Bone Basin area, and an area southeast of the Mayflower Mine.

I wish to take this opportunity to extend my thanks to Dr. E.S. Perry, Dr. George Kiersch, and Mr. Alvin Hansen all of the geology department for their kind assistance and instruction during the trip. Also, I would like to thank the following men wi th whom I worked; Mr. John Downing, Mr. Norman King, and Mr. Willard Leskela.

LOCATION AND ACCESSIBILITY

Whitehall, Montana is located in Jefferson County 32 miles east of Butte on U.S. Highway No. 10. The Northern Pacific Railroad also goes through the town and the Milwaukee Railroad passes within 5 miles, to the south of the town. All of the areas that were mapped are easily accessible from Whitehall on graveled county roads. Some of the minor roads are not graveled and become very slippery during rainy seasons. The South Boulder Canyon is about 15 miles to the southeast of Whitehall. Renova is located near the Jefferson River about 8 miles south of Whitehall. The Mayflower Mine is about 12 miles slightly southeast of the town.

CLIMATE AND VEGETATION

In this area the average annual rainfall is from 10 to 15 inches. The country is therefore semi-arid and irrigation must be provided for the farm lands. The crops raised in the valley are the usual mountain valley products such as; grains, hay, potatoes, and the more hardy vegetables. The more arid uplands are used as grazing lands for cattle and sheep.

Along the river bottoms willows, poplars, and cottonwoods grow in great profusion. Range grass, scrub pine, junipers, and sage brush constitute the vegetation of the uplands.

Temperature variations in this area are great, from 100°F in the summer to -30° F in the winter.

PHYSIOGRAPHY AND TOPOGRAPHY

The most striking features of the topography are the high Tobacco Root Mountains rising to elevations of 10 and 11 thousand feet; and the great Jefferson Valley which reaches from Twin Bridges to the Jefferson Canyon. The major drainage in the area is the Jefferson River which meanders through the valley. The river flows through a deep gorge at the east end of the valley and joins the Madison and Gallatin Rivers at Three Forks to form the Missouri River.

Only a few streams are found in the area; the drainage of the uplands is accomplished by intermittent streams which carry the run-off from snows and rains. The South Boulder area is drained by the South Boulder River which flows into the Jefferson River.

The mountains which have been formed by the folding of sediments rise rather suddenly from the valley floor, but have been smoothed down to some extent by erosion. High ridges and some cliffs are formed by the more resistant sedimentary strata. The elevation of the valley floor is about 4000 feet above sea level.

STRATIGRAPHY

One of the first necessities in geologic mapping is the establishment of the geologic column for the particular area. This is often a very difficult task; because very seldom are all of the strata in an area found to be so exposed as to furnish the entire geologic sequence. Hence, in many cases the column must be pieced together bit by bit, by correlating fragments found throughout the area.

We were very fortunate, however, because in the South Boulder Canyon almost the entire sequence of rocks in this area is found exposed. This geologic section is the south limb of a syncline. The beds dip about 40° N and have a strike of N 65° W. Only one fault is encountered in the section and its effect upon the column is to repeat two of the beds.

Two days were spent studying the formations as found in the section. In this time it was possible to learn the correct geologic sequence and to make detailed studies of the rocks found. This was important because in the areas to be mapped later many of these formations were encountered. A map of the area was furnished upon which we sketched the contacts between formations.

The following description of the formations follows the normal sequence of deposition, as they were studied, from the oldest to the youngest. A map of the area and a columnar section are found on the next two pages: Page 5A and Page 5B.

ARCHEOZOIC AND PROTEROZOIC ERAS

Pony Series:

The Pony series are the oldest known rocks of this area. They form the basal complex and are thought to underlie all rocks throughout the state. The rocks are highly metamorphosed schists and gneisses and their origin is doubtful. Lack of rocks such as quartzites and marbles in the Pony series tends to indicate that the origin is igneous. These rocks form the core of the Tobacco Root Mountains, indicating the great antiquity of the range. In the field the rocks of the Pony series can be recognized by the typical gneissic character, with bands of light colored quartz and feldspar alternating with hornblende and biotite. Biotite and hornblende schists are also very common in the Pony series. The series is highly contorted and folded and has complex fault systems. In areas that are covered the rocks can often be detected by shiny biotite specks in the soil. The age of the Pony series is thought to be Archean.

Cherry Creek Series:

Although this formation is not found in South Boulder Canyon, its presence in nearby areas establishes this position in the geologic column. An erosional unconformity exists

ERA	PERIOD	FORMATION	SYMBOL	COLUMN	THICKNESS	LITHOLOGY
CENOZOIC	Tertiary	Lakebeds	Tlb		Variable	Soil and sediments laid down by erosion in once existing lakes.
MESOZOIC	Cretaceous	Livingstone	Klv		2000'	Andesites containing flat oriented phenocrysts of feldspar in a very fine grained matrix. Series of agglomerates.
		Colorado	Kc		100'	Greenish gray to black shale which on weathering forms gumbo.
		Kootenai	Kk		875'	Base is a porous, medium grained "salt and pepper" ss. Top is brilliant red shales and a gastropod ls.
	Jurassic	Morrison	Jm		250'	Series of soft, sandy, varigated shales. May be any color.
		Ellis	Je		300'	Interbedded ls., ss., sh. Index fossil - star crinoid
PALEOZOIC	Permian	Phosphoria	Pp		100'	Black chert base overlain by an oolitic phosphate bed and oil shales.
	Penn.	Quadrant	Pq		200'	A dense, hard, vitreous quartzite.
	Mississippian	Amsden	Pa		350'	Light sugary grained, crystalline limestone. 10 ft. red shales at bottom.
		Madison: Mission Canyon	Mmc		1250'	A very resistant, white, massive, crystalline, fossiliferous limestone.
		Madison: Lodge Pole	Mlp		1100'	A very dense, fine grained, black limestone with shaly beds.
	Devonian	Three Forks	Dtf		285'	A grayish green shale containing thim sandy and calcareous beds.
		Jefferson	Dj		1150'	A black, sugary, crystalline dolomite which on a fresh break gives off a fetid odor.
	Cambrian	Dry Creek	Єdc		90'	Impure, sandy, redish brown shale.
		Pilgrim	Єpm		400'	Massive, mottled, soft dolomite called the "zebra Limestone".
		Park	Єpa		100'	A green, fissile, argillaceous, micaceous shale.
		Meagher	Єm		440'	Massive, mottled, gray, rather fine grained magnesium limestone. Called the "Black and Gold" ls.
		Wolsey	Єw		250'	A green, argillaceous, micaceous shale showing worm tracks.
		Flat Head	Єf		85'	Pure, pink, hard, vitreous quartzite.
ARCHEOZOIC	Pre-Cambrian	Pony	AR		5000'	Complex schists and gneisses showing bands of feldspar, hornblend, and quartz. Bands may contain calcite. Stringers of quartz and pegmatite dikes are common.

between the Pony and Cherry Creek series. The Cherry Creek is also a series of highly metamorphosed gneisses and schists, and it is very often difficult to differentiate it from the Pony series. However, in many places bands of marble and quartzite are found, therefore indicating a sedimentary origin. Again, the Cherry Creek is highly folded and contorted. These rocks tend to be lighter in color than the Pony series.

Belt Series:

Between the Cherry Creek and Belt series there exists an erosional unconformity. The Belt, although not found at South Boulder, is the third member of the pre-Cambrian rocks found in this area. In the Jefferson Canyon the Belt formation consists of a conglomerate that contains pebbles and rather large boulders of gneiss, quartzite, and marble. The conglomerate grades into an arkose to the north and east. At Renova the arkose is overlain by fine grained vari-colored shales and argillites. This gradation from conglomerate to arkose to shale in such a short distance indicates that a delta condition existed, with a land mass to the southeast and a large river pouring these clastic sediments into the sea which lay to the north. When viewed from a distance the Belt formation has a deep brown look, much darker than the overlying Paleozoic rocks. The Belt series is thought to be late Proterozoic (Algonkian) in age.

PALEOZOIC ERA

Cambrian

Flathead:

The first Cambrian formation found is the Flathead quartzite and is middle Cambrian in age. The rock shows cross bedding in many places, indicating shallow depositional enviornment. The rock is a hard, coarse grained, pink, vitreous quartzite cemented with silica. This resistant rock often outcrops in conspicuous ridges accompanied by talus slopes of large, blocky, angular quartzite boulders. This formation is from 75 to 100 feet thick. The rock gets more impure toward the top and grades into the Wolsey shale. (See plate 1, Page 8)

Wolsey:

The Wolsey formation is a green, micaceous, and argillaceous shale. The shale is characterized by peculiar markings which look like worm trails. The formation becomes more limy toward the top and eventually grades into the overlying limestone. The soft shale weathers easily and therefore forms grass covered depressions and valleys. The formation is 300 feet thick. (See plate 2, Page 8)

Meagher:

The Meagher limestone is a formation about 450 feet thick. Chemically the rock is a magnesian limestone containing from 5 to 15% magnesium. The lower 100 feet of the formation consists of a black slabby limestone. The next member of the formation is a mottled "black and gold" limestone. This black and

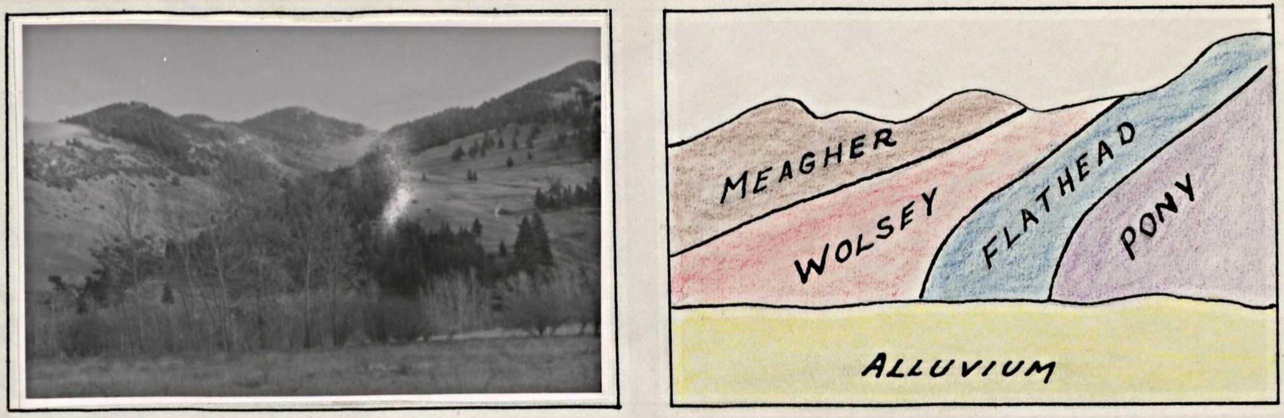


PLATE 1

East side of South Boulder Canyon showing pre-Cambrian and Cambrian formations.

PLATE 2

Wolsey Shale

PLATE 3

Meagher Limestone

buff mottling is very characteristic of the Meagher but only occurs in certain horizons.

At the top 10 or 20 feet of the Meagher there is a zone that contains trilobites. These trilobites are broken up probably by wave action in a shallow sea. Also in this horizon there are located flat limestone fragments which can be termed as an edgewise conglomerate. The presence of and edgewise conglomerate further substantiates the theory of shallow water in the late stages of deposition of the Meagher.

The Meagher stands out in outcrop in relation to the adjacent shales. The dip of the formation is 40° N and strikes N 65° W. (See plate 3, page 8)

Park:

Up lift in some remote area, Canada or Idaho may have been the cause for the deposition of the Park shale. No outcrops of this formation can be found because it is very soft and weathers into grassy slopes and valleys. The formation is a green, fissile, argillaceous, micaceous shale. Often only small chips of Park shale can be found in the top-soil and can sometimes be found in such excavations as gopher holes. This shale is distinguished from the Wolsey by lack of worm trails and by the fact that it is more fissile. The thickness of the formation is from 75 to 100 feet.

Pilgrim:

The Pilgrim formation has the chemical composition almost pure dolomite. This formation stands out in large ridges and weathers into large blocks. Another weathering feature is shown on hand specimens by small ridges and grooves formed in the rock. The lower 30 or 40 feet of the Pilgrim resembles the Meagher formation. However, the Pilgrim is characterized by a distinctive mottling in two tones of gray. This mottling has led to the name "zebra limestone" to be given to the rock. There are no distinctive fossils but the two tones of gray and a sugary texture are a great aid in identifying the rock. The formation has a thickness of about 400 feet and the dip is about 42° W. (See Plate 4, page 8)

Dry Creek:

This formation, the Dry Creek shale, is the uppermost of Cambrian strata in this area. The shale is sandy and very impure. Dry Creek shale does not appear in outcrop very often and usually occurs as a grass covered slope or depression. Fragments of reddish, brown, sandy Dry Creek shale occur as float and can sometimes be found where ditches have cut through the topsoil to expose the formation. The ground in this formation has a reddish cast due to the presence of iron. The Dry Creek formation is 90 feet thick.

Ordovician and Silurian

There are no Ordovician or Silurian rocks in this area. Either there was no deposition during these periods or there was deposition with subsequent erosion to remove all traces of rocks of these two geologic periods.

PLATE 4

Pilgrim Formation

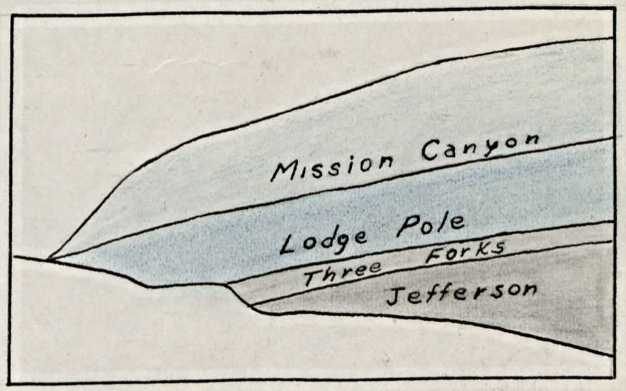


PLATE 5

"Mountain Making", Madison Limestone

PLATE 6

Livingstone Formation

Devonian

Jefferson:

The Jefferson dolomite is the first formation of the Devonian period and lies directly over the Cambrian due to the lack of Ordovician and Silurian strata. The formation is approximately 1100 feet thick and can be divided into two rather clearly defined horizons. The lower portion of some 300 feet can be best described as a black or dark gray, muddy, magnesian limestone. The upper portion of the formation is black, sugary, crystalline dolomite. Freshly fractured specimens of the rock emit a fetid odor due perhaps to the presence of sulfur. In some horizons the formation has inclusions of drusy quartz geodes. There are no distinctive fossils to be found in the Jefferson formation. In this area the Jefferson is not a ridge former but in other areas it usually does outcrop as a ridge.

Three Forks:

The Three Forks shale is a formation which almost invariably forms a valley due to the soft nature of the rocks. The formation consists of gray to greenish fissile shales which are intercalated with one inch lenses of sandstones and limestones. Fossils are very common in this formation, brachiopods and bryozoans being in greatest abundance. The formation is approximately 300 feet thick.

Mississippian

Madison:

The Madison group of sediments is divided into two separate formations, the lower member is known as the Lodgepole formation and the upper member is designated as Mission Canyon. The total thickness of the Madison group is about 2350 feet.

Lodgepole:

This lower member of the Madison group is about 1100 feet thick and consists of a dense, fine grained, black limestone with shaly partings between beds. The rock has much the appearance as a fine grained basalt. Crinoid stems, bryozoans, and brachiopods are very common is the Lodgepole formation.

Mission Canyon:

The Mission Canyon or upper member of the Madison group is a white, massive, crystalline, limestone. The crystals are easily discernable in hand specimens and look about the size of a match head. Some portions of the formation have chert zones, which are probably due to secondary filling of porous zones in the limestone. The Mission Canyon stands out in bold outcrop and is often called the "mountain making limestone". The formation has many fossils with crinoids, brachiopods, bryozoans, and some molluscs being common. The Mission Canyon is about 1250 feet thick. (See plate 5, page 11)

Amsden:

The Amsden formation is a limestone which resembles

Mission Canyon very greatly. However, 10 to 20 feet of red beds known as "Amsden reds" lie between the Madison and Amsden limestones. If these red beds can be discovered then the Madison and Amsden can be separated. The Amsden is about 350 feet thick. Although the Amsden is placed in the Mississippian period by most stratigraphers it also extends into the Pennslyvanian. It can therefore be considered as transitional formation between two periods.

Pennsylvanian

Quadrant:

As stated before, the Amsden is a transitional formation; and no sharp contact between it and the overlying Quadrant quartzite can be found. The Quadrant is a pink hard, vitreous, pure quartzite. A few thin layers of interstratified limestone are found in the quartzite formation. The basal beds of the formation show cross-bedding. The formation is very resistant and forms ledges and ridges wherever it outcrops. Large boulders weather out and form characteristic talus slopes. The Quadrant is about 200 feet thick.

Permian

Phosphoria:

The basal member of this formation is a quartzite conglomerate about 10 feet thick followed by a black chert. This black chert is irregularly banded and has a chonchoidal fracture and is very characteristic of the Phosphoria. Overlying the chert is a this bed of phosphate rock. This phosphate rock has an oolitic texture and weathers to a light gray or bluish tint, known as "phosphate bloom". Several of these thin beds of phosphate rock are found in the formation. In other parts of the state the beds thicken and are mined for the phosphate. Also found in the formation are about 30 feet of black fissile oil shales. These shales contain kerogen and will produce oil upon destructive distillation. A match flame held to a fragment of the shale gives off the distinctive pertroliferous odor. Some shaly sandstones are also found in the formation. Contrary to the logical conclusion the formation was not named for the phosphate present but was named for a town in Utah, where the formation outcrops. The total thickness of the formation is about 100 feet.

MESOZOIC ERA

Triassic

Triassic formations are absent in this portion of the state. The permian seas perhaps withdrew at the end of the Paleozoic Era and this area was a land mass in Triassic times.

Jurassic

Ellis:

The Ellis formation consists of shales, limestones and sandstones. The Ellis is rather difficult to pick out and hence sequence in the geologic column may be the best way to recognize the formation. The base of the formation is a yellow chert upon which are laid a series of brown, green, and gray shales. The upper member of the formation is a gray massive limestone whick contains an index fossil for this formation. This fossil is a star shaped crinoid stem and occurs quite abundantly in the limestone. Also present in the limestone are fragments of oyster shells which make the rock glisten when broken and a fresh surface is exposed. The thickness of the Ellis is about 300 feet.

<u>Morrison</u>:

The Morrison formation is a series of variegated shales. The shales are very impure in many cases can be classified as shaly sandstones. The color variation in the Mottison is great. Gray, green, red, buff, and maroon shales are found. This difference in color may be attributed to the chemical state of the iron present. The ferrous iron tends to give the duller greens and grays; while the ferric iron gives the more vivid reds and maroons. The Morrison formation is a Terrestrial deposit, with the materials of deposition coming from the rising Cordillera in the west.

In other portions of the state and in Wyoming the Morrison has yielded dinoseur remains. One of the best clues to the identification of the Morrison is to correlate it with the overlying Kootenai formation. In this area the thickness of the formation is about 250 feet.

Cretaceous

<u>Kootenai</u>:

The Kootenai formation is thought to be essentially a terrestrial deposit and consist of sandstones, shales, and some limestone. The basal member of the formation is a medium grained rather compact sandstone in which are found white quartzite particles and black chert particles. This gives the sandstone a characteristic appearance and it has been given the applicable name of "sale and pepper sandstone". Overlying the sandstone is a series of brilliant red shales known as the "Kootenai reds". About two-thirds of the way up the formation the limestone member 75 feet thick encountered. This limestone contains fossil gastropods and for this reason has been labled the "gastropod limestone". The gastropods have been identified by paleontologists as a fresh water species. The formation is capped by a sandstone which does not resemble the basal member. The formation is approximately 850 feet thick.

Colorado:

In the plains of the eastern part of the state the Colorado attains a thickness of 2000 feet; but in the mountain regions such as South Boulder only about 100 feet if Colorado shale is found. The shales are gray, green and black; and upon wetting a very sticky gumbo is formed.

Livingstone:

The Livingstone formation is a series of agglomerates and lava flows which occured close to the end of Cretaceous time and preceded Larmide folding. Thelower portion of the formation is about 1000 feet of agglomerate and consists of rounded pebbles of basic lava in a matrix of volcanic mud. Overlying this agglomerate is a lava flow which is andesitic character for the most part. About 500 feet of these lavas are present. Another agglomerate similar to the basal member is the next in the series. Capping the formation is about 500 feet of porphyritic lava. This rock is a fine grained andesite containing lath like crystals of white feldspar which have a parallel orientation. The ground-mass is of a deep brown to green in color; and the presence of white phenocrysts gives a texture that has been called "oatmeal rock".

The complete thickness of the Livingstone has been estimated to be 2000 feet. (See plate 5, page 11)

CENOZOIC

Tertiary

Lake Beds:

The Cenozoic sedimentation is represented principally as Tertiary lake bed deposits. These deposits cover most of the low lying areas and primarily interstratified sands and gravels. Stream gravels, sands, and alluvial fan deposits are aslo classified here.

HISTORICAL GEOLOGY

Intense metamorphism, complicated folding, and faulting of the Pony series, the basal comples, has left their origin very obscure. These rocks were eroded and brought to a base level with a subsequent influx of seas and deposition of the Cherry Creek sediments. Uplift and accompanying metamorphism changed the Cherry Creek to a series of schists and gniesses similar to the Pony series. A long period of erosion followed and the area was again depressed beneath the seas. A land mass to the southeast then furnished the sediments for the thick Belt formation which was deposited to the northwest and covered a large area. The Belt is the last of the pre-Cambrian formations in the area and is labeled as Algonkian in age. No intense mountain making is evident between the Proterozoic and Paleozoic eras, however a gentle warping of the Belt sediments has been reported.

With the advent of Cambrian time the entire Montana area was a low-lying land surface and hence no lower Cambrian sediments are found. Advancing middle Cambrian seas began the sedimentation of the Paleozoic era. The era was marked by widely fluctuating seas, with complete submergence in many periods and occassional emergence and partial erosion of the rocks. All of the Paleozoic strata are nearly parallel, however many hiatuses in the depositional cycle indicate emergence as low lying land surfaces. A condition such as this may account for the absence of Silurian sedimentation or perhaps erosion of the rocks may be the chief cause.

Life was abundant during the Paleozoic era and warm waters had to be present at times to account for the presence of corals. Limestones are the predominant rocks of the period which would indicate that erosion was taking place over widespread low lying lands.

No mountain making took place during the Paleozoic era, however a broad regional upwarping is evident. The era approached its close with a widespread deposition of sands which would indicate that uplift was taking place in some distant region. The Pennsylvanian and Permian seas were shallow as is evidenced by the ripple-marked and cross-bedded Quadrant formation and the special shallow sea conditions which must have existed to deposit the oolitic phosphate of the Phosphoria.

At the close of the era the Permian seas withdrew and left a large low lying area with a desert climate. Hence the Mesozoic ere is represented by Jurassic and Cretaceous sediments only. Complete submergence in Jurassic resulted in the deposition of shales and limestones.

The lower Cretaceous is marked by widespread piedmont and coastal plain lands with the beginning of the great Laramide uplift in the west. The upper Cretaceous seas fluctuated widely and resulted in an interfingering of marine shales and terrestrial coastal plain deposits. As opposed to the great thicknesses of Paleozoic limestones, the Mesozoic is best represented by shales and sandstones.

At the end of Cretaceous time igneous activity began to play an important role and the great thicknesses of Livingstone volcanics were spilled out upon the surface and into the seas. Intrusion of such masses as the Boulder and Tobacco Root batholiths took place at this time or perhaps in very early Tertiary (Paleocene).

In Tertiary times the mountains uplifted by the Laramide orogany underwent deep erosion and an approach to base level. Block faulting, warping and uplift in the west then occured in

Eocene time. The down dropped blocks caused a series of mountain valley lakes to be formed such as the Jefferson valley. The subsequent erosion has caused drainage of most of the lakes and has produced our present topography.

The Pliestocene glaciers have left their mark upon the topography with cirques; U-shaped valleys, such as South Boulder Canyon; and glacial moraine.

IGNEOUS ROCKS

Most of the igneous rocks of the areas in whick work was done have been discussed to come extent in the section on rock descriptions. The pre-Cambrian Pony and Cherry Creek series have been intruded by cark colored sills, granitic rocks, and pegmatites. Also, it is very difficult to determine the origin of many of the schists and gneisses of the pre-Cambrian. The mineral composition of many of these rocks, however, suggests that their origin might well be igneous.

The entire Paleozoic era transpired without igneous activity. Late in the Mesozoic era in upper Cretaceous time a great series of lava flows spilled out over the flat lying sediments of the area. These volcanics are discussed under stratigraphy and are known as the Livingstone formation.

In early Tertiary (Paleocene) times came the intrusion of the Boulder batholith and other related igneous masses. It is thought that such igneous bodies as the Tobacco Root batholith were intruded at the same time; and perhaps all of these plutons are actually from the same source. Effects of these large igneous bodies were tremendous, but out area has not been affected to any great extent.

STRUCTURE

The structural geology of this area can best be brought out by a brief discussion of broad overall regional structure.

Intense folding and complicated fault patterns in the pre-Cambrian systems indicate great orogenic forces as being active in those times. Very little work has been done in conjunction with the structure in these rocks.

With the advent of the Laramide orogeny in late Cretaceous time the sediments of the Paleozoic and Mezozoic eras were subjected to intense folding and faulting. Synclines and anticlines were formed first as a result of gentle upwarping, greater and continuing forces tended to overturn many of the folds and in many cases fracturing and overiding of beds ocurred. Consequently, western Montana is marked by a series of low angle thrust faults with lateral displacements of great magnitude.

After the great mountain building activity had died out block faulting of large magnitude and wide extent took place. Probable reasons for this block faulting are explained as being a relaxation in the great tangential forces which had caused the mountain building. These fault blocks find expression today as the large inter-montane valleys of western Montana.

Locally, structures will vary and many minor faults and folds have been formed. These local structures in our area will be discussed in the section where these areas are taken up in detail.

DESCRIPTION OF THE MAYFLOWER AND RENOVA AREAS

Several crews worked on the map of the Mayflower area, which accompanies this report. The maps were combined to show a better picture of the structure.

The map shows a syncline that plunges to the southeast. The south limb of the syncline dips to the north at about 40°. The north limb of the syncline has been cut by the Mayflower fault, which has thrown strata of Cambrian age against Cretaceous rocks. A cross section A-A has been drawn to illustrate the structure. Cambrian strata at the north end of the cross section dip almost vertically and are cut off by the fault. The more gently dipping beds to the south also terminate at the fault. See cross section on page 24A.

An explanation of this structure is as follows. A series of flat lying sediments were subjected to tangential north and south forces. A syncline developed, but with an increase in force the north limb became almost vertical. These brittle rocks did not become overturned but rather a fault developed to take up the stress. The fault is a high angle thrust fault with a dip of about 60 to 70°. Some lateral movement along the fault is also evident by the displaced strata in the northeast section of the map. Hence, the Mayflower fault may be termed as a hinge fault.

At the south end of cross section A-A another fault is encountered. This is a normal fault as shown on the cross section, and repeats two of the formations, Quadrant and Phosphoria.

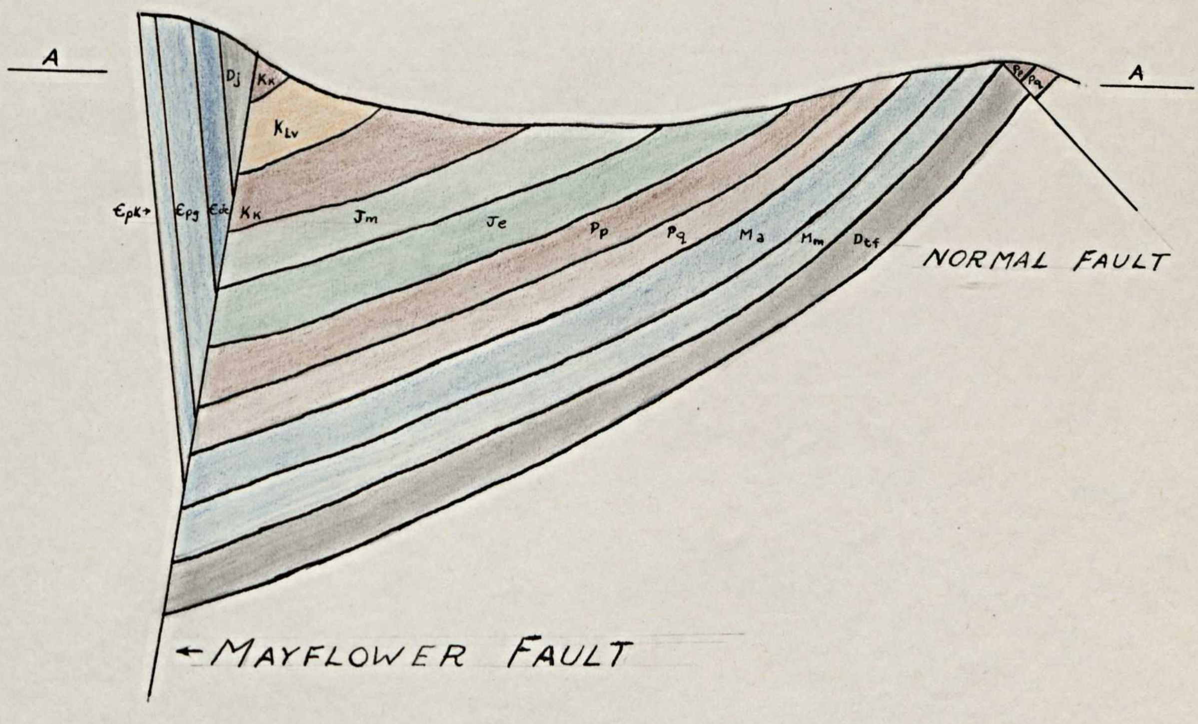
The map labled as the Renova - Bone Basin Area, was drawn up from work don by three crews. Our area of this map is shown in the ledgend as the work done by crew No. 1.

In this area we followed Cambrian strata along high ridges which they had formed. A series of short choppy faults were encountered and are shown on the map. These faults appear to be about vertical and have the same general trend in strike. Most of the faults have a strike of about N 50° E. It was proposed that perhaps one of these faults is a continuation of the strong Mayflower fault. This is possible because the faults have the same general trend. However, the area between the Mayflower and Renova was not mapped so that this idea cannot be verified.

It has been stated by Tansley and Schafer that, "these faults appear to be an adjustment of relatively brittle rock layers to the sharp folding of Paleozoic rocks around the northern nose of the range--the broken apex of a subordinate fold on the major dome." [1]

The rocks found in this area are much the same as studied in the South Boulder Section, and not much difficulty was encountered in the identification of the strata. The faults also were identified quite easily except on talus covered slopes.

[1] Tansley, Schafer, and Hart, A Geological Reconnaissance of the Tobacco Root Mountains, p 20.



CROSS SECTION A-A

PLATE 8

Mayflower Mine

Madison County, Montana

ECONOMIC GEOLOGY

The greatest percentage of Montana's mineral wealth has been produced from the south-west portion of the state. Mountain making and igneous activity have caused this great concentration of mineralization.

The specific areas discussed in this report have only two mines of economic consideration. These mines are the Mayflower and Florence.

Available figures on production show that between the years of 1896 and 1901 the Mayflower mine yeilded about $1,250,000. This was produced from a high grade gold ore which averaged about $150.00 a ton. During this period the property was owned by William A. Clark. At present the mine is owned by the Anaconda Copper Mining Company and has been shut down since the wartime ban on gold mining went into effect.

The Mayflower ore shoots are of the fissure type and lie on the northwest side of the Mayflower fault. The ore shoots dip steeply and are associated with the Wolsey shale of the Cambrian period.

The Florence mine at present is being operated by a single lessee and no figures are available as to prior production.
A picture of the Mayflower mine is shown on Plate 8, page 25.

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