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Geology of the Renova-Bone Basin and Mayflower Mine Areas

R. L. Burns

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GEOLOGIC MAPPING CLASS
MONTANA SCHOOL OF MINES
SEPTEMBER 1947

View looking north, Mayflower Mine area, showing the Flathead, Wolsey, and Meagher of the Cambrian.

Mayflower Mine, near Whitehall, Montana.

Frontispiece

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INTRODUCTION

This report has been compiled from the data collected during the September, 1947, geologic field trip of the Montana School of Mines. The trip, under the direction of Dr. E. S. Perry, consisted of two weeks of field mapping and observation near Whitehall, Montana, and one week at the Montana School of Mines preparing this report.

During the field work, three areas were visited -- South Boulder, Renova-Bone Basin, and the Mayflower Mine. C. S. Swanson, K. Stout, R. J. Meehan, and the author were the members of the crew that compiled the data for this report. The maps in the report were made by the use of plane table and stadia rod. A Brunton compass was used to determine the dip and strike of the beds.

ACKNOWLEDGEMENT

The author wishes to thank Dr. E. S. Perry, Dr. George Kiersch, Mr. Alvin Hanson, and Mr. Uuno Sahinen for their invaluable assistance during the trip.

PHYSIOGRAPHY

Whitehall, Montana, thirty miles southeast of Butte, Montana, on U. S. Highway no. 10, lies in the broad level Jefferson valley, surrounded by rugged, mountainous country. The elevation ranges from 4500 ft. in the valley to 7000 ft. on some of the mountains. The area is traversed by two railways, the Northern Pacific, and the Milwaukee.

CLIMATE & VEGETATION

The semi-arid, temperate climate promotes the growth of typical mountain flora of the western United States -- conifers at the higher elevations with sage brush and many types of hardy grasses in the valley and foothills. (See the photographs accompanying this report.)

The Jefferson valley is an area of extensive agricultural activity -- both the cultivation of cereal grains and the grazing of sheep and cattle.

GENERAL GEOLOGY

STRATIGRAPHIC GEOLOGY (See Plate I)

ARCHEOZOIC

The Basal Complex, thought to underlie all Montana sediments, consists of complex schists and gneisses. Due to metamorphic activity, it is not certain whether the origin of the basal complex is sedimentary or igneous. The contorted bands are sometimes limey and garnet is often present. The basal complex has been divided into two parts:

(1) The Pony Series, at the bottom of the basal complex, is the most complex of the Pre-Cambrian deposits and its origin has not been ascertained.

(2) The Cherry Creek, not seen in the area consists of limestones, marbles, and quartzites of sedimentary origin. Many metamorphic minerals are contained in the marbles and quartzites. Some of the dolomitic limestone bands are 800 to 1000 ft. thick and often carry talc.

PROTEROZOIC

The Belt Series, lying above the basal complex, grades from a series of conglomerates, 1000 to 2000 ft. thick, at the bottom thru arkose, 1500 to 2000 ft. thick, in the middle to grey and silver-grey (often with red and blue tints) fine-grained shales. The

STRATIGRAPHIC COLUMN SOUTH BOULDER SECTION

AGE	PERIOD	FORMATION	SYMBOL	COLUMN	THICKNESS	LITHOLOGY
MESOZOIC	CRETACEOUS	Livingston	Kl			Lava Flows Agglomerates
MESOZOIC	CRETACEOUS	Colorado	Kc		60	Gray greenish shale
MESOZOIC	CRETACEOUS	Kootenai	Kk		950	Sandstone, Has salt and pepper appearance, red shales
MESOZOIC	JURASSIC	Morrison	Jm		275	Variegated shales
MESOZOIC	JURASSIC	Ellis	Je		160	Shales, Limestones, Sandstones, Star Crinoids
PALEOZOIC	PERMIAN	Phosphoria	Pp		75	Chert, Oil shales, Phosphate beds
PALEOZOIC	PENNSYLVANIAN	Quadrant	Pq		290	White & pink quartzite
PALEOZOIC	MISSISSIPPIAN	Amsden	Ma		275	Limestone underlain by red shale beds
PALEOZOIC	MISSISSIPPIAN	MADISON: Mission Canyon	Mmc		1400	White massive limestone, Forms mountains and ridges, Contains crinoidal fossils
PALEOZOIC	MISSISSIPPIAN	MADISON: Lodgepole	Mlp		1000	Fine grained, dense, black, limestone, has shaly parting
PALEOZOIC	DEVONIAN	Three Forks	Dtf		400	Fossiliferous shale, contains sandy & limey beds
PALEOZOIC	DEVONIAN	Jefferson	Dj		1150	Black crystalline dolomite, Fetid odor
PALEOZOIC	CAMBRIAN	Dry Creek	Cdc		80	Brown, sandy shale
PALEOZOIC	CAMBRIAN	Pilgrim	Cpg		260	Cliff forming dolomite
PALEOZOIC	CAMBRIAN	Park	Cpk		90	Green, fissile shale
PALEOZOIC	CAMBRIAN	Meagher	Cm		450	Magnesian limestone Mottled appearance Trilobites
PALEOZOIC	CAMBRIAN	Wolsey	Cw		260	Green, fissile shale
PALEOZOIC	CAMBRIAN	Flathead	Cf		130	Pink quartzite
ARCHEOZOIC	PRE CAMBRIAN	Pony				Basal Complex, Gneisses and Schists

entire series is about 5000 ft. thick.

PALEOZOIC

Cambrian -- (No lower Cambrian in Montana)

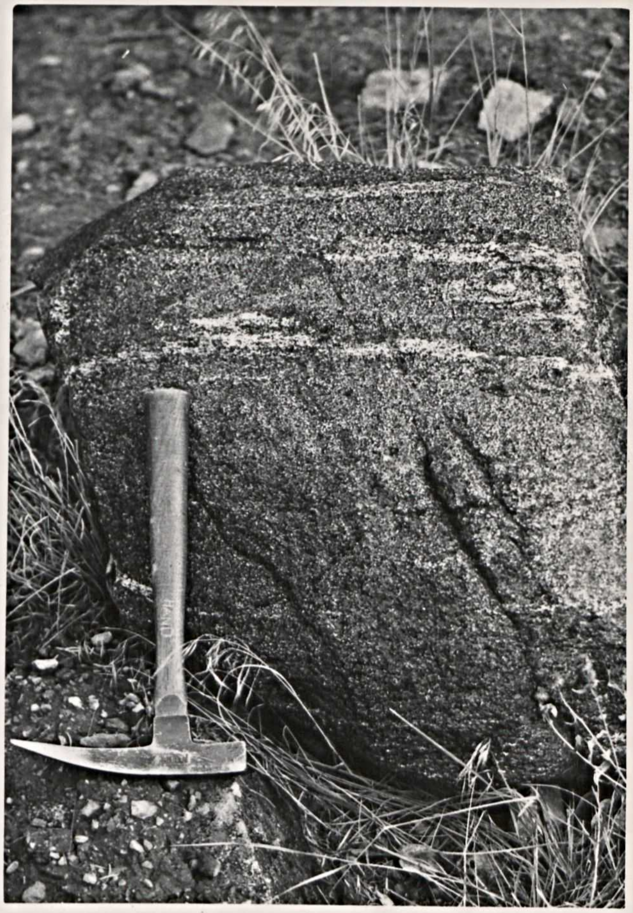
The Flathead quartzite, the earliest Cambrian sediment in Montana, is a cross-bedded quartzite of pure quartz. The individual bands, originally sandstone, vary from 6 in. to 1 ft. thick. The thickness of the entire bed varies from 75 to 100 ft.

Because this sediment is usually a hard, vitreous quartzite, it weathers more slowly than the surrounding sediments, forming ledges, walls, and ridges. In some places, however, weathering has shown more effect and the outcrops are more difficult to distinguish.

Following the common sequence of sandstone, shale, and limestone, we find the Wolsey shale lying on the Flathead. The green, fissile, micaceous, argillaceous Wolsey grades from the quartzite rather abruptly. Next, limey bands appear interspersed with sandy bands. The entire bed is about 300 ft. thick, with worm tracks profusely evidenced in the shale.

Next the Meagher limestone, containing 5-15% magnesium, appears. Small bands of grey and buff, mottled limestone appear -- called "Montana Black and Gold." Small bands of oolitic material are also found. Trilobites are carried at the top of the Meagher, almost a coquina in places. Edgewise conglomerates also are found in the upper Meagher. The entire bed is about 800 ft. thick.

Above the Meagher limestone, the Park shale, 80 to 100 ft. of green, fissile, argillaceous, micaceous shale, makes its appearance. The Park will often be mistaken for the Wolsey if the sequence of beds is not observed. The Park usually is evidenced by small chips and flakes of green shale.



Pony gneiss, South Boulder

Wolsey, Mayflower Mine area

Plate I

Next we meet the massive Pilgrim dolomite. The contact between the Park and the Pilgrim is well marked. The Pilgrim, a mottled, two-toned, grey dolomite, forms blocky cliffs and ridges. The lower Pilgrim looks very much like the Meagher, but the middle portions, which weather in peculiar small ridges and depressions, prove the difference. The bed is about 200 to 300 ft. thick. Fragments of fossils (mostly trilobites) are found near the top of the formation.

The shales and sandstones of the Dry Creek, laying on the Pilgrim, weathers easily and consequently is found in valleys and depressions. The outcrop area is evidenced by small, flat, float chips of reddish brown sandy shales and impure sandstone. The sandstone layer can be seen plainly in the Mayflower area. This formation of shales and sandstones, the uppermost Cambrian in this area, is 75 to 100 ft.thick.

DEVONIAN -- (The Ordivician and Silurian are absent in this area.)

The Jefferson dolomite has two divisions; the lower, a muddy looking dolomite, is about 300 ft. thick, while the upper division, crystalline dolomite which commonly exudes a fetid odor from a freshly broken surface, is about 700 ft. thick. In the uppermost sediments are found the few fossils evidenced. Also, small quartz geodes are sometimes encountered. Some light-colored, sandy beds are seen near the top.

The Three Forks, the next formation is composed of greenish-grey alternating bands (about 1 in. thick) of sandy shales and limey shales, crowded with Devonian fossils. A band of yellow sandstone (the Sappington sandstone), with which coal is associated in some places, marks the top of the formation. The total thick-

Meagher, Wolsey, Flathead,
Mayflower Mine area

Blocky Pilgrim, South Boulder

Plate II

ness of the bed is about 300 ft.

MISSISSIPPIAN --

The Madison formation is a rather pure limestone that has two divisions.

(1) The Lodgepole, the lower division, is composed of 1000 ft. of fine, dense, black, limestone with shaly partings about ½ in. apart. The formation is so dense and fine-grained it is sometimes mistaken for basalt.

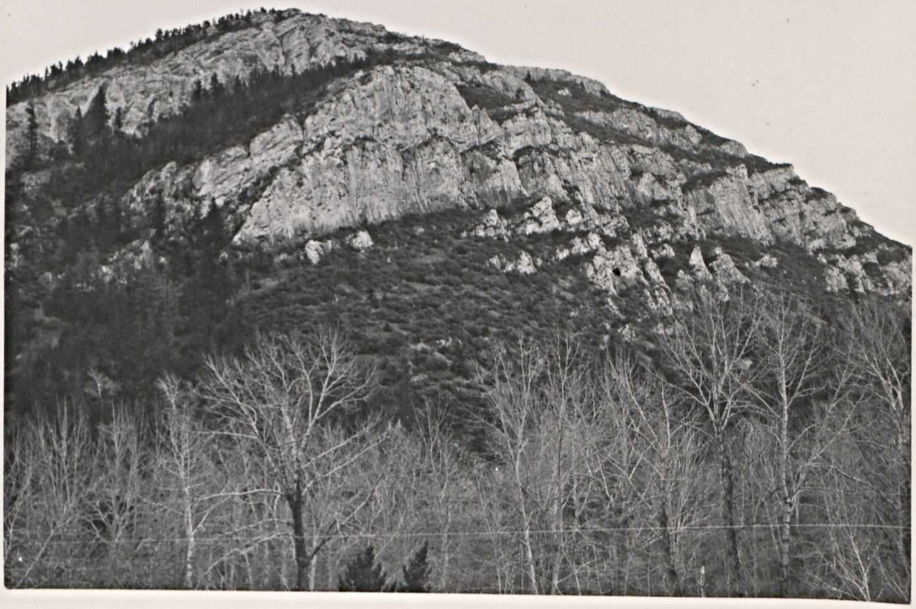
(2) The Mission Canyon, the upper member, is white, crystalline (crystals the size of a match head) limestone about 1000 ft. thick. Crinoidal fossils abound. Seams of grey chert are seen at irregular intervals. The Mission Canyon is a mountain making formation.

The Amsden, about 300 ft. thick, resembles the Mission Canyon of the Madison. The division, however, is marked by the distinctive Amsden red beds -- a red shale deposit 10 to 20' thick. Although this deposit is covered due to its inability to withstand weathering, float from the beds can usually be traced thus closely approximating the position of the outcrop area. The formation weathers to form valleys and depressions. The uppermost 30-40 ft. consists of a reddish shale. Fossils are found in some horizons.

PENNSYLVANIAN --

The Quadrant is a hard, vitreous, pinkish quartzite formation that somewhat resembles the Flathead. The deposit often forms block ledges and hills. Boulders (diam. of 3 ft.) are sometimes found and cover the contacts. The formation is about 300 ft. thick. Thin-bedded, cherty limestone strata, alternating with the quartzite

Dry Creek sandstone,
Mayflower Mine area



Madison, South Boulder

Plate III

layers, are encountered.

PERMIAN --

The bottom of the Phosphoria formation, 75 ft. thick, is marked by a thin bed of black chert with which is associated a deposit of phosphate rock 1 to 10 ft. thick. The black, oolitic phosphate weathers to a light bluish-grey rock; the oolites bleach more readily than the matrix. The Phosphoria also contains a deposit of black, fissile, oil shale at the top, 25 to 30 ft. thick. The oil shale and phosphate rock make the Phosphoria one of the most easily distinguished formations.

MESEZOIC

JURASSIC -- (There is no evidence of the Triassic in this area.)

The Ellis, usually covered, is recognized by the sequence of variable shales, limestones, and sandstones. The base of the Ellis is marked by a bed of yellow chert peculiar to this area. Star crinoids, the size of a match head, and belemites are found in the Ellis. The lower beds are, in some places, crowded with Jurassic fossils, mostly oyster shells. The middle and upper portions, however, are barren of fossils.

The Morrison is a series of variegated shales -- grey, red, green, blue, buff, etc. Sections of the formation are sometimes sandy. Because the deposit weathers easily, it is usually covered. The total thickness is 300 to 400 ft.

CRETACEOUS -- (Lower)

The Kootenai formation, about 800 ft. thick, has a basal sandstone ledge, about 50 ft. thick, of medium grained white quartz and

Kootenai,
Mayflower Mine area

Livingston,
South Boulder

Plate IV

black chert, often called "salt-and-pepper" sandstone. Above the sandstones, brilliant red shales appear. Higher in the formation a limestone member appears between soft shales, making a distinctive formation. Great quantities of gastropods the size of a pencil head, sometimes approaching a coquina, are found in the limestone.

CRETACEOUS -- (Upper)

The Livingston formation consists of agglomerates overlain by lava flows which in turn are overlain by agglomerates with lava flows superseding once more. The lava flows are porphrytic andesites with well developed feldspar phenocrysts in a fine grained, greenish-grey matrix (often called "oatmeal" rock.)

CENOZOIC

TERTIARY --

No Tertiary lava flows are evidenced in this region. Tertiary Lake Beds are quite common in the area, forming around the edges of the valleys.

QUATERNARY --

Quaternary Alluvium overlays the Tertiary lake beds in the valleys. The Jefferson valley is composed of Quaternary alluvium.

HISTORICAL GEOLOGY

ARCHEOZOIC

The Archeozoic history is mostly obscured because of the metamorphic character and structural complexity of the Pony group. There is no doubt that along with folding and metamorphism of these beds there came igneous intrusion. Mountains made up of these

fol

folded Pony rocks were eroded and depressed beneath the sea where they received the limey muds making up the Cherry Creek formation. These beds were crumpled and elevated to mountains and were subsequently weathered and eroded.

PROTEROZOIC

Belt --

Again the land was depressed during which time the Belt series was deposited due to disintegration of Pony gneisses and Cherry Creek beds. The epicontinental sea of this region was to the west with the land masses to the east. This places the area under study on the shore line. Large rivers dumped their loads of decomposed Archeozoic deposits in this region. Thus the area from Bozeman to Butte (the shallow shoreline) shows deposits of coarse conglomerates and arkose. As the sinking of the ocean floor continued, finer sediments were deposited forming quartzites and argillites grading to fine grained shales.

PALEOZOIC

Cambrian --

During early Cambrian, uplift resulted in most of Montana and the area to the east becoming a land mass, preventing deposition. For this reason there are no early Cambrian formations. Later the seas to the west migrated eastward covering Montana. The Flathead was deposited on the extremely flat, horizontal bottom, making a thin uniform deposit of quartzite.

Ordivician and Silurian --

Something happened in western Montana whereby neither Ordivician nor Silurian deposits are present. It has not been determined whether they were eroded or never deposited.

Devonian --

Although the Ordivician and Silurian are absent, no angular unconformity can be seen in the contact between the Devonian and the Cambrian.

Mississippian & Pennsylvanian --

An uplift at the end of the Mississippian caused erosion with subsequent depression and deposition of the Quadrant sandstone, marking the Pennsylvanian. Shallow seas (with some shore lines in this area) were prevalent during the Pennsylvanian.

Permian --

Deposits of oolitic phosphate rock (collophanite, tri-calcium phosphate) mark the Phosphoria of the Permian. This marine deposit was laid down in shallow water.

MESOZOIC

Triassic --

At the close of the Permian, uplift, which caused the westward retreat of the shorelines, prevented the deposition of Triassic formations. The period was one of erosion, forming karsts in the Madison formation (the most famous of which is the Lewis and Clark Cavern), and general porosity.

Jurassic --

The lower Jurassic was marked by the subsidence of the Triassic land masses and consequent deposition of the Ellis under marine conditions. This formation is characterized by varying lithology, not always of the same sequence. Toward the end of the period, the marine seas were replaced with terrestrial conditions. The Morrison, formed of fresh water lake deposits, resulted. This formation contains the fossil remains of dinosaurs (Brontosaurus, etc.)

Cretaceous --

The terrestrial conditions remained constant from the Morrison to the Kootenai. In the uppermost Kootenai, fossils of such fresh-water life as snails, clams, etc. are found. The extent of these fossils show evidence of fresh water lakes of considerable size. Between the lower and upper Cretaceous, a disturbance changed the depositing conditions from terrestrial to marine with seas to the east and south and mountains to the west. The shorelines of these seas migrated back and forth across Montana forming alternate land and sea deposits.

During the middle of the upper Cretaceous (at the end of the Colorado), the Laramide revolution took place. The resulting crumpling and faulting of formations from Alaska to Cape Horn removed the seas from the Montana region, never returning. For this reason, all formations subsequent to the Colorado are of a piedmont nature. Following this orogeny, which had formed the Rocky Mountains, came a period of igneous intrusion (Livingston), during which the Tobacco Root batholith, forming the present Tobacco Root mountains of this region, although no outcrops of the batholith are seen in the area. The syenite sills of the Renova-Bone Basin area are believed to originate from this plutonic. Through the mountain ranges formed, a drainage system was set up whereby the Jefferson and Madison rivers ran into the Snake river to the south.

CENOZOIC

Tertiary & Quaternary --

Subsequent faulting and warping along with igneous activity which took place during the Eocene period wrought a great change in the topography. River valleys were blocked by lava flows and fault dams, bringing about a change in the stream gradient. The water thus dammed formed a chain of lakes, while the faulted blocks were elevated to mountains. Rejuvenated streams running down steep slopes carried mud, sands, and gravel into the lakes. Distant volcanoes blew great amounts of dust into the air which eventually found its way to the lakes. All this brought the formation of the chalky lake beds observed in the northern part of the Mayflower and Renova-Bone Basin areas.

Finally the waters cut their way out of the dams and drained the lakes, but the main direction of drainage had been reversed so the Jefferson and the Madison rivers ran into the Missouri river to the north as they do now. The fault block mountains now stood out and the present topographic appearance was achieved.

Pleistocene cold brought on a period of glaciation which filled the valleys with debris. Vigorous streams cut through them and broke them down. There is no evidence of glaciation having taken place in the mapped area. The alluvium of the valleys is subsequent to the glaciation and is the most recent deposit in the region.

STRUCTURAL GEOLOGY

The Mayflower fault is the outstanding structural feature of the area. The upthrown side is on the north. Pre-Cambrian and Cambrian rocks have been displaced about 10,000 ft. until they outcrop at the same level as the Tertiary volcanics. A number of drag faults which relieved pressure from the Mayflower movement can be seen in many of the strata.

Tertiary lake beds and Quaternary alluvium cover most of the northern area. As one travels south toward the Mayflower fault the beds will be encountered in ascending order, that is , from the older to the younger. These beds dip nearly vertically.

After crossing the fault, the first bed encountered is the Tertiary volcanics and then comes the rest of the series in descending order. The beds now have a strike close to northeast and dip rather steeply to southeast. Intense faulting took place in the entire region. There are two major faults trending to the northeast. The first is probably a strike fault resulting from the other. It is here that the beds of the Boulder Creek series which run in an east-west direction butt against the northeast striking beds of the Mayflower area. Stresses due to this movement were set up in the country rock causing numerous minor faults. An intricate pattern of beds and faults result. From the time spent in this particular region it would be difficult to do much toward solving it. The most significant movement is not the vertical displacement, but the change in strike seen here.

All this faulting took place during Eocene times when the fault block mountains were formed. A small amount of igneous activity accompanied this movement. The syenite sills of the Renova-Bone Basin area are an important structural feature.

ECONOMIC GEOLOGY Metallics

The only ore deposit of any commercial significance in the area is that mined at the Mayflower mine. The ores lie on the northwest side of a strong fault trending about N 50° E and dipping nearly vertically. The fault cuts Cambrian Limestones and shales with limestones carrying the principle ore shoots. The mineralization is hypogene in character. Above the 300 ft. level the ore consists of oxides enriched by superficial agencies. Below this to the 800 ft, level, the ores were tellurides. Tellurium was noted in the ore shipped, and it is believed that the tellurides were in the primary mineralization.

The Mayflower under the Clark management, from 1896 to 1901, yielded $1,250,000 from high grade ore running about $150/ton. The ore above the 300 ft. level was entirely stoped out with an equal amount taken out below this level. The West Mayflower adjoining on the west has produced about $50,000 from much lower grade ore. The mine was developed by a 700 ft. adit and a winze sunk to a depth of 925 ft. on the major ore shoot. No ore was found on the 800 or 900 ft. levels. There were two ore zones reached by this adit, a north zone and a south zone. The south ore zone consisted of two major and one minor ore shoot averaging 60 ft. in length, five feet in width, and going down vertically to a depth of 700 ft. This zone did not extend below a depth of 150 ft.

The south zone was stoped down about 900 ft. An underground hoist pulled the ore up out of the stope to the adit where it was hauled out. The ore from the north zone was dropped to the haulage level through a transfer raise.

The West Mayflower was also developed by tunnels and winzes.

Here there is only one small ore shoot having commercial value. A raise has been driven to the surface which has aided in further development.

The area surrounding the mine has numerous prospects on the faults present and some shafts, of considerable depth, indicating extensive mining in past years, on the contact between the Flathead and Wolsey. From these shafts considerable valuable ore was taken during the heyday of the region (circa 1900.)

The Renova-Bone Basin area, like the Mayflower, is pock-marked with prospect pits along faults and Flathead-Wolsey contacts. The only important deposit discovered, however, is that of the Florence mine where a fault cuts the Flathead-Wolsey contact. Formerly, the mine was of considerable economic importance. The ore occurs in fracture zones and consists of lead and copper sulphide ores bearing gold. At the present (1947), however the lessee working the mine has been unsuccessful in uncovering further commercial deposits. It was believed, though, by the incipient economic geologists in the party that the use of proper geologic methods (each with his own theory, of course) would greatly improve chances for discovery of pay ore.

The South Boulder Creek area, though prospected, has proven to be barren so far. One prospector sunk 70 ft. on a heliotrope outcrop believing it to be a copper deposit.

ECONOMIC GEOLOGY Non-Metallics

The Cherry Creek dolomitic limestones often carry talc of hydrothermal origin. Near Ennis, Montana, commercial deposits are as large as 100ft. by 300 ft. The Virginia City and Dillon areas also show commercial deposits. Vermiculite is found associated with the Cherry Creek schists.

The dark grey and buff sections of the Meagher (Montana Black and Gold) and to a lesser extent the similar sections of the Pilgrim have been exploited, with minor success, as an ornamental building stone.

Commercial deposits of coal are sometimes associated with the Sappington sandstone of the Three Forks.

Sections of the Madison yield commercial limestone deposits, though no evidence of commercial exploitation in this area was seen.

The oolitic phosphate deposits of the Permian have been exploited in many areas, however, this area shows no extensive production. The Permian oil shales, also in the Phosphoria, have been the subject of considerable research due to the presence of kerogen, which yields large amounts of petroleum when distilled. No commercial-scale process has been developed as yet that will compete with the petroleum industry.

The erosional conditions that caused the karsts in the Madison also caused general porosity, one result of which is the Kevin-Sunburst oil field in northcentral Montana. No evidence of petroleum has been discovered in the surveyed area, however.

Coal seams of importance underlie the Kootenai. Low-grade deposits of this type have been uncovered in this general area. The sandstone of the Kootenai has been a major petroleum producer in other areas.

The Quaternary alluvium of this region may be said to be of economic importance due to the extensive agriculture it supports.

DESCRIPTION OF DISTRICTS

SOUTH BOULDER

The South Boulder area was visited to aquaint the student with the ideal stratigraphic section found in this area. The beds, dipping from 70° to the North in the Belt series to nearly 0° in the Livingston, were cut by South Boulder Creek. This afforded a sequence which lends itself to easy observation and study. Since the area was visited only for the observation of an ideal section and because the beds were extremely regular with only one fault (of little importance), no maps were made of the area.

RENOVA-BONE BASIN

The first region mapped was the Renova-Bone Basin area, sections 9 and 10, T 1 S, R 4 W. The strata have been subjected to intense faulting. The faults generally tend to strike to the north. The area has been extensively prospected, with one producer, the Florence mine, yielding considerable profits in the past. Little activity can be seen at the present time, however.

The oldest formation encountered was the Belt arkose. On the west a large outcrop of Belt is seen with another outcrop of Belt in the southeast corner. Since the two are separated by Cambrian and Devonian sediments, one is led to believe a small block fault followed by, or concurrent with, other minor faulting is the cause of the present juxtaposition of sediments.

In the southwestern corner of the surveyed area, a quartz vein was mapped which showed extensive prospecting; no indication was found, however, that indicated discovery of an economic deposit.

The chalky Tertiary gravels in the center of the area form the lower hills that mark the beginning of the northwestern slope of the Tobacco Roots. The lower elevations contain Quaternary alluvium.

A syenite sill was found in the northwest corner outcropping from the Belt arkose. Due to its resistance to weathering this syenite forms many of the hills in the immediate vicinity to the northwest.

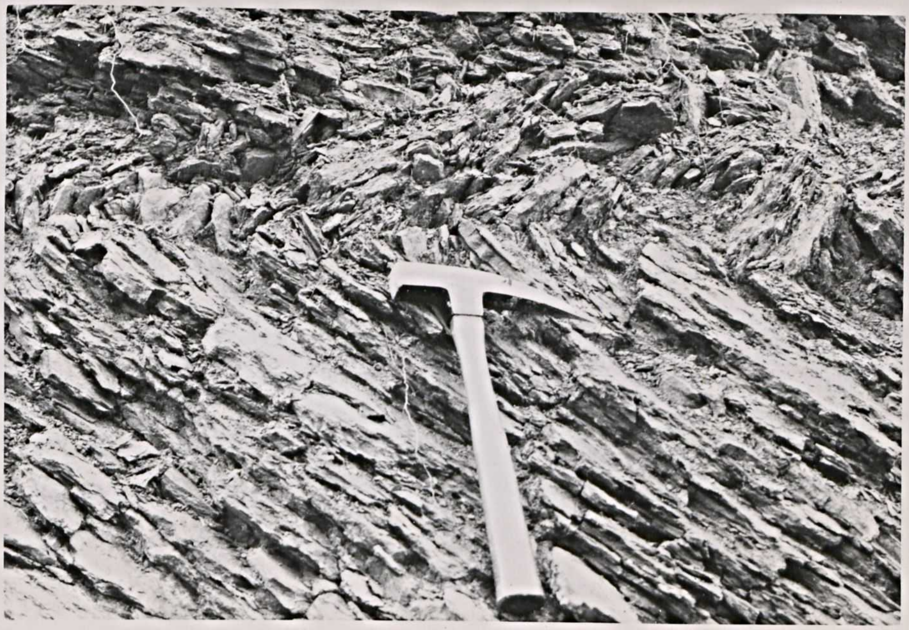
The Cretaceous volcanics on the east are strikingly apparent due to the parallel ridges formed.

MAYFLOWER

The last area surveyed was that of the Mayflower mine, sections 15, 16, 21, 22, 27, 28, 32, and 33, T 1 N, R 3 W. The survey was started at the mine and continued north to the Jefferson River. Only the area north of Mayflower fault was mapped. The fault separates Cretaceous volcanics on the south from Belt, Cambrian, Devonian, and Mississippian sediments on the north.

The entire area is one of intense and irregular folding and faulting. With the exception of two minor faults, probably concurrent with the Mayflower, found in the southern section mapped, all the faults encountered were extremely irregular and very difficult to decipher with accuracy.

A strike fault in the Meagher was followed north from the Mayflower fault to the Tertiary gravels which border the Cambrian. Except for an intensely folded region in the center of the mapped area and other minor deviations, the strike of this fault is nearly north and south.



Drag folds in Wolsey caused
by intense tectonics,
Central Mayflower Mine area

Mayflower Fault and
East Mayflower Mine dump

Plate V

The Belt occupies the western portion of the survey while the Tertiary gravels abound in the east. The central area where the most intense tectonics are observed appears to be a syncline with a general sequence, west to east, of Belt, Flathead, Wolsey, Meagher, Wolsey, Flathead, Belt with Tertiary gravels superimposed on the east. Small hills of Belt and Cambrian sediments protrude from the west-central Tertiary gravel area.

CONCLUSIONS

The trip, with the exception of occasional inclement weather, was considered interesting and successful by the party. The two-fold purpose, i.e., to acquaint the student with (1) geologic mapping methods and (2) a typical Montana stratigraphic column, was achieved.

BIBLIOGRAPHY

The areas visited have been mapped in lesser detail by the U. S. G. S. and reports of their findings may be found in "The Three Forks Folio", which covers the Tobacco Root Range, and "The Dillon Quadrangle", which takes in a description of the Highland mountains. Memoir No. 9, "A Geological Reconnaissance of the Tobacco Root Mountains" by Wilfred Tansley, Paul A. Schafer and Lyman H. Hart, published at the Montana School of Mines, takes up the Renova district in detail. In addition to the above there has been a great deal of work done on adjacent areas by former geology field mapping classes of the Montana School of Mines, accounts of which may be found in the files of the Geology Department, Montana School of Mines.