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A Report of the Geology of the Golden Sunlight Mining District

Roy A. McCready

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Submitted to the Geology Department of the Montana School of Mines in partial fulfillment of the requirements for the Degree of Bachelor of Science in Mining Engineering.

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Table of Contents.

Illustrations

Introduction

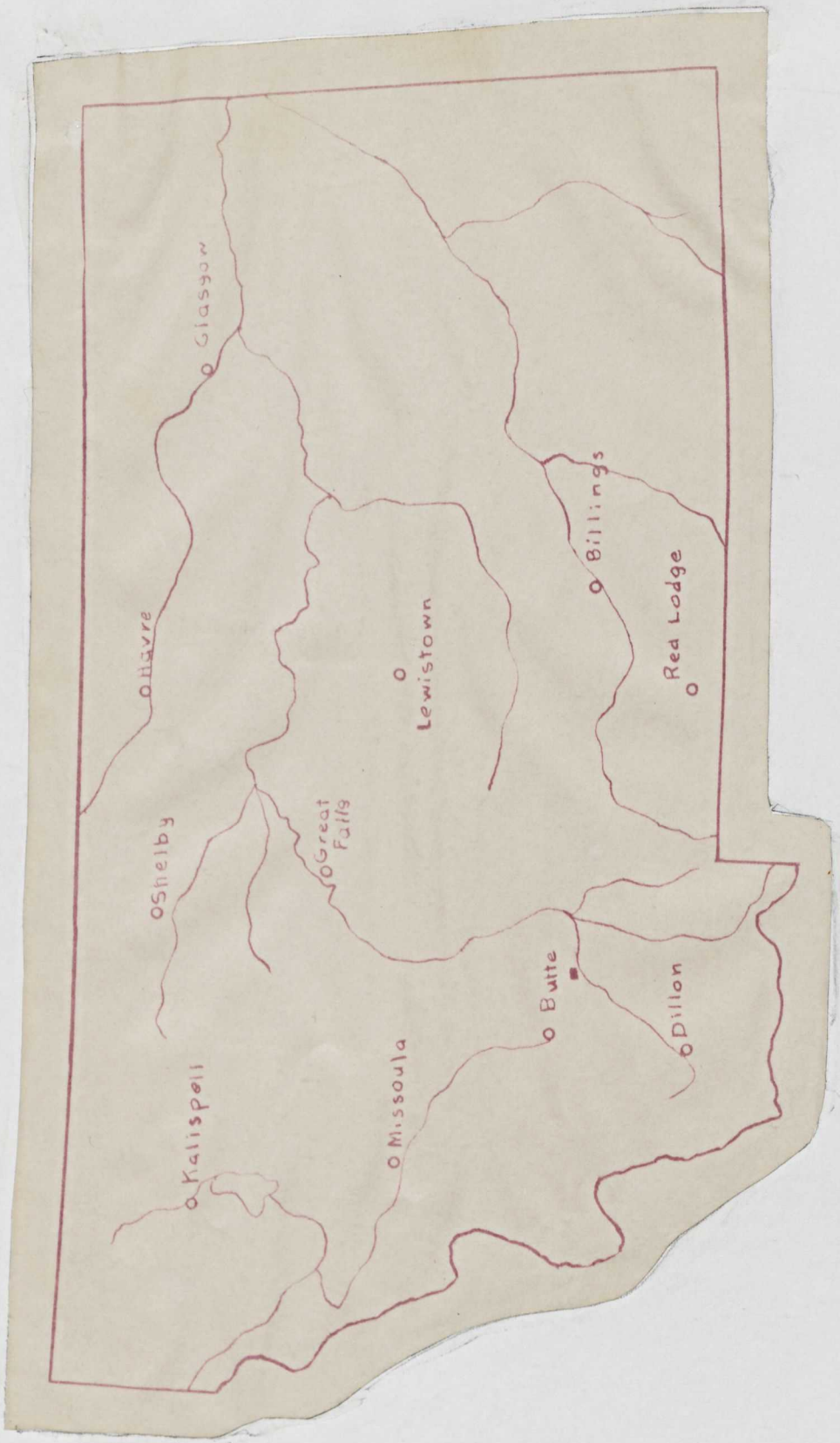
This paper is a ~~result~~ report of a geological survey made of an area of approximately fifty square miles lying North-East of Whitehall, Montana, in the region of the Golden Sunlight Mine. The survey was made in September, 1938, by a field party consisting of twenty-three members of the senior class of the Montana School of Mines, who were assisted by Drs. E.S.Perry, G.F.Seager, and L.L. Sloss, all of the geology department of this institution.

Heretofore, little or no knowledge of the geological features of this region has been available; an exception to this is the geological work obviously done by the Golden Sunlight Mining Company. With this view in mind, Dr. E.S.Perry chose this region for survey because it would serve two purposes, namely, one of providing a good mappable area where the students could get experience in field geological work, and the other of which would be of value in the future to the Montana State Bureau of Mines and Geology.

The field mapping was carried on by plane table stadia work, pacing traverses, and automobile reconnaisance surveys, with reference to horizontal distances. In order that the students might have some knowledge of the geological age and sequence of rocks in this region, the South Boulder River Region, lying about six miles South- East of this region, was measured and the thicknesses of the various beds were determined. The fact that there is a very small distance between these two regions makes correlation possible.

The author wishes to acknowledge the very able assistance offered by Drs. E.S.Perry, G.F.Seager, and L.L. Sloss, without whose help, this survey would have been almost impossible. The capable and cooperative assistance of the following men, who were party members to the author, is very much appreciated: Messers J.Bukvich, H.Johnson, and J. Engstrom.

Plate I.


Glasgow
Havre
Shelby
Great Falls
Lewistown
Billings
Red Lodge
Kalispell
Missoula
Butte
Dillon

The Geology of the South Boulder Section

The oldest exposed rocks in this region are the Pony gneisses and schists , belonging to the Archean or Archeozoic Era. These rocks represent an unknown number of periods of sedimentation, in part accompanied by much vulcanism; these periods were doubtless separated by times of crustal disturbance and igneous intrusions that built mountains, and by prolonged erosion intervals. The structures here show evidence of intense folding. The rocks contain large amounts of hornblende. Their thickness is not known.

Resting unconformably upon the Pony Series is the Flathead quartzite.These rocks, being of lower Cambrian age, are remarkably persistant quartzites and sandstones. Owing to the hardness of the beds as exposed in most localities, this quartzite is conspicuous topographically and forms a reference horizon. The color of the rocks is pink and the thickness in this region is about 180 feet. At the base of this formation is a conglomerate zone or horizon containing pegmatitic rock fragments. The beds strike approximately S.60°E. and dip about 40° to the north-east.

Above the Flathead quartzite is the Wolsey shale. According to Peale,"there are thin beds of glauconitic limestone interlaminated with the shales, and several of these bands have been found to be fossiliferous. They are frequently micaceous on the surface and contain green grains of what is apparently glauconite. The general color of the beds is green due,in all probability to the occurrence of this mineral,

which is a hydrous silicate of iron and potassium." The shale members are predominately areanaceous at the base and grade into calcareous members near the top. Worm trails were found in abundance in a horizon located about the center of the beds. Due to the soft nature of these beds, their weathering results in concealment in most places, but characteristic ravines are formed and these may be readily traced. The thickness of this shale is about 300 feet and its strike and dip are controlled by the Flathead quartzite.

The Meagher Limestone formation lies above the Wolsey Shale. It is of lower Cambrian age. According to Weed, "These rocks are thinly and irregularly bedded limestones, consisting of pure gray limestone mottled with patches of buff-colored arenaceous, clayey matter. The exposed edge of the beds shows wavy-almost crinkled- bedding planes. The upper beds are spotted with green glauconitic grains and contain numerous fossil fragments." Oolites were found in some places. This rock is used commercially as a decorative building stone. The thickness was determined to be about 430 feet and the strike and dip are approximately the same as the lower formations already described.

Of middle Cambrian age is the Park Shale which lies on top of the Meagher Limestone. Weed described these shales as being gray to greenish micaceous shales. Toward the top of this shale are intercalated thin layers of pebbly limestone. The rock is papery, that is, it crumbles easily.

The thickness is 90 to 100 feet in this region. The shales are easily eroded but do not form such deep ravines as do the Wolsey Shales.

The Pilgrim Limestone of upper Cambrian age lies above the Park Shale. This formation consists of a massive, dark-colored, dolomitic limestone of a sugary texture containing dark stringers running throughout the rocks. The rocks at the top of the formation are fetid, giving off the odor of hydrogen sulfide when struck with a pick. There are some shale members in the upper layers. Weed found that the beds contained some fossil remains. These beds form low cliffs or cap mesas. The thickness is about 800 to 900 feet.

The rocks of uppermost Cambrian age in this section are grouped in a formation called the Dry Creek Shale. They consist of a serees of brick red to bright yellow sandy beds. Their thickness is about 100 feet.

The oldest Devonian rocks of this section are grouped under the Jefferson Limestone formation which consists of a massive, poorly-bedded, dolomitic, crystalline limestone series. The lowest beds form a bold bluff or escarpment that rises abruptly above the Dry Creek Shale formation. Corals are abundant. Weed describes these rocks as being characterized by chocolate to steel-gray limestones, coarsely crystalline in nature, and having a distinctly granular texture. He goes on to say that they emit a strongly fetid odor when struck with a hammer; their color is due to organic (nitrogenous) matter.

The thickness of this formation is approximately 650 feet.

The Threeforks Shale lies above this limestone series and is of upper Devonian age . It consists of light- colored shaly limestones which are rather hard. The color varies from predominating red to green. The thickness as was measured is 370 feet. The beds dip about 37° to the north-east.These Devonian sediments rest unconformably on the lower rocks of Cambrian age. Ordovician and Silurian rocks are not present in Montana.

Above the shales rests the Madison Limestone of lower Mississippian age. These rocks are massive ridge-forming, light-colored limestones with some dark-colored calcareous shales at the base. Chert nodules are found throughout this formation and fossils are very abundant. Brachiopods, horn corals, and crinoids are common . This formation is easily recognized in Western Montana because of its mountain or ridge- forming characteristicts and its light color. The formation is about 2800 to 3000 feet thick in this section and the strike and dip is generally the same as that of lower formations already described.

The Amsden formation is recognized as the uppermost Mississippian formation. Its thickness is 160 feet in this section and it consists of red shales and sandstones in the basal and middle regions or layers with white colored limestone at the top.

The only representative of Pennsylvanian rocks in this region is the Quadrant series, which consists of a

light-colored quartzite about 170 feet thick.

The Phosphoria formation of Permian age rests above the quartzite beds. This formation is characterized by the occurrence of phosphate oolites in beds of cherty shales and limestone.The rocks are dark colored as a result of these oolites,and the thickness is 240 feet.

A rather large unconformity is represented by the rocks above the Phosphoria, which are grouped in the Ellis formation, which is of lower Jurassic age. The Triassic rocks are not present here. The rocks of the Ellis consist of thinly bedded, sandy and calcareous shales. The color is red to green and the total thickness is 70 feet.

Of upper Jurassic age are the overlying beds of the Morrison formation. The rocks are varigated limestones and shales. The bedding is quite well developed in this section and the thickness is 340 feet.

The Kootenai formation of probable lower Cretaceous age, rests on the Morrison Limestone. The rocks consist of limestone and sandstone members; the limestones are a result of fresh water sedimentation and from here on up to the present day formations, the sediments are terrestial, not marine. The sandstones possess a peculiar texture, caused by the presence of some dark constituents. It is commonly known as the "salt and pepper" sandstone. The thickness of this formation is 690 feet.

Above the Kootenai is the Colorado Shale formation. These rocks are of lower Cretaceous age and are about 225 feet thick in this section. The lower layers consist mainly of shale and the upper layers consist of interbedded shales and fresh water limestones. The rocks are highly fossiliferous, and the shale weathers rather easily.

The next 1600 feet of rock consists of an agglomerate belonging to the Livingston formation. There are brecciated fragments of volcanic material cemented in a sandy matrix.

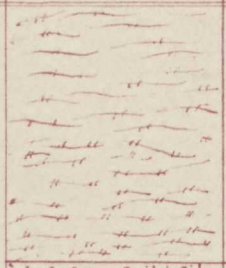
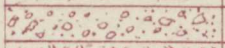
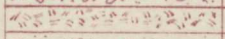
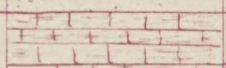
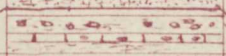
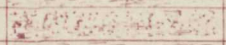
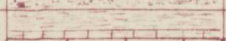
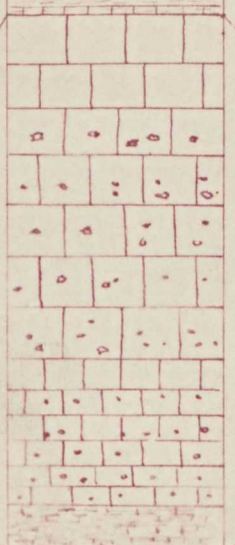
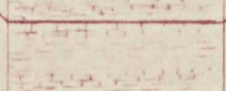
Above these rocks is a basalt porphyry flow of a thickness of about 130 feet. Resting above this basalt is another agglomerate zone about 180 feet in thickness.

The uppermost beds exposed in the South Boulder Section consist of andesite porphyry flow rocks approximately 1350 feet thick. The andesite in this region is commonly referred to as " oatmeal porphyry" due to the appearance of the rock which is caused by the presence of large phenocrysts of a light-colored mineral, an alkalic plagioclase.

The entire group of volcanics described above is classed as the Livingston formation. It was noted that the dip of the lower members was about 35° to the north-east whereas, the dip of the upper volcanics was much less than this figure. This phenomenum may be explained by the fact that these rocks form the north limb of anaanticline or the south limb of a large syncline, the latter being probably the true case here.

Plate II.

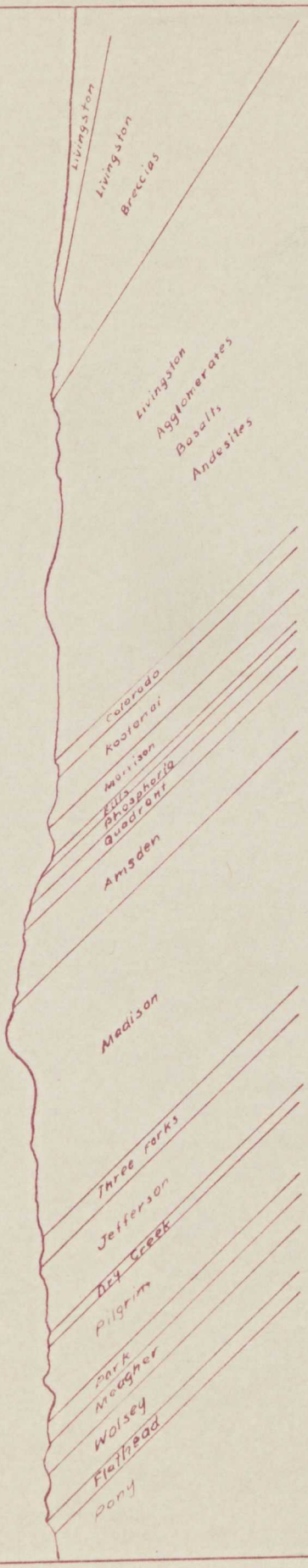
COLUMNAR SECTION
SOUTH BOULDER SECTION

PERIOD	FORMATION	COLUMN	THICKNESS	SYM	CHARACTERISTICS
CRETACEOUS	LIVINGSTON		1340'	Klv	ANDESITE PORPHRY "OAT MEAL" PORPHYRY
			180'	Klv	AGGLOMERATE
			130'	Klv	BASALT PORPHRY
			1610'	Klv	Agglomerate
	COLORADO		225'	Kc	SHALE AND LIMESTONE HIGH IN FOSSIL CONTENT
	KOOTENAI		690'	Kk	FRESH WATER LIMESTONE WITH "SALT + PEPPER" SANDSTONE
JURASSIC	MORRISON		340'	Jm	VARIGATED LIMESTONE AND SHALE
	ELLIS		70'	Je	SANDY + CALCAREOUS SHALE
PERMIAN	PHOSPHORIA		240'	Cp	CHERTY SHALES + LIMESTONE WITH OOLITIC PHOSPHATE
PENN.	QUADRANT		170'	Cq	LIGHT COLORED QUARTZITE
MISSISSIPPIAN	AMSDEN		160'	Ca	RED SHALES + LIMESTONES
	MADISON		2800'	Cm	MASSIVE RIDGE FORMING LIGHT COLORED LIMESTONE WITH SOME SHALES AT BASE. CHERT NODULES THROUGHOUT, DARK CALCAREOUS SHALE AT BASE. HIGHLY FOSSILIFERROUS
DEVONIAN	THREE FORKS		370'	Dtf	LIGHT COLORED SANDY + LIMEY SHALES RATHER HARD. RED TO GREEN
	JEFFERSON		665'	Dj	MASSIVE POORLY BEDDED DOLOMITIC LIMESTONE CRYSTALLINE - FETID
	DRY CREEK		90'	Cdc	SANDY REDDISH - YELLOW SHALE

			1610'	K_{lv}	Agglomerate
	COLORADO		225'	K_c	SHALE AND LIMESTONE HIGH IN FOSSIL CONTENT
	KOOTENAI		690'	K_k	FRESH WATER LIMESTONE WITH "SALT + PEPPER" SANDSTONE
JURASSIC	MORRISON		340'	J_m	VARIGATED LIMESTONE AND SHALE
	ELLIS		70'	J_e	SANDY + CALCAREOUS SHALE
PERMIAN	PHOSPHORIA		240'	C_p	CHERTY SHALES + LIMESTONE WITH OOLITIC PHOSPHATE
PENN.	QUADRANT		170'	C_q	LIGHT COLORED QUARTZITE
	AMSDEN		160'	C_a	RED SHALES + LIMESTONES
MISSISSIPPIAN	MADISON		2800'	C_m	MASSIVE RIDGE FORMING LIGHT COLORED LIMESTONE WITH SOME SHALES AT BASE. CHERT NODULES THROUGHOUT, DARK CALCAREOUS SHALE AT BASE. HIGHLY FOSSILIFERROUS
DEVONIAN	THREE FORKS		370'	D_{tf}	LIGHT COLORED SANDY + LIMEY SHALES. RATHER HARD. RED TO GREEN
	JEFFERSON		665'	D_j	MASSIVE POORLY BEDDED DOLOMITIC LIMESTONE CRYSTALLINE - FETID
CAMBRIAN	DRY CREEK		90'	ϵ_{dc}	SANDY REDDISH - YELLOW SHALE
	PILGRIM		825'	ϵ_{pi}	MASSIVE DARK COLORED DOLOMITIC LIMESTONE - MOTTLED - LIGHT SUGARY WITH DARK STRINGERS. TOP IS FETTED H_2S SOME SHALES IN UPPER PART
	PARK		90'	ϵ_{pa}	GREEN PAPER SHALE - THIN BEDS
	MEAGHER		470'	ϵ_m	BLACK and GOLD MOTTLED LIMESTONE, OOLITES
	WOLSEY		320'	ϵ_w	FINE-GRAINED GREEN PAPER SHALE, WORM TRAILS
	FLATHEAD		180'	ϵ_f	PINK QUARTZITE
PRE-CAMBRIAN	PONY		?	AR_p	GNEISS AND SCHIST

Plate III.

IDEAL CROSS SECTION OF SOUTH BOULDER AREA



The Geology of the Golden Sunlight Area

Character of Surface

For the most part the topography of this region is flat,or nearly so, except in the eastern part, where there is a mountain range about 1000 to 1500 feet in relief. This range is drained by intermittent streams which empty out into two broad valleys, the Whitetail to the west, and the North Boulder to the east. With the exception of one or two small springs, the mountain country is dry; this,of course, depends on the season.The mountains are covered with dense forest growth on the higher slopes to the north, while the lower slopes contain almost no vegetation excepting grass and sage-brush. The North Boulder River and the Whitetail Creek cut through old lake beds probably of Tertiary age.

General Geology

The oldest strata in this region ~~is~~ are the Belt Shales. These rocks consist of shales and argillites of Pre-Cambrian age- probably of the upper Proterozoic Era. They cover an area of approximately two square miles, extending from the southern extremity of the mountain range to a point approximately one mile north of the Golden Sunlight mine, and to the west about one mile. The adits of the Golden Sunlight mine open on the eastern slopes of this range; since the shales at the foot of the mountain on this side grade into, or are covered by, alluvium, nothing is known of the eastern extremity of the Belt formation.

According to A.C.Peale, "The rocks consist of an alteration of coarse, micaceous sandstones and conglomerates

with beds of hard argillaceous slates and bands of thin bedded,dark blue, silicous sandstones. The indurated clay-slates present a variety of colors-yellowish-brown, olive-green, and bluish-black predominating. The beds are very fissile, frequently breaking down into fine splintery debris, generally of a light color and with frequent local bands of a bright red tint as though the beds had been subjected to heat. These appear to be scattered over the country irregularly and their weathering gives a very bright-colored debris".

The Belts are a non-fossiliferous group of clastic beds sometimes slightly metamorphosed, which lie between the Archean gneisses and a belt of quartzite, the Flathead. The thickness of these beds was not determined because of the fact that they ware absent in the South Boulder Section ; however, the author estimates this thickness at several thousand feet; it can be seen then that they occupy quite a large space in the stratigraphic column. The strike of the beds varies; the general strike is North 45^{o}-55^{o} West and the dip is approximately 30^{o} to the northeast. It was noted that in the vicinity of the Golden Sunlight mine and to the west of there, the rocks have a slatey character and in most places are thinly bedded ; the fact that the slates are broken up along the bedding planes affords a fairly accurate means for determining strike and dip . It was stated that the dip of the rocks in this vicinity is about 30^{o} ; this applies only to the rocks in the area due west of the mine. The dip angle becomes greater to the north.

About one-half mile north of the mine, the character of the rocks is somewhat changed. Here, the rocks are more compacted and are harder, having a bluishitint ; they have a somewhat glassy appearance which is undoubtedly due to silicification. They form massive bluffs or cliffs due to their resistance and their weathered surfaces are red to brown in color.

Igneous intrusion is evidenced by the exposure of several syenite porphyry dikes and dark,basic , lamprophiric dikes which cut the Belt slates to the north and south of the mine. The workings of the mine are located on the contacts of several of these syenite dikes, which, according to the staff of the mine, flatten out to the east producing a sill structure.

Arcosic sandstones are found near the northern extremities of the Belts, but the extent of this arcose is not known because very little was exposed. It can be grouped with the Belts.

At this point mentioned above, the Flathead Quartzite outcrops. This rock is very similar to that of the South Boulder and it dips to the northeast at about 60°. This outcrop is found in thehigher slopes of the range and can be easily recognized by its characteristic ridges. A glance at the upper left-hand corner of the map illustrated on Plate IV. will show the outcropping of this quartzite. It extends about 1800 feet in an easternly direction at which point or position it disappears. The younger Cambrian sediments such as the Wolsey Shale and the Meagher Limestone, also seem to disappear after extending about 1000 feet to the east. This cutt-

cutting off of these members indicates faulting, which is evidenced by the presence of the Livingston lavas, seemingly thrown up against the outcrops, rather the top of the beds, of the Belts and Cambrian rocks described. These igneous rocks cover a large area and extend about 4500 feet to the east. The contact between the Belt rocks and this flow rock can be easily and clearly traced for considerable distance.

This fault is undoubtedly a normal fault, striking approximately 65° in a northwest direction and dipping rather steeply.to the north.

Another large fault is found to the east, where the Cambrian rocks once more appear, but they strike almost due North and dip very steeply to the east. The strike of this fault is about 30° to the north-east and it appears to dip steeply. It becomes exceedingly difficult to interpret what has happened that would cause this change in strike ofthe sediments . Since the northern extent of these faults is not known, the relative movements can not be determined. Further work in the region north of this area will be necessary before a correct interpretation can be made.

The outcrops of the Cambrian sediments in this eastern part can be traced very easily and quickly. Walking across the outcrops in an eastern direction, or at right angles to the dip, one crosses the Cambrian, Devonian, and Mississippian formations. To the south,the strike changes gradually from almost due North to almost due West; there is a rounding of the outcrops here which indicates the presence of a rather large syncline to the east. In other words, these

rocks appear to form the western limb of a syncline. This , however, is not backed by sufficient evidence to make it hold fast, because the rocks to the east were not examined.

In the central part of the region shown on Plate IV. the rocks are covered by a widespread mantle of alluvium which is of Quaternary age. Every type of rock found in this region is found in this deposit.

Structural Geology.

There is very little evidence of folding in this region. There was considerable faulting to the north and west of the mine as is shown by the presence of large normal faults. It seems that this range is an erosional remenant of a large uplifted block. The close proximity of the Belts to the Livingston lavas to the north validates this theory.

There are some smaller faults in the Belts near the mine, but they are of little importance from a structural or commercial standpoint. This uplifting of the beds, along with their faulting came after the extrusion of the Livingston lava, which came at the close of the Cretaceous Period. This crustal deformation can be placed in the last stages of the Rocky Mountain Erogeny.

Economic Geology.

At present the Golden Sunlight mine is the only property in operation in this region, on the east side of this mountain range. There are several other mines operating on the west side . The deposit at the Golden Sunlight

property is being mined for gold. The ore occurs along the contacts of the Belt Shale with syenite porphyry dikes. The width of the mined zone varies, that is , the ore is found in the shales which are brecciated in many places, and also in the porphyry. These breccias were probably formed by forces of intrusion accompanied by external forces. The gold was presumably deposited by magmatic solutions which emanated from below , following the injection of the syenite. It is highly probable that these solutions replaced appart of the wall rocks and deposited the gold therein. The occurrence of gold in the breccias is a result of deposition by probably the same solutions.

Scattered irregularly throughout the shales, are reddish stained zones. One of these zones occurs about one-fourth of a mile north of the mine, and it is exposed for a distance of 150 feet. This red staining appears to have been caused by leaching and subsequent oxidation of the residual iron bearing minerals.

It was noticed that the rocks from nearby prospects holes contained pyrite along or within the bedding planes. Evidently this pyrite was injected between the bedding planes by solutions which emanated from below.

Addition. The region mapped by the author's party included Sections 17, 18, 19, 20, and 21 of Township 2 N., Range 3, W..

Conclusions or Summary.

The geology of this region may be summarized as follows:

This region as a whole presents an excellent picture of all the formations from the Pre-Cambrian up to the Mississippian Period. This applies only to the region mapped by the author's party. The rocks here have been uplifted, tilted,and faulted greatly to the north, thus producing a rather large mountain range as a result.

Very little mining is done in this section, excepting that done at the Golden Sunlight mine. The ore here occurs associated with porphyry dikes which intrude the Belt Shale. There is considerable brecciation along these contacts.

The immense covering of alluvium on the lower slopes of the mountains and out in the valleys gives evidence of a long erosion period.That faulting and uplifting of these rocks in this region took place, is certain; the author concludes that this crustal deformation came about in the last stages of the Rocky Mountain Erogeny. This interpretation is supported by the occurrence of the Livingston lavas which are tilted and faulted in the north part of this section. The size and displacement of these faults is tremendous in places.