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The Jefferson Canyon Gypsum Deposit.

Arthur Talpt

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THE JEFFERSON CANYON
GYPSUM DEPOSIT

by

Arthur Talpt

A Thesis
Submitted to the Department of Geology
in Partial Fulfillment of the
Requirements for the Degree of
Bachelor of Science in Geological Engineering

MONTANA SCHOOL OF MINES
BUTTE, MONTANA
June, 1938
A. Looking Northwest

B. Looking Northwest

General views of the gypsum deposit near Limespur, Montana
THE JEFFERSON CANYON
GYPSUM DEPOSIT

by
Arthur Talpt

1934

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MONTANA SCHOOL OF MINES
BUTTE, MONTANA
June, 1938
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THE JEFFERSON CANYON
GYPSUM DEPOSIT

by

Arthur Talpt

INTRODUCTION

Gypsum deposits are widespread geographically and are in many geologic formations. Ordinarily their character and origin, for the most part sedimentary, are not difficult to ascertain. However, near Lewis and Clark Cavern National Monument (Morrison Cave) about 15 miles east of Whitehall, Montana, occurs a deposit of gypsum unique in many respects, because it has characteristics suggesting that it is an epigenetic deposit in a broad general way similar to certain metalliferous deposits of the Rocky Mountains.

As a thesis to be offered in partial fulfillment of the requirements for a degree of Bachelor of Science in Geological Engineering at the Montana School of Mines under the able directorship of Eugene S. Perry, assisted by Dr. L. L. Sloss and Dr. G. F. Seager, a study of these deposits was undertaken.

Field work was accomplished during the fall of 1937 and during the spring of 1938. An alidade, with plane table and stadia rod, Brunton compass, tape and pacing were employed in mapping.

Acknowledgment is made to information contained in "A Geological Reconnaissance of the Tobacco Root Mountains, Madison County, Montana,"
by Tansley, Schafer, Hart, Memoir No. 9, Montana Bureau of Mines and Geology, and to "Gypsum Deposits of the United States" by R. W. Stone, U. S. G. S. Bull. 697.

**GEOGRAPHY**

**LOCATION AND ACCESSIBILITY**

The Jefferson Canyon gypsum deposit is in the northern tip of the Tobacco Root Mountains or in the southeast corner of Jefferson County. It lies about 50 miles southeast of Butte or 15 miles due east of Whitehall, in the Jefferson Canyon.

Through the Jefferson Canyon runs two transcontinental railroads and a government highway. The railroads are the Northern Pacific, with stops at Limespur about two miles from the deposit; and the Chicago, Milwaukee, St. Paul and Pacific. From government highway No. 10 about one mile east of Limespur an old road turns north, the old Morrison Cave road, along which the gypsum quarry may be reached about a third of a mile from the highway.

**CLIMATE AND VEGETATION**

The region is high and semi-arid, with an average annual precipitation of 10 to 15 inches.

The maximum and minimum temperatures are about 90 degrees and minus 30 degrees respectively; however, the below zero atmosphere is dry and generally calm and the summer evenings are cool. Altitude of the region is about a mile above sea level.

Sagebrush, jack pines, willows, and a hardy grass make up most of the not too abundant vegetation. Several farms exist in the area by combination of dry land farming and stock raising.
PHYSIOGRAPHY

RELIEF AND DRAINAGE

The difference of highest and lowest elevation is approximately 1,500 feet, the lowest being the Jefferson River, along highway No. 10, and the highest being the top of a rolling plateau—the gypsum quarry being situated about 500 feet above the river. During uplift of the plateau, the Jefferson River steadily cut downward, to form the steep-sided Jefferson Canyon, giving the area most of its extreme relief.

The area is east of the Continental Divide, consequently, the drainage is to the Gulf of Mexico by the way of Missouri and Mississippi Rivers; the Jefferson River joining the Gallatin and Madison Rivers farther east at Three Forks. Most of the streams in the area are intermittent—all drain into the Jefferson River.

GENERAL FEATURES AND GEOLOGY

The map of the gypsum quarry represents a thousand-foot square, but in order to generalize on typical features and geology a large area must be considered.

In spite of uplift an ancient rolling surface of relatively low relief lies a thousand or more feet above and to the north of the gypsum quarry. To the south lies the Jefferson River just leaving Jefferson Canyon with its steep cliff-like canyon walls which are composed chiefly of Madison limestone.

Folding and faulting in the region has been pronounced. Folding has resulted in overturned members, and faulting has placed pre-Cambrian members adjacent to Devonian, Cretaceous formations next to Permian, and Tertiary against Mississippian.
<table>
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<td>Livingston</td>
<td>Ki</td>
<td></td>
<td>1075+</td>
<td>Agglomerate, Basalt, Andesite, and tuff</td>
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<tr>
<td></td>
<td>Colorado</td>
<td>Ke</td>
<td></td>
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<td></td>
<td>Ellis</td>
<td>Je</td>
<td></td>
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<td>Pb</td>
<td></td>
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<tr>
<td></td>
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<td>Pq</td>
<td></td>
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<tr>
<td></td>
<td>Amsden</td>
<td>Ma</td>
<td></td>
<td>200</td>
<td>Ls (red sandy shale at base)</td>
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<tr>
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<td>Upper</td>
<td>Mn</td>
<td></td>
<td>2240</td>
<td>Cherty Limestone</td>
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<tr>
<td></td>
<td>Madison</td>
<td></td>
<td></td>
<td></td>
<td>Black Limestone</td>
</tr>
<tr>
<td></td>
<td>Lower Madison</td>
<td></td>
<td></td>
<td>110</td>
<td>Sandy Limestone</td>
</tr>
<tr>
<td></td>
<td>Three Forks</td>
<td>Dv</td>
<td></td>
<td>210</td>
<td>Green Shale</td>
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<tr>
<td>Devonian</td>
<td>Jefferson</td>
<td>Di</td>
<td></td>
<td>1125</td>
<td>Dolomitie</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td>Yogo</td>
<td>Ey</td>
<td></td>
<td>265</td>
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<td>Dry Creek</td>
<td>Ew</td>
<td></td>
<td>90</td>
<td>Sandy Shale</td>
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<tr>
<td></td>
<td>Aglum</td>
<td>Em</td>
<td></td>
<td>315</td>
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<tr>
<td></td>
<td>Park</td>
<td>Ew</td>
<td></td>
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<td>Shale</td>
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<td></td>
<td>Meagher</td>
<td>Em</td>
<td></td>
<td>480</td>
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<td></td>
<td>Wolsey</td>
<td>Ew</td>
<td></td>
<td>320</td>
<td>Sandy Shale</td>
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<tr>
<td></td>
<td>Flathead</td>
<td>Er</td>
<td></td>
<td>90</td>
<td>Massive Quartzite</td>
</tr>
<tr>
<td>Pre-Cambrian</td>
<td>Pony</td>
<td></td>
<td></td>
<td>?</td>
<td>Gneiss &amp; Schist</td>
</tr>
</tbody>
</table>
Geologic formation in the area are many and varied. The geologic column is not complete, signifying unconformities, some which represents a long period of time. A representative columnar section has been taken along South Boulder Canyon (not shown on map) as a visual aid in understanding the stratigraphic problem in the gypsum quarry.

GENERAL GEOLOGY
GEOLOCIC FORMATIONS

Although many rocks listed in the columnar section do not appear on the gypsum quarry map (Plate IX) they lie in the immediate vicinity. Only brief descriptions will be given of them.

Pre-Cambrian

First of the pre-Cambrian rocks are the Pony series. The Pony series is made up of both light- and dark-colored gneisses and schists. Black amphibolite schist composed chiefly of hornblende with faint bands of feldspar is the most characteristic rock in this series. Another characteristic rock of this series is the light-colored, quartz-feldspar bearing graphic pegmatitic gneiss. The Pony series may be found in a drag block of a large fault about a thousand feet northeast of the gypsum quarry. Much of the area contains a conglomeritic and shaly arkose lying below and unconformably to the Flathead formation of the lower Paleozoic and also unconformably to the pre-Cambrian Pony series. The arkose may be a red brick-like rock with large pebbles or may be a grey-green conglomerate or shale. The formation appears to be a mass of but little sorted material, but bedding is evident. This formation is conspicuous about a thousand feet to the north and northwest of the gypsum quarry.
Paleozoic

The Paleozoic formations stand at steep angles and in sharp folds, and are cut by many faults, some which are of great magnitude.

The Flathead quartzite of middle Cambrian age, the basal member of the series, is hard, compact, brittle and of a pink color. Conglomerates and cross bedding are particular features of the base of the formation. It is found to the northeast with the Pony series.

The rest of the Cambrian rocks are referred to by Peale* as the Gallatin formation. They consist of Wolsey formation, a greenish shale lying above the Flathead; Meagher formation, a "black and gold" limestone used as an ornamental building stone; Park formation, another green shale; Pilgrim formation, a blue-gray mottled limestone; Dry Creek formation, a quartzitic shaly sandstone; and Yogo formation, a limestone with quartz geodes. These names were applied by Weed* to similar rocks near Great Falls.

Above the Gallatin lies the Devonian Jefferson limestone characterized by its black color when freshly broken and its dark brown appearance when weathered. Thin-bedded paper-thin Three Forks shale of Devonian age follows the Jefferson limestone.

Mountain-forming Madison limestone of Mississippian age is white, massive, fossil bearing and forms the steep cliffs of the area. The Amsden formation overlying the Madison is divided into two parts: limestone above and red shale below.

The Quadrant formation overlying the Amsden is Pennsylvanian in age and consists of alternating members of quartzite and limestone.

*See Bibliography.*
Kootenai red beds in quarry No. 3
Gray oolitic phosphate-bearing rock gave the Permian formation the name "Phosphoria".

Ordovician and Silurian formations are known to be present.

**Mesozoic**

The Triassic, the lowermost Mesozoic sediment, is also absent.

The lowest formation present of the Jurassic period is the Ellis, a fossil oyster-bearing limestone with a base of brownish-black chert. The Morrison formation of the same period is present as a series of variegated shales.

The Kootenai formation, (Plate IV) marking the beginning of the Cretaceous period, has a large basal sandstone overlain by red beds. Part of the Kootenai is sometimes called the Dakota which is a blue-grey, gastropod-bearing limestone. Middle Cretaceous time is represented by the Colorado, a fine-grained dark grey shale. The Livingston formation, Upper Cretaceous, consists of agglomerates and lavas. The lavas are basalt and andesite. The agglomerates are lava boulders in a lava mud. This formation is found about a thousand feet to the east of the gypsum quarry.

**Cenozoic**

Cenozoic strata consists chiefly of Tertiary alluvial debris and terrace gravels. The alluvial debris is composed of coarse material which is the result of flashy rainfall. Between the gypsum quarry and the Jefferson River to the south lies Cenozoic sediments.
Plate V

A. Quarry No. 1 looking North

B. Quarry No. 3 looking Northwest

C. Quarry No. 4 looking North

Views of the gypsum quarry about two miles east of Limespur
Igneous Rocks

Igneous activity is represented by both acidic and basic rocks. Farther to the west acidic dikes were intruded. Later came extrusions of a basic magma material forming sheets and flows of andesite and basalt.

STRUCTURE

A series of large scale faults has been the result of tremendous uplift at or near the time of batholithic intrusions—the time of Laramide uplift. Simple and overturned folds, and general confusion of the stratigraphic column resulted.

On the side of the hill west of the gypsum quarry is a number of nearly horizontal outcrops dipping westward or into the hill. The outcrops are part of an overturned fold; the southern portion of the crest, which lies between the gypsum quarry and the Jefferson River, has been eroded away; the northern portion of the fold, which lies north of the quarry, also appears to be eroded away, but landslip phenomena probably slow and gradual has taken place. Uplifting and faulting of a limestone mass north and adjacent to the overturned fold has caused a landmass to slip. A landmass of Madison and Jefferson limestone has slipped downward, pushing the crest of the fold several hundred feet southward to the position of the present quarry. During movement a segment of the fold carrying quarries No. 1, 2, 3, (Plate V, A, B,) broke away and came to rest while the rest of the fold, containing quarry No. 4, (Plate V, C,) continued a hundred feet further down and came to rest.

Part of the Jefferson and Madison limestone continued to override the slipping mass and came to rest several hundred feet farther down.
from quarry No. 4, leaving a debris of brecciated limestone behind. The structure of the mass of Jefferson and Madison limestone is a tightly folded anticline pitching steeply to the south.

On the east wall of quarry No. 4 (Plate IX) is evidence of a steeply pitching anticline, sloping roughly to the southeast. There is also evidence of horizontal faulting of some displacement, beds which dip steeply upward and suddenly hook over. Gypsum beds are found in the southern end of this east quarry wall, a seemly remote place for gypsum but which is very likely the continuation of gypsum beds from one side of an anticline to the other side. This is likely evidence that the two anticlines just mentioned may have been one; horizontal faulting and sudden hooking over of beds indicate this assumption.

GEOLOGIC HISTORY

The pre-Cambrian rocks in the region have been strongly metamorphosed so little can be learned from them. However, it is believed these rocks have been folded, depressed beneath seas, uplifted, deformed, eroded, several times before the Paleozoic sediments were deposited.

A series of uplifting and depressing of the land brought about the accumulation and partial erosion of the Paleozoic sediments.

Alternation of terrestrial deposits and marine sediments make up the major portion of the Mesozoic era into thick deposits of sandstones and shales.

The latter part of the Mesozoic saw the Rocky Mountain orogeny followed by intrusion which formed many batholiths. The Tobacco Root batholith was intruded about this time.
Erosion brought the Rocky Mountain deformation to low relief; drainage was to the west. A minor deformation took place bringing about block faulting, which is prevalent in western Montana. Also warping and thrusting, and extrusion of lavas occurred. Result of this was the formation of block fault mountains, numerous lakes and reversing of the stream gradient to the east.

Soon the lakes were filled with sediments from the rejuvenated topography and outlets of the lakes were lowered by erosion leaving the present day lake beds dry.

After Pleistocene glaciation, glacial debris was spread in many places. Now the glaciers are gone and streams are just getting a good start in tearing up the land surface. It might be said the region is a rejuvenation of a mature land surface.

MINERALOGY AND GEOLOGY OF GYPSUM

CHEMICAL AND PHYSICAL PROPERTIES

Gypsum is a common mineral, which occurs in both massive and crystalline form, and is widely distributed geographically and geologically. Gypsum is a hydrous calcium sulphate, having the chemical formula CaSO$_4$·2H$_2$O. This formula, reduced to its final components, is:

<table>
<thead>
<tr>
<th>Component</th>
<th>Percentage</th>
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<tbody>
<tr>
<td>Calcium sulphate (CaSO$_4$)</td>
<td>79.1%</td>
</tr>
<tr>
<td>Lime (CaO)</td>
<td>32.5%</td>
</tr>
<tr>
<td>Water (H$_2$O)</td>
<td>20.9%</td>
</tr>
<tr>
<td>Sulphur trioxide (SO$_3$)</td>
<td>46.6%</td>
</tr>
</tbody>
</table>

Pure gypsum, the sulphate of lime with water of crystallization, is seldom found in nature, for nearly all gypsum deposits contain oxides
of iron and aluminum, carbonates of calcium and magnesium, and other impurities. The anhydrous calcium sulphate, anhydrite, which has the formula \( \text{CaSO}_4 \), is often associated with gypsum either disseminated through it or occurring with or in it in separate masses.

The crystalline form of gypsum, selenite, is the standard for the second degree (hardness 2) in the Mohs scale of hardness. Gypsum is so soft that it can be scratched with the finger nail, and it can thus easily be distinguished from other minerals that have a similar appearance. The specific gravity of the pure mineral ranges from 2.30 to 2.33—that is, one cubic foot of gypsum is 2.3 times as heavy as one cubic foot of water.

Pure rock gypsum is white and selenite is colorless and transparent or translucent. Owing to impurities, however, gypsum ranges through grey to black, from flesh pink to red and brown, and some is yellow or pale blue. Pure powdered gypsum is white.

Gypsum is soluble in hydrochloric acid but does not effervesce or gelatinize. It does not dissolve in sulphuric acid. It is slightly soluble in water. At 32\( ^\circ \) F. (0\( ^\circ \) C.) one part of gypsum dissolves in 415 parts of water, and at 75.2\( ^\circ \) F. (24\( ^\circ \) C.) one part of gypsum dissolves in 378 parts of water. In time, however, rain and groundwater have a marked effect on gypsum, eating deeply into its outcrops and causing the formation of sinks and caves, in places of considerable extent.

VARIETIES

Gypsum occurs as rock gypsum, gypsite, selenite, and satin spar.

Rock gypsum, or massive gypsum, the form in which the mineral is most commonly found, is the form that is of the greatest economic value
(because, after it is calcined and then mixed with water, it will set or harden and can be used as wall plaster. It was used this way by the Egyptians 4,000 years ago). This variety occurs interbedded with sedimentary rocks and is composed of minute, even microscopic crystals, which make a generally opaque rock. Rock gypsum that is fine-grained, white, slightly translucent, and suitable for carving and sculpturing is known as alabaster. Rock gypsum occurs in beds ranging from thin layers covering small areas to deposits 60 feet or more thick and extending for many miles.

Gypsite, or earthy gypsum, is soft, incoherent, impure gypsum formed at the surface by the evaporation of gypsiferous water. It is an efflorescent deposit and ranges from material so powdery that it resembles wood ashes through sandy and earthy phases to a form that is slightly consolidated. Few deposits of gypsite are over 20 feet thick, and the largest cover only a few acres.

Selenite is a variety of gypsum which occurs in distinct crystals or in broad folia. Pure selenite is colorless and transparent. Selenite splits easily into sheets, and therefore, as it is transparent, it is often mistaken for mica, but sheets of selenite are not elastic like mica. (The largest crystals known are over four feet long, but these are rare.)

Satin spar is a crystalline variety of gypsum made up of needle-like fibers. It occurs in narrow veins or seams, rarely over three or four inches thick, either in massive gypsum deposits or in the wall rocks near these deposits. It is nowhere sufficiently abundant to be commercially valuable. Satin spar is usually white or pink, and the
fibers are perpendicular to the walls of the vein. It is deposited by the evaporation of gypsiferous waters and usually lies below a bed of gypsum.

Anhydrite is calcium sulphate, the formula for which is CaSO₄. It is of the same chemical composition as gypsum except that it contains no water of crystallization. By the absorption of two parts of water it turns to gypsum. This process actually takes place in nature and in some places has doubtless resulted in the alteration of beds of anhydrite to beds of gypsum. Anhydrite may be formed from solutions of gypsum at various temperatures when the solutions contain sufficient quantities of certain other salts. In a saturated solution of sodium chloride gypsum changes to anhydrite at a temperature of 30°C (86°F.), a temperature commonly reached in summer. This fact satisfactorily accounts for the formation of anhydrite in nature from concentrated sea water or lake brines. (The similarity of anhydrite to gypsum and limestone is so marked that doubtless it has been wrongly identified many times. The simplest tests to distinguish them are those for hardness and specific gravity, for anhydrite is harder and heavier than gypsum.)

CLASSIFICATION OF DEPOSITS

Gypsum deposits may be classified by their origin, mode of occurrence, position with relation to the earth's surface, and in other ways. Gyspse and gypsum dunes are accumulations on the surface, whereas satin spar and rock gypsum occur within other rocks. Differentiation by mode of occurrence makes the following separation: interbedded, efflorescent, and periodic—lake deposits, veins, dunes, and isolated crystals.
Deposition from Solutions

It is generally believed that most of the important deposits of rock gypsum of the world have been formed by the evaporation of sea water. This method of formation is inferred from the fact that the beds are usually interbedded with shales, sandstones, and limestones which have been deposited in seas or lakes. A scarcity or total absence of fossils in the gypsum-bearing rocks show that the water in which they were deposited had reached a degree of concentration that was unfavorable to life. Calcium sulphate is not precipitated until about 80 percent of the water has been evaporated. Thick deposits, which are not of great extent and grade laterally into much thinner deposits covering wide areas, are accounted for by Branson's* modified bar hypothesis. A part of this modified bar hypothesis is the assumption that when the isolated seas were formed the sea water had already reached a considerable degree of concentration, and so the interior receiving basins would be supplied with highly concentrated waters instead of normal sea water. The greater thickness of a gypsum bed may also have resulted, too, from currents shifting the unconsolidated gypsum along the bottom.

Water making its way through joints, fissures, and bedding planes of gypsum-bearing strata may take up calcium sulphate in solution. This water may come to rest in passageways in the gypsum beds or in the adjacent wall rock and there by evaporation deposit the gypsum as selenite or satin spar. These crystallizations in seams and veins are clearly secondary deposits and of later origin, for they not uncommonly cut beds of gypsum and adjacent rocks. The passages thus filled may have been very narrow at first but became enlarged gradually by solution and pos-
sibly by the expansive force of the growing crystals. Gypsite or gypsum earth is found in many places in the western states, usually in regions where beds of rock gypsum occur. Gypsite probably is derived from primary deposits through the circulation of groundwater. The spring theory of origin is generally accepted for deposits of this class, for water percolating through gypsum beds dissolves a portion of the rock and on issuing at a lower point as a spring redeposits the gypsum by evaporation, aided perhaps by the action of organic matter of decaying vegetation; also water may come up through beds of rock gypsum and form gypsite at the surface directly over the primary deposit. In either event a crust of minute gypsum crystals would be formed on the surface and increase gradually in thickness. Microscopic examination shows that gypsite consists of small irregular crystals and plates of gypsum. The deposits are so soft as to be easily worked with a spade, and some of the gypsite is very light and powdery. Gypsite deposits are thin and of little area; that is, they are rarely more than 15 feet thick and cover only a few acres. They are rather impure also, owing to the presence of sand, clay, lime carbonate, and organic matter, brought in by surface agencies.

Deposits Produced by Alteration

The origin of gypsum maybe explained in a number of ways, each applicable to a particular kind of deposit, and all based on the fact that gypsum is produced by the chemical action of sulphuric acid on calcium carbonate. Gypsum may thus be formed in the laboratory, the reaction stated in its simple form being:

-14-
The origin of some gypsum has been attributed to the alteration of limestone by the action of sulphuric acid in water from sulphur springs. The acid may be accounted for by the oxidation of sulphureted hydrogen, and this acid, working through cracks, joints, and bedding planes in limestone, reacts with calcium carbonate and forms calcium sulphate. Gypsum is formed likewise by sulphurous acid, which escapes around the fumaroles of volcanoes, also sulphuric acid derived by groundwater from pyritic shales. A more or less constant supply of acid in groundwater might in time change bedded limestone to apparently bedded gypsum. Alteration of anhydrite to gypsum has already been mentioned.
Secondary gypsum in shale. Note how crystallization has separated shale laminae.

A. Dark portion is limestone; intermediate portion is primary rock gypsum; light portion is secondary gypsum.

B. Secondary gypsum in shale. Note how crystallization has separated shale laminae.

Photographs of gypsum and gypsum-bearing rock.
CHARACTER OF JEFFERSON CANYON GYPSUM

Jefferson Canyon gypsum occurs as rock gypsum, gypsite, selenite, and satin spar. Some types are more important than others.

Primary Rock Gypsum

Primary rock gypsum, or massive gypsum is found in an adit, in a raise holed through from the adit and in pits near the raise, all which are on the upper central portion on the large map (Plate X). A specimen of rock gypsum is shown in Plate VII, A. The dark or black band and spots are carbonaceous limestone sometimes known as "stink stone". The darker grey portion which makes up the largest percent of the specimen is an impure gypsum, the impurity being limestone or shale. It is evident that the gypsum at one time was anhydrite from the fact that this specimen is highly fractured and the individual pieces which are not fractured are very much distorted as shown in the lower right of the specimen. The white portion which fills the fractures and forms veinlets as shown in the extreme lower right is secondary gypsum probably from the reworking of rock gypsum by solutions.

Secondary Rock Gypsum

Secondary rock gypsum, thought to be a form of gypsite, is the most common form of gypsum in this area and is found in most of the workings. Plate VII, B, is an average specimen, the white field is slightly consolidated fine-grained gypsum; the dark field is a rusty oxidized-covered green shale. The gypsum has taken the form of small lenses, each overlapping the other, containing within and without a
Plate VII

A. Recrystallized gypsum in limestone.

B. Old dumpcart used in early mining operations.
rust coated thin green shale. Another form of gypsite which is very soft and powdery to resemble wood ashes is found in several adits. But these are efflorescent deposits and are of no consequence.

Satin Spar

Satin spar is in minor quantities and is found in narrow veins or seams not more than an inch in width. It is generally found near the rock gypsum. It is made up of needle like fibers perpendicular to the vein wall.

Selenite

Selenite is in minor quantities also. Its crystals are very small and in formless masses. It is found near outcrops and in minute veinlets.

Plate VIII, A, shows the power of crystallization; gypsum-bearing solutions apparently worked through a minute fracture in limestone and recrystallized which results in expansion and consequently widening and lengthening of the fracture, thereby making room for more solution to pass through.
EXPLOITATION

The Jefferson Canyon gypsum quarry was exploited by the Three Forks Cement Company from 1911 to 1929. Approximately 100,000 tons of gypsum have been removed, varying in grade from 50 to 86 percent gypsum. Operations ceased when the better grade of gypsum was mined out.

During the eighteen years of somewhat intermittent operation, the gypsum was mined by contract by John W. Lyon in 1911 and by his son Charles Lyon from 1913 to July 13, 1929.

Method of mining or quarrying is known as the glory hole, that is an adit was driven under the deposit and mining was carried upward until the work place resembled a huge inverted cone with its apex forming the chute mouth in the adit. Horse drawn dump carts (Plate VII, B) were employed in removing waste to dumps and gypsum to bins. Four was the average number of men employed, but during extensive development as high as 35 men were employed. Average tonnage was 25 to 30 tons per day at $2.00 a ton, f.o.b.
POSSIBLE ORIGIN OF

JEFFERSON CANYON GYPSUM

The deposit of Jefferson Canyon rock gypsum is believed to have been precipitated either in the form of gypsum or anhydrite or as a mixture of the two from evaporating sea waters along with the limestones or shales which are interbedded with the gypsum. The gypsum occurs as a large bed or lens intercalated in the Jurassic limestone, because gypsum beds were not observed elsewhere in the region.

In all probability, water making its way through joints, fissures, and bedding planes of gypsum-bearing strata may take up calcium sulphate in solution. This water may come to rest in passageways, in the gypsum beds or in the adjacent wall rock and by evaporation deposit the gypsum as gypsite or secondary gypsum.

It was observed the gypsum was very pure near the surface outcrops and impurities increased with depth. Evidently gypsiferous solutions were evaporated as soon as it neared the surface; heat may have been supplied by the sun as each gypsite deposit is well on the southern side of the hill and near the surface. Also deposition may have been aided by reaction with shale which was turned from a ferrous condition to a ferric condition. Grade of the gypsite and gypsum varied with depth from about 85 to 50 percent or less. In general the gypsite is confined at or adjacent to rock gypsum deposits, and the high grade is found in an "enriched zone".

Satin spar and selenite may have practically the same origin as gypsite, that is, by the evaporation of gypsiferous solutions. Prob-
Solution channel lined with limonite.
ably the only difference is that satin spar and selenite were not the result of vigorous solution action and strenuous evaporation.

Efflorescent gypsum, or powdery gyspite, is formed from the direct contact of gypsiferous solution with air.

It may be mentioned here that solution channels (Plate VIII,) are found everywhere, some being open cavities, containing gypsum which show the effect of solutions, other cavities lined with limonite and still others filled with very fine unconsolidated sand. The solution may have been sulphureted water as indications of alteration of brecciated limestone is found everywhere and calcite veins are very common in the massive Madison limestone.
CONCLUSIONS

In concluding, it is thought that the age of the gypsum is Jurassic (Morrison), deduced from the relative position of the gypsum beds to the overlying Kootenai beds. The gypsum was originally in the form of rock gypsum formed under marine conditions and much of it has been reworked by water (springs) and redeposited.

Much of the gypsum is impure, the best and minable gypsum was situated near the surface of outcrops.

As to future prospecting most of the best gypsum has been removed, and all that remains is low grade gypsum which is situated below the quarry floor. A few drill holes may verify or disprove this statement, and if disproved it may still be said that the gypsum deposit with all exploited gypsum is a relatively small deposit.

But if prospecting for gypsum is to be desired this writer would seek out the conspicuous Kootenai "red beds" (not to mistake Amsden "red beds" for Kootenai) and search below these red beds for "oyster bearing" Ellis formation and then search between the Ellis and Kootenai for gypsum efflorescence or gypsite, then to finally determine the extent of deposit by drill holes. It also must be borne in mind the deposit must be easily accessible, close to market, fairly pure, easily mined and of some size to be profitable.
BIBLIOGRAPHY

Peale, A. C.

Stone, R. W.

Tansley, Schafer, Hart

Weed, W. H.
GEOLoGIC MAP OF JEFFERSON CANYON GYPSUM DEPOSIT