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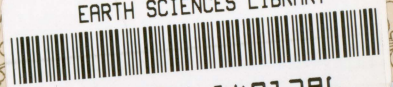
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A THESIS SUBMITTED TO THE FACULTY  
OF THE GRADUATE SCHOOL OF THE  
UNIVERSITY OF COLORADO IN  
PARTIAL FULFILLMENT OF  
THE REQUIREMENTS FOR  
THE DEGREE

MASTER OF SCIENCE

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INTRODUCTION

FIELD AND OFFICE WORK

The field work for this thesis was done during the summer of 1921. Russell Gibson, W.O. Thompson, H.P. Andrews, and the writer spent 10 days measuring sections, hunting fossils, and securing other data for the stratigraphy of the Beafoliff district. W.O. Thompson and the writer spent 3 weeks making an examination of the Ground Hog mine. The office and laboratory work for this thesis was done by the writer.

INTRODUCTION

ACKNOWLEDGEMENTS

A plan of the Ground Hog mine provided by the Empire Zinc Company greatly facilitated the examination of that mine. Valuable assistance was received from Mr. Gus Obenshead, who held the Ground Hog mine under lease at the time this work was going on.

I am greatly indebted to Professor H.D. Crawford, under whose direction this thesis was written; to Professors Julius Henderson and A.J. Zieje, who assisted in the identification of the fossils and criticized this thesis; and to Professor H.D. George for many suggestions and criticisms. I have en-

I N T R O D U C T I O NF I E L D A N D O F F I C E W O R K

The field work for this thesis was done during the summer of 1921. Russell Gibson, W.O. Thompson, E.P. Andrews, and the writer spent 10 days measuring sections, hunting fossils, and securing other data for the stratigraphy of the Redcliff district. W.O. Thompson and the writer spent 3 weeks making an examination of the Ground Hog mine. The office and laboratory work for this thesis was done by the writer.

A C K N O W L E D G M E N T S

A plan of the Ground Hog mine provided by the Empire Zinc Company greatly facilitated the examination of that mine. Valuable assistance was received from Mr. Gus Ohmstead, who held the Ground Hog mine under lease at the time this work was going on.

I am greatly indebted to Professor R.D. Crawford, under whose direction this thesis was written; to Professors Junius Henderson and A.J. Tieje, who assisted in the identification of the fossils and criticized this thesis; and to Professor R.D. George for many suggestions and criticisms. I have en-

deavored to acknowledge sources of information by footnote references.

Emmons, S.F., Geology and mining industry of Leadville, Colorado: Mon. U.S.G.S. No. 12, 1856, pp. 53-70.

Emmons, S.F., Geology and mining industry of Leadville, Colorado: Mon. U.S.G.S. No. 12, 1856, pp. 100.

Emmons, S.F., On the origin of fissure veins: Colorado Scientific Society Proc. Vol. 2, 1857, pp. 204.

The Redcliff mining district is located in the southeast part of Eagle County, Colorado. The northern limit of the Mountains lies a short distance to the southwest of this district. The district is drained by Eagle River and its tributaries. The Denver and Rio Grande R.R. runs directly thru the mining region. A good automobile road connects Redcliff and Gilman with Glenwood Springs to the west and Leadville to the southeast.

Arthur, Oscar, On the volcanic craters and fumarolic activities: Geol. Mag., Vol. 33, 1896, pp. 425-427.

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## L I T E R A T U R E   A N D   P R E V I O U S   G E O L O G I C W O R K

Paule, A.C., Adirondack valley - Eagle River - Sawatch Range: Seventh Ann. Rept. U.S. Geol. and Geog. Survey of the Territories, 1874.

Previously published reports have been few and very brief on either the mines or the stratigraphy of the Redcliff district. Writings which have some bearing on either the stratigraphy of the Redcliff district or the geology of the Ground Hog mine are listed below. Literature used in this report is suitably referred to by footnotes.

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Peale, A.C., Arkansas valley - Eagle River - Sawatch Range: Seventh Ann. Rept. U.S. Geol. and Geog. Survey of the Territories, 1874.

Spurr, J.E., Geology of the Aspen mining district, Colorado: Mon. U.S.G.S. Vol. 31, 1895, pp. 4-41.

PALEOZOIC SEDIMENTS

Paleozoic sediments entirely cover the Redcliff district, with the exception of localities where Eagle River and some of its tributaries have cut through the sedimentary rocks and for another 100 feet or more into the granites and gneisses.

Most of the sedimentary rocks contain very few fossils, due, probably, to the metamorphism of the strata. However, one or two beds, especially in the Carboniferous shales and

limestones, contain a number of fossils. Paleontologically four distinct formations may be differentiated in this region. A lithological study in connection with the above might possibly warrant further division.

CAMBRIAN-PRYORIAN (?) SEDIMENTS

QUARTZITE SERIES

DESCRIPTION

Cambrian quartzite rests directly upon the granites, gneisses, and schists of the district. The base of the Cambrian, consisting of about 10 feet of sediments, is co-

P A L E O Z O I C S E D I M E N T S

Paleozoic sediments entirely cover the Redcliff district, with the exception of localities where Eagle River and some of its tributaries have cut through the sedimentary rocks and for another 100 feet or more into the granites and gneisses.

Most of the sedimentary rocks contain very few fossils, due, probably, to the metamorphism of the strata. However, one or two beds, especially in the Carboniferous shales and limestones, produced quite a number of fossils. Paleontologically four distinct formations may be differentiated in this region. A lithological study in connection with the above might possibly warrant further division.

C A M B R I A N - D E V O N I A N (?) S E D I M E N T S

Q U A R T Z I T E S E R I E S

D E S C R I P T I O N

Cambrian quartzite rests directly upon the granites, gneisses, and schists of the district. The base of the Cambrian, consisting of about 10 feet of sediments, is es-

essentially a conglomeratic arkose, made up of disintegrated granite materials. The pebbles in the conglomerate are rounded fragments of quartz, varying in size, with a maximum of about three-fourths inches in diameter. The finer grains consist essentially of quartz and feldspar, largely microcline. From a microscopic examination of some of the crushed material, the cementing substances appear to be silica and a kaolinitic material, the latter probably from the alteration of the feldspar. A little higher up the conglomerate grades into a fine-grained quartzite, very compact, and well cemented with secondary quartz. The quartzite is bluish-white and is composed almost entirely of pure quartz grains averaging 2.5 mm. in diameter. A few very small crystals of pyrite replacing a part of the individual grains of quartz were revealed by the microscope.

In a section measured at Gilman compact, pure quartzite continues to a thickness of about 220 feet. At 55 feet above the granite, there is a micaceous streak 3 or 4 inches wide; but this, when examined under the microscope, appears to have been originally a fine-grained micaceous quartzite, whose brownish appearance is due to weathering. Seventy-six feet above the granite, occurs a 2-foot bed of sandy limestone. It is particularly noticeable, in that it is much less resistant to erosion than the overhanging quartzite above it. From 126 to 157 feet above the granite, alternating beds of dense, white quartzite and of porous, brown, iron-stained quartzite predominate. Above this the usual compact quartz-

ite with a few beds of more porous, nonresistant, sandstone continues for 65 feet.

At this horizon occurs a distinct change in the character of the sediments. For 105 feet the sediments are mainly alternating beds of calcareous and argillaceous sandstones or quartzites, arenaceous limestones, and thin, hard, platy, gray to green shale. The sediments are very thinly bedded, averaging less than 1 inch in thickness. The sandstones are reddish-brown in color, the shales a light grayish green. The first 5 feet of this division is succeeded by a 24-foot zone of alternating beds of gray, crystalline, arenaceous limestones, thin slaty, friable shales, and 6-inch beds of greenish-gray sandstone. Some of the limestone has a mottled appearance caused by a considerable number of elongated brownish iron-stained spots. Examination with the microscope suggested that, originally, the elongated blotches were probably limestone pebbles and had been replaced by dolomite. About 225 feet above the granite the hard somewhat wavy quartzite is purple in color, and weathers to dark or brownish purple. Closely associated with the bed of purple quartzite and seemingly grading into it are bright-green to dirty-purple, porous quartzites. These beds are similar to beds of glauconitic quartzite described by other writers in this general vicinity\*.

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\*Peale, A.C. Annual Report of the Hayden Survey for 1874, pp. 112.

\*Eldridge, G.H. Geologic Atlas U.S., folio 9, Anthracite-Crested Butte, Colorado, pp.6.

\*Spurr, J.E. Geology of the Aspen Mining District, Colorado Monograph 31, U.S.G.S., 1898, pp. 6.

About 325 feet above the base of the formation, is a 15 to 16 foot bed of hard, white, resistant, fine-grained, thick-bedded quartzite, strikingly similar to the massive quartzite in the first 225 feet of the formation. The last 14 to 15 feet of the quartzite bed consists of thick-bedded sandstone containing quartz pebbles up to three-eighths of an inch in diameter. Near the top the grains of quartz are largely embedded in calcareous cement, and the sandstone becomes less resistant to erosion. Due to a banded deposition of the sand grains it weathers in rough slabs. The total thickness of the quartzite series is about 355 feet.

#### CONDITIONS OF DEPOSITION

The conglomerate at the base indicates an advance of the sea over a well planed down and eroded granite floor, which had apparently suffered sufficient disintegration and decomposition to produce a residual layer of siliceous material. The white, pure, well-washed and rounded quartz grains above the conglomerate indicate continuing submergence. In all probability the sand was deposited not far from shore, and the land mass may be assumed to have been of low relief, the quartz grains seem to have been well washed and rounded before being carried to the sea and then to have been deposited in comparatively shallow water. The shaly and calcareous

beds in the upper part of the formation indicate deposition in deeper water. The quartzite at the top of the formation is evidence of a return to shallow water conditions. The land mass supplying the sediments was, in all probability, the region now occupied by the Sawatch Mountains\*. Thus the sediments may well have been carried into the Cambrian seas from the south. possibility that Ordovician limestone and Silurian or Devonian quartzite\* (Porting?) are represented in this region. It is certain, from faunal evidence, that the first 260 feet of the red AGE rocks must be upper Cambrian. However, there is some doubt as to the age of the sediments above that horizon. Addit

CAMBRIAN

In the zone of alternate shales, limestones, and thickness sandstones between 248 and 253 feet above the granite, a fragment of a trilobite was found. It was identified with little doubt as Dikellocephalus (Saukia) pepinensis. In the same strata were found a few small brachiopods identified as Westonia (ella?). The fossil evidence indicates upper of Cambrian age and agrees with that of the Cambrian in other localities. As the first 260 feet of the quartzite formation is upper Cambrian from fossil evidence, the overlying beds to within 30 feet of the top of the quartzite series are probably also upper Cambrian, inasmuch as they are, lithologically,

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\*Walcott, C.D. Bulletin U.S.G.S. No. 81, 1891, pp. 368.

very similar. In the district, about 40 miles southwest, the Cambrian is stated to be 350 to 400 feet thick, but farther north in the same district it commences to thin out and is only 200 feet thick. **ORDOVICIAN AND DEVONIAN ?** It is seen that the supposed Cambrian at Redcliff is considerably thicker than in localities immediately surrounding it. On the other hand, there is a possibility that Ordovician limestone and Ordovician or Devonian quartzite\* (Parting?) are represented in this region. It is certain, from faunal evidence, that the first 260 feet of the sedimentary rocks must be upper Cambrian. However, there is some doubt as to the age of the sediments above that horizon. Additional evidence strengthens the possibility of the presence of other sediments than the Cambrian Sawatch quartzite. In the Ten Mile district, ten miles east of this section, the Cambrian\*\* is given a thickness of 160 to 200 feet, above that is 120 to 160 feet of Ordovician limestone and 15 to 60 feet of Ordovician or Devonian quartzite. In the Leadville district, 20 miles south-east of this locality, the Cambrian\*\*\* is represented by 150 to 200 feet of quartzite, to the Ordovician is assigned 160 feet of limestone, and to the Parting quartzite a thickness of 60 feet.

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\*Girty, G.H. The Carboniferous Formations and Faunas of Colorado. Prof. Paper No. 16, U.S.G.S., 1903.  
 \*\*\*Emmons, S.F. Geology and Mining Industry of Leadville, Colorado. Monograph 12, U.S.G.S., 1898, pp. 58.  
 \*\*Emmons, S.F. Ten Mile District Special Folio, Colorado U.S.G.S., 1898.

In the Aspen district, about 40 miles southwest, the Cambrian\* is stated to be 350 to 400 feet thick, but farther north in the same district it commences to thin out and is only 200 feet thick. From the above data it is seen that the supposed Cambrian at Redcliff is considerably thicker than in localities immediately surrounding it. On the other hand, there is not sufficient difference in thickness to account for more than one-half of the normal thickness of the Ordovician or for a little more than the assigned thickness of the Parting quartzite. Further evidence in favor of the other than Cambrian sediments in the 355-foot section is the fact that there is, seemingly, no apparent unconformity between the so-called Cambrian and the Leadville Devonian limestone. Within a thickness of about 15 feet, there is gradation from sandstone through calcareous sandstone and arenaceous limestone to limestone. In addition to this Zaphrentis fossils similar to those in the Devonian formation were found at least 2 feet below the Devonian limestone in the top of the 30-foot zone of quartzite. This fossil evidence practically proves that the upper 30 feet of the supposed Cambrian cannot be earlier in age than Ordovician. Finally the 30 feet at the top of the debatable beds is lithologically very similar to the Parting quartzite of

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\*Spurr, J.E. Geology of the Aspen Mining District, Colorado. Monograph 31, U.S.G.S., 1898, pp. 10.

Emmons, S.F. Geology and Mining Industry of Leadville, Colorado, U.S.G.S. Monograph 18, 1884, pp. 59

the Leadville and Ten Mile districts. Considering the upper 30 feet as Parting quartzite would leave a thickness of 325 feet for the Cambrian, provided that the Ordovician White limestone is not represented in this locality.

Certainly the Ordovician White limestone cannot be present in its greatest thickness, that is 200 feet. It is true that mottled limestone beds between 225 and 250 feet above the granite resemble a bed of the same character in the Leadville district, which Mr. S.F. Emmons\* has considered a horizon marker for the top of the Cambrian. Yet, in the Redcliff district, Cambrian fossils were found 10 feet higher than the mottled limestone beds. It follows that the Cambrian must be thicker at Redcliff than it is at Leadville or in the Ten Mile district. It is, then, probable that the next 65 feet of similar sediments is also upper Cambrian.

To sum up, whether one considers the upper 30 feet as Sawatch quartzite (Cambrian) or Parting quartzite (Ordovician or Devonian) has been largely a matter of opinion. However, it is my belief that the evidence strongly favors Devonian Parting quartzite for the upper 30 feet. A question may be asked here. What caused the absence of the Ordovician limestone, if it is true that Devonian sediments rest directly on the quartzite of the Cambrian age? Inasmuch as Ordovician limestone is found in both the Leadville and Ten Mile districts to the east and south-east of this section and in

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\*Emmons, S.F. Geology and Mining Industry of Leadville, Colorado, U.S.G.S. Monograph 12, 1886, pp.59

the Aspen district south-west from this region, with no perceptible thinning towards Redcliff, it would not be logical to assume that the Ordovician limestone was not deposited in this locality. If then Ordovician sediments were originally laid down in the Redcliff district, it follows that the Ordovician limestone must have been eroded completely away, if it is not represented in this district. This hypothesis would necessitate, at least, a disconformity somewhere between the top of the known Cambrian and the base of the Devonian Parting quartzite, provided that the writer is correct in assuming that the Devonian sediments lie directly on the Cambrian formation. Although a disconformity was not located in the field it is very possible that one may occur in the obscured beds just below the supposed Ordovician or Devonian Parting quartzite.

At the present time the age of the Parting quartzite remains unsettled. Formerly it was believed to be Devonian, but later evidence suggests it to be Ordovician. Fish remains found in the Aspen district were originally assigned to the Devonian but are now believed to be Ordovician in age. The fact that the Parting quartzite is ordinarily not separated from the Ordovician limestone by an unconformity even though the entire Silurian formation is absent, is additional evidence that the Parting quartzite is Ordovician in age.

Above the quartzite is a 12 - 14 - foot zone of quartzite breccia composed of fine quartz grains, angular fragments of lime-

DEVONIAN - MISSISSIPPIANSEDIMENTSLEADVILLE LIMESTONEDESCRIPTION

The lower limit of the Leadville limestone is here considered to be the limestone beds immediately overlying the calcareous sandstones or arenaceous limestones, which weather out in brown slabs. As stated before, an unconformity was not perceptible, instead, a gradual transition from the pure quartzite below to the limestone above was noted. The upper limit of the Leadville is taken as the base of the black shales immediately above massive-bedded limestones. This makes a total thickness of about 170 feet for the Devonian-Mississippian limestones. The base of the formation or about 60 feet consists of even and fairly thin-bedded, dense, hard, blue-gray, crystalline limestone or dolomite. The beds weather light gray. A few narrow chert bands are present, as are also a few thin partings of gray shale. Above this limestone or dolomite, occurs a 2-foot bed of remarkably persistent quartzite. The quartzite consists of fine, white, pure, well-rounded quartz grains firmly cemented with both siliceous and calcareous materials. Above the quartzite is a 10 - 14 - foot zone of quartzite breccia composed of fine quartz grains, angular fragments of lime-

stone, and both angular and rounded fragments of chert, all of which are bound together with calcareous cement. Some of the larger fragments of limestone are 5 inches in diameter, but the average diameter of the fragments is about three-quarters of an inch. The upper part of the Leadville limestone, 95 - 100 feet in thickness, is different in character from the lower part. The bedding is very massive. On the face of some of the almost vertical cliffs of weathered limestone, one can see almost no bedding whatever. The limestone is dark-blue and weathers to a brownish-gray. It is coarsely crystalline and granular, especially in the upper part. A characteristic feature of the limestone is a ribbed structure or a banded appearance caused by irregular lines and spots of white crystalline material. This structure is often rather fine, there being 4 - 5 white lines per inch, but in other places they are farther apart. The miners term such rock "zebra" limestone. This so called zebra limestone contains several dark cherty beds which are especially resistant to erosion. There are also many irregular vugs in the limestone, some of which are at least 4 inches long, and lined with crystals of dolomite. About 25 qualitative tests were made upon the limestone of this formation. From these tests the following generalizations can be made: *Shallow water -- ordinarily not over 120 feet deep*

1. The entire formation is dolomitic.
2. Silica occurs in the first 60 feet of the formation in amounts up to 10 percent.
3. Silice is noticeably lacking in the "zebra" limestone

above the quartzite and breccia.

4. A considerable amount of phosphate was found in one

thin bed of white limestone 6 - 8 feet above the

breccia in the "zebra" limestone.

5. The white spots or lines in the "zebra" formation

are also dolomitic.

6. Traces of aluminum and iron occur throughout the

formation.

#### CONDITIONS OF DEPOSITION

Ordinarily limestone is considered a fairly deep-water deposit. In the case of the Leadville limestone, however, the fact that the land was, in all probability, still low in relief and that the streams were carrying material chiefly in solution into the areas covered by seas, would lead to the conclusion that the limestone was deposited in moderately shallow water. The Leadville formation contains many corals at the base and for a considerable distance at the top. Some of the conditions for coral life are:

1. Shallow water -- ordinarily not over 120 feet deep and usually less.
2. Warm water -- not below 68 degrees Fahrenheit.
3. Water free from land waste.
4. Water containing carbonate of lime, oftentimes

carried in by currents.

5. Water of normal salinity.

These factor strengthen the first argument for shallow water deposition.

The shaly partings indicate either cyclic changes in climate over a low land, or, less likely, a gentle elevation of the land. The quartzite bed in the middle of the formation probably indicates a distinct elevation of the land in order that the fine-grained sand might be carried farther out to sea. The breccia above the quartzite suggests stormy conditions in addition to the elevation; at such times the rough waves and tides may have broken up a portion of the earlier deposited limestone into angular fragments and carried them farther out to sea, where they were deposited over the quartzite layer. It is possible that the quartzite and breccia represent an elevation and also a considerable time interval before the next sedimentation, especially since it was necessary for the pre-existing limestone to become thoroughly solidified before it could be broken up into angular fragments.

### AGE

A few Devonian fossils were found at the base of this formation. The identifiable Devonian brachiopods found were

Baron, U.S. Geology and Mining Industry of Leadville, Colorado. Monograph 12 U.S.G.S. 1886, pp. 65.

Spirifer whitneyi. They occur in a 5-foot zone at the base of the formation. A number of corals (Zaphrentis sp.) were found both at the base and at the top of the formation. No other identifiable fossils were found in the Leadville limestone formation. However, it is reasonable that the upper part of the formation is Mississippian, inasmuch as Mr. S.F. Emmons has determined the same bed\* to be Lower Carboniferous in the Leadville district. The dividing line between the Devonian and the Mississippian could not be placed by fossil evidence, but a likely place for it lithologically would be at the quartzite and breccia bed 60 feet above the base of the formation.

## P E N N S Y L V A N I A N   S E D I M E N T S

### W E B E R   F O R M A T I O N

#### D E S C R I P T I O N

#### W E B E R   S H A L E S

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\*Girty, F.H. The Carboniferous Formations and Faunas of Colorado. Prof. Paper No. 16 U.S.G.S., 1903, pp.222-223.

\*Emmons, S.F. Ten Mile District Special Folio, Colorado U.S.G.S. 1898.

\*Emmons, S.F. Geology and Mining Industry of Leadville, Colorado. Monograph 12 U.S.G.S. 1886, pp.66.

The Weber sediments (in the Ten Mile\* and Leadville\*\* districts) have been divided, by Mr. S.F. Emmons, into two formations, the Weber shales and the Weber grits. In order to keep the same terminology, a similar division will be used in this paper. The term Weber formation in this paper, will include both divisions. Correlated sediments in other districts are known by widely different names, probably because of the varying character of the formation.

The lower limit of this formation is the base of the carbonaceous shales immediately overlying the massive Leadville limestone. The two formations are separated by a distinct plane which in many places is marked by an intrusive sheet of porphyry. The upper limit of the formation is not so well defined. About 310 feet above the base of the shales, the sediments become arenaceous in character, quartzites and conglomerates predominating. This horizon is variable, but was considered the top of the Weber shales. The first 100 feet of the shales consists mainly of dark blue-black carbonaceous material, which is friable, thin, platy and which weathers readily. Thin beds of very impure coal, averaging 2 - 3 inches in thickness, occur at several horizons near the base of the shales. Even beds of blue-black impure limestone averaging 4 - 8 inches in thickness were laid down at regular intervals

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\*Emmons, S.F. Ten Mile District Special Folio, Colorado. U.S.G.S. 1898.

\*\*Emmons, S.F. Geology and Mining Industry of Leadville, Colorado. U.S.G.S. 1898, Monograph 12, pp.67.

within the shales. A 2-foot bed of dark-colored, medium-grained, somewhat calcareous quartzite occurs 16 feet above the base of the formation. One-hundred feet up in the shales, the sediments become more arenaceous. Thin beds of green to red micaceous sandstone alternate with the shales and with the few impure beds of limestone. Approximately 170 feet above the Leadville limestone is a 13-foot bed of quartzite sandstone which contains two 1-foot layers of conglomerate. The 190 feet at the top of the Weber Shales is distinctly arenaceous, with beds of quartzitic sandstone and conglomerate predominating and a few minor beds of sandy shales.

#### WEBER GRITS

Above the Weber shales are the Weber grits. They have an approximate thickness of 2800 - 3000 feet. Though a section was not measured, a fairly reliable estimate of the thickness was made, using a geologic map in connection with a number of dips. The Weber grits consist essentially of quartzitic, arkosic sandstones with a few partings of arenaceous shales and several massive beds of dolomitic limestone. The sandstones or grits are composed chiefly of angular grains of quartz, pink feldspar, and a considerable quantity of muscovite, at least a part of which must be secondary. Toward the top of the formation the sandstones become more conglomeratic in

character, containing fragments of schist, gneiss, granite, and even of limestone. The massive beds of dolomitic limestone which are from 20 - 50 feet thick show marked lateral variation. And although they do not outcrop continuously, it is believed that some of them thin out entirely. These limestone beds occur near the top of the formation.

#### CONDITIONS OF DEPOSITION

After the time interval had elapsed which separated Mississippian and Pennsylvannian sedimentation in this region, the seas again covered the land. The shales and limestones indicate a comparative shallow water deposition, inasmuch as the material for their formation was being derived from a lowland of earlier limestones and shales, while the sandy members in the upper part of the formation suggest that the limestone and shale materials had been removed and that granite was furnishing the sediments. A more doubtful interpretation is that the deposition occurred in relatively deep water and that the sandy members are accounted for by elevation of the land. The thin partings of impure coal indicate an accumulation of vegetable material under swampy or lagoonal conditions which necessarily adds considerable weight to the first interpretation of depositional conditions. Thus the Weber shales indicate a tran-

sition from marine conditions of the Mississippian period to the shallow non-marine conditions of the Pennsylvanian period. The upper part of the Weber formation or, in the main, the Weber grits, represents somewhat different conditions of deposition. Extreme lateral variation, an enormous thickness of conglomerate, reddish sandstones, and grayish-green shales, and much crossbedding suggest continental and even delta deposition\*. In all probability, the land mass supplying the sediments for the Weber formation lay to the south in the area now occupied by the Sawatch mountains. The fragments of granite, gneiss, and schist found in the conglomerate indicate that the sediments came from a land mass of the same kind of material.

#### AGE

The Weber formation is considered lower Pennsylvanian by Mr. G.H. Girty\*. A number of fossils were found in the first 75 feet of shaly beds and are identified as follows:

1. Chonetes sp.
2. Derbya crassa.
3. Aviculopecten (occidentalis?)
4. Aviculopecten sp.
5. Reticularia perplexa
6. Bryozoa (Probably Rhombopora lepidodendroides)

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\*Barrell, J. Criteria for the recognition of ancient delta deposits. Geol. Soc. Am., Bull., xxiii, pp. 377-446, 1912.

\*\*Girty, G.H. The Carboniferous Formations and Faunas of Colorado. Prof. Paper 16 U.S.G.S. pp. 264, 1903.

As far as these fossils can be identified, they coincide with other lists of fossils from the Weber shales. The fossil evidence in this section itself is not sufficient to determine the exact age of the Weber shales in the Redcliff district. However, the fact that the Weber shale fossils of Redcliff are found in the same formation in surrounding districts and the fact that the Weber shales of these various districts\* are similar in other characteristics is conclusive evidence that the lower part of the Weber formation at Redcliff is of the same age as the Weber shales of the Ten Mile and Leadville districts. Girty believes the same formation in the Ten Mile and Leadville districts to be lower Pennsylvanian. It is obvious that if it is Pennsylvanian in those districts the Weber shales must be of the same age at Redcliff.

In the massive dolomitic beds, believed to be at or near the top of the Weber grits, were found:

1. *Productus cora*.
2. *Reticularia perplexa*.

These types have also been found in the same limestone beds of the Leadville and Ten Mile regions.

A 20 - 30 - foot bed of a more pure variety of limestone (not dolomitic) which is in the neighborhood of 3000 feet above the base of the Weber shales yielded the following:

1. *Reticularia perplexa*.
2. *Meekella striaticostata*.
3. *Crinoid* sp.

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\*Girty, G.H. The Carboniferous Formations and Faunas of Colorado. Prof. Paper 16 U.S.G.S. pp. 264, 1903.

Although these fossils are not strictly lower Pennsylvanian types, they are found in the upper portion of the Weber grits elsewhere and they do not, necessarily, cast any doubt on Girty's determination of the formation as lower Pennsylvanian.

### MAROON FORMATION

Although no field work was done in the Maroon formation or in the Wyoming formation, which is the next succeeding formation, a short description of them is given in order to complete the Paleozoic section. Several miles to the north-east of this district, the Maroon formation outcrops. It is composed chiefly of red or maroon-colored sandstone, has a thickness of about 1500 feet, and is believed to belong to the Upper Coal Measures, Pennsylvanian.

### P E R M O - P E N N S Y L V A N I A N

### W Y O M I N G F O R M A T I O N

Above the Maroon and outcropping successively farther north-east are about 1500 feet of brick-red beds of sandstone, called the Wyoming formation. No fossils have been discovered

in these beds. Emmons\* says that if the Permian is represented in Colorado, it would be included in these beds, they have, however, been considered Triassic because of their lithological similarity to known Triassic beds. Emmons, presumably, correlates this formation with the Fountain, Lyons, and Lykins formations of the Front Range. With this, the writer does not agree, but is of the opinion that the Wyoming may be equivalent to the Lykins\* formation of the Front Range which is considered, with a remote possibility, that the upper one-third is Triassic. Spurr\*\* describes beds of a similar character which he assigns, provisionally, to the Triassic period. Darton has produced some evidence that the Wyoming formation is equivalent to the "Permian" of the Mississippi valley and Girty\*\*\* suggests that the evidence should not be disregarded. Because of the lack of fossils, however, the age of the Wyoming formation is still uncertain. Nevertheless, the writer is of the opinion that Wyoming formation is Permo-Pennsylvanian in age.

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\*Henderson, Junius. The Cretaceous Formations of North-Central Colorado. Bull. 19, Colo.G.S., pp.76, 1920.

\*\*Spurr, J.E. Geology of the Aspen Mining District, Colorado. U.S.G.S. Monograph 31, pp.37, 1898.

\*\*\*Girty, G.E. The Carboniferous Formations and Faunas of Colorado. U.S.G.S. Prof. Paper 16, pp.190, 1903.

GENERALIZED SECTION OF THE STRATIGRAPHY, REDCLIFF, COLO.

Figure I

Trias?	Wyoming formation.		1500±	Intense brick-red sandstones and shales.
Upper Penn.	Maroon formation.		1500±	Red sandstones and shales with drab limestones
Lower Penn.	Weber formation. "grite"		2800±	Coarse, light-colored sandstones, passing into conglomerate, with micaceous shales, and dolomitic limestone.
Miss. Devonian Cambrian	Porphiry Leadville form.		300 80	Carboniferous, fossiliferous shales. Porphyry measured at Eagle Bird Gulch. Compact, heavy-bedded, blue, dolomitic limestone. Contains chert concretions
Miss. Devonian Cambrian	Sawatch formation.		175 355	White quartzite passing into calcareous shales above.
pre-Camb.	Granite and gneiss			Massive complex of pre-Cambrian granite, gneiss, and schist.

## II. GROUND HOG MINE, REDCLIFF DISTRICT, COLORADO

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The Ground Hog mine is located in the quartzite ledge on the north-east side of Eagle river about halfway between the towns of Redcliff and Wilson in Eagle County, Colorado.

The Ground Hog mine is one of the early properties of the Redcliff district and was first worked in 1885. The workings of the mine are said to be more extensive than those of any other single mine in the district. The mine

## II. GROUND HOG MINE, REDCLIFF DISTRICT, COLORADO

loss is extensive scale. A number of leasers, several of whom have made small fortunes out of rich ore shoots or pockets, have worked at different parts of the mine at the same time.

At the present time the mine is owned by William S. Evans of Denver, Colorado, and at the time the work for this report was done, was held under lease by Gus Christend, who was working several of the ore bodies single handed.

Until recently, the ore was tramped by bucket down to the Denver and Rio Grande R.R. tracks from the Redcliff incline head house, but at the present time, the ore is freighted by wagon from the head house to Redcliff, where it is loaded on cars.

## II. GROUND HOG MINE, REDCLIFF DISTRICT, COLORADO

H I S T O R Y

The workings of the mine extend down the dip of the quartzite in a general direction of N. 45° E. for a distance of 1500 feet. The dip of the quartzite is from 12° to 40°.

The Ground Hog mine is located in the quartzite ledge on the north-east side of Eagle river about halfway between the towns of Redcliff and Gilman in Eagle County, Colorado.

The Ground Hog mine is one of the early properties of the Redcliff district and was first worked in 1885. The workings of the mine are said to be more extensive than those of any other single mine in the district. The mine has been operating since its opening on a more or less intensive scale. A number of lessees, several of whom have made small fortunes out of rich ore shoots or pockets, have worked at different parts of the mine at the same time.

At the present time the mine is owned by William G. Evans of Denver, Colorado, and at the time the work for this report was done, was held under lease by Gus Ohmstead, who was working several of the ore faces single handed.

Until recently, the ore was trammed by bucket down to the Denver and Rio Grande R.R. tracks from the Doddridge incline head house, but at the present time, the ore is freighted by wagon from the head house to Redcliff, where it is loaded on cars.

D E S C R I P T I O N

The workings of the Ground Hog mine extend down the dip of the quartzite in a general direction of N. 45° E. for a distance of 1500 feet. The dip of the quartzite is from 12° - 15° N. 40° - 45° E., and as the incline goes into the side of Battle Mountain, the deepest workings are about 800 feet below the surface. The workings extend about 1400 feet in width or in a northwest direction.

The mine has been worked from twelve main inclines and several minor ones. At the present time not all of the inclines open at the surface. However, they are connected under ground. Once inside the mine, it is possible to go thru the entire workings, with the exception of a few drifts filled with water or waste, and a few of the minor drifts from the surface not joined with the main workings. The mine was also formerly connected with the surface by several shafts, all of which have fallen into disuse and have become partially filled or destroyed.

In many places the side drifts become very small, usually about two and a half to three feet high, with scarcely enough room for a man to crawl through, though they extend several hundred feet in length. The main inclines or crosseuts are usually of sufficient height to allow an ordinary man to walk erect, except a few places where the quartzite was particularly hard and where tracks had taken

up some of the space.

At the present time five of the inclines and the Nottingham or main crosscut are tracked and more are partially tracked, although only two inclines, the Doddridge and Nottingham, and the main crosscut are used for haulage purposes. There are two head houses in repair at the opening of the Nottingham and Doddridge inclines and bear their respective names. The mine or buildings are not wired for electricity, hence steam and gasoline is used for hoisting purposes. At one time a considerable portion of the mine was piped so that air could be used for drilling, but the air system was also out of repair at the time of our examination.

### P R O D U C T I O N

Although a great part of the production of the Ground Hog mine was from rich shoots or pockets, for which records of approximate production have been kept, it is next to impossible to make an estimate on the total production of the mine.

The Forgy Bullion hole, which is located in the Nottingham (right) incline about 225 feet above the main crosscut, produced about \$37,000 worth of ore.

The Doddridge winze located in the Nottingham incline 100 feet below the main crosscut produced about \$50,000

worth of ore.

A small stope on No. 4 South drift produced about \$4,000 worth of ore carrying \$15.00 in gold and 15 ounces of silver. No. 3 South produced a total of about \$47,000 worth of ore.

The Baldwin and Oneal Bullion place, which is located 300 feet down the Doddridge incline, produced \$12,000 worth of oxide ore.

The Woods and Henderson Bullion shoot 200 feet down the same incline produced \$10,000 in oxide ore.

The total production in the Doddridge incline area below the main crosscut is said to have been about \$500,000.00.

The above figures were supplied by Dismant Bros. of Red-cliff and represent the production of only a few of the richest shoots or bullion pockets in the mine. However, from these few figures (\$660,000) it can be seen that the mine must have produced a considerable amount of ore.

## G E O L O G Y

### F A U L T I N G

The fissures and faults apparently trend in two general directions in the mine. The first group strike N. 35° W. or approximately that, and compose the minor system. The second group strike N. 40° - 45° E. and compose the major system.

and leave the zone at MINOR SYSTEM This type of fracturing is known as stepped fault zone. In practically all of the strong northeast faults, evidence of movement can be obtained.

The faults of the minor group are nearly vertical and form, not a zone of fracture, but one single, sharp, and almost straight fissure. None of the northwest fissures carry any evidence of movement or faulting but all seem to have originated from a common cause. Such fissures might have been caused in the brittle quartzite when the Sawatch uplift occurred, forcing the strata to dip  $12^{\circ}$  -  $15^{\circ}$  northeast in this region. These fissures occur very regularly and oftentimes not over 10 feet apart. Hence, a considerable amount of displacement or adjustment could have taken place, and yet when distributed among so many breaks the chances are that there would be no perceptible evidence of movement in any single fissure. This group of fissures, very closely, resemble jointing in igneous rock.

One minor fracture which leaves the zone and crosses the main incline shows a displacement of three feet, and the fault surface was nicely grooved and slickensided. The MAJOR SYSTEM shows that the blocks must have moved up or down with relation to each other. An attempt was made to trace this fault to the surface in order

The faults of the major system strike northeast, between  $N. 40^{\circ}$  -  $45^{\circ}$  E. and are, in most cases, about vertical. However, these northeast faults are not single fractures, but are composed of several fractures, constituting a zone of faulting. Many of the different faults in the zone come in

and leave the zone at small angles. This type of fracturing is known as sheeted fault zone. In practically all of the strong northeast faults, evidence of movement can be obtained, some of which are slickensiding, grooving and even actual displacement. Probably the two most important faults of this group in the mine are those bearing the names Cleveland and Doddridge.

#### CLEVELAND FAULT

The Cleveland fault strikes from N. 45° - 55° E. and is vertical. It can best be seen about forty feet east of the Doddridge incline opposite the main crosscut. The faulted zone is from 12 to 15 feet wide and contains immense quantities of gouge and breccia. One minor fracture which leaves the zone and crosses the main incline shows a displacement of three feet, and the fault surface was nicely grooved and slickensided. The grooves are vertical showing that the blocks must have moved up or down with relation to each other. An attempt was made to trace this fault to the surface in order to determine the actual displacement. This was almost impossible because it was not opened up in a sufficient number of places and because the zone of faults widened, many of them leaving the main zone. On the surface small separated faults probably belonging to the Cleveland zone indicated

very little actual displacement and gave no evidence of any great movement. It is possible that the zone represents considerable back and forth movement without a great deal of displacement, especially, as there is no large displacement on the surface. At the present time this fault contains red iron oxide, brown iron oxide, and many crystals of quartz.

#### DODDRIDGE FAULT

The Doddridge fault can best be seen at the Doddridge winze 100 feet below the main crosscut in the Nottingham incline. It strikes N. 45° E. and is vertical. The zone is about ten feet wide and is also well brecciated and filled with gouge. The fault is stoped out 35 feet above, but owing to rotten and decayed timbering could not be examined. The Doddridge winze sinks 160 feet on the fault to the granite, but owing to water only two levels below could be examined. In the two lower levels, very highly polished mirror-like slickensiding was noticed. The grooves were horizontal, however, so that the fault movement must have been at right angles to the direction of the movement of the Cleveland fault. The fault zone was partially filled with sulfide ore and drusy quartz gangue. In all probability the deposition of most of the ore in the mine was controlled by the northeast system of faulting.

### BEDDING FAULTS

In addition to the systems of fractures many bedding faults of varying size were encountered in the mine. They were often cut in two or displaced by the other systems. As a rule they were from 2 to 4 inches wide and tightly filled with gouge, and were not found to be mineralized.

### C H A R A C T E R O F W A L L R O C K

As the greater part of the Ground Hog mine is an incline which follows the dip of the quartzite or in other words follows one horizon in the quartzite, there is little to be said about the character of the wall rock. The bed which seems to have been followed so persistently, is a medium-grained porous sandstone or quartzite, which dips  $10^{\circ} - 12^{\circ}$  N.  $45^{\circ}$  E. It is not as well silicified as the most of the quartzite formation and when not entirely replaced with ore, the bed is dark colored as if it had been stained with iron bearing solutions. This porous non-resistant quartzite bed averages about 2 feet in thickness. Below it is the usual white, pure, compact, fine-grained quartzite. Above this porous bed is quartzite very little different from the quartzite below the bed, excepting that it appears

to be even more dense and compact, whiter and purer than the usual quartzite. In fact the upper quartzite bed is so dense and hard that it shatters like glass or pure quartz when struck with a hammer. The Doddridge winze has been driven down thru the quartzite a distance of 160 feet and into the granite. Owing to the fact that the winze was watered 90 feet below the main level, no work could be done in the granite. Stopes No. 3 and 4 South have been driven up into the quartzite a distance of 35 to 40 feet. About 30 feet above the main level the usual compact, fine-grained quartzite, seemingly grades into more shaly members. Some of these shale beds are quite calcareous in character and were readily replaced by ore.

#### ORE DEPOSITS

The ore deposits of the Ground Hog mine may be divided into two types, which are, nevertheless, very closely associated with each other. These are the fissure and replacement deposits.

#### FISSURE DEPOSITS

At the present time no fissure deposits of any importance are opened up in the mine, with the possible exception of

Practically every fissure, fault, or fracture in the quartzite in the Ground Hog mine is partially, if not completely, filled with mineral. However, the minor system of fissures is very narrow, allowing little room for deposition from solution. Thus the veins striking N. 30° W. are of very little economic importance, except where they intersect a vein from the other system. And although the minor fissures may possibly have been filled with ore bearing solutions, the wall rock suffered very little replacement. On the contrary, the major faults striking northeast seem to have controlled the greater part of the ore bearing solutions. In addition to being wider than the fissures striking northwest, they are more closely packed with mineral. Moreover the solutions replaced a variable amount usually several inches, of the quartzite on both sides of the faults of the major group. The fissure deposits are characterized by a very pronounced crustification. Crystals of sphalerite having been deposited over the pyritohedrons of pyrite. The last deposition was that of quartz or of barite. In both cases several layers of the crystallized material are encrusted on the sphalerite. Some of the highest grade ore in the mine occurs as fissure deposits in the faults and fractures striking northeast. Invariably, however, the fissure-filled deposits pinch out a few feet, both above and below, the main level in the Ground Hog mine.

At the present time no fissure deposits of any importance are opened up in the mine, with the possible exception of

that in the Doddridge fault zone. This deposit is discussed later.

### REPLACEMENT DEPOSITS

As was stated in connection with the fissure deposits, the ore bearing solutions replaced several inches of wall rock on each side of the fissure. In many places the mineral was found disseminated thru the quartzite beyond the zone or limits of complete replacement. However, the most important replacement deposit in the mine was the almost complete replacement, especially when near one of the major faults or fissures, of the porous non-resistant, 2-foot bed of sandy quartzite. This is the bed referred to before and which was followed by the main incline of the Ground Hog mine. This particular bed must have given to the ore solutions a channel of easy circulation. Hence, it was largely replaced throughout the mine. It was undoubtedly this easily replaceable bed, which has made the mine a commercial possibility: first, because the bed was much easier to mine than the ordinary hard quartzite, thus reducing the cost of mining; and second, because the bed itself contained an enormous amount of ore, especially when entirely replaced. Characteristics of this deposit which coincide with replacement criteria are:

1. Presence of complete crystals of pyrite in the quartzite wall rock.
2. Preservation of the original structure of the replaced bed of quartzite.
3. Absence of crustification.
4. Presence of unsupported masses of quartzite in the bed of pyrite.
5. Form of the deposit.

There can be little or no doubt as to the character of the deposition, especially since all of the criteria coincide with what seems to be the only logical conclusion.

It is perhaps well to mention here that the ore is of two general types. In some cases the ore was very compact and hard. In other cases it was more fragmental and granular and although it retained the structure of the original quartzite, it did not seem to be cemented (if I may use that term) as well as the more compact material. Ordinarily, the granular ore was of low grade and though it was easier to mine it was looked upon with disfavor by the lessees.

The almost complete replacement of the 2-foot bed is, at present, indicated by the vugged or dug out condition of that bed. The character of the replacement can be seen very well at the Ohmstead ore face which is about 150 feet from the lower end of the Doddridge incline. At this face the replaced portion varies from 6 inches to 2 feet thick. The replacing material (pyrite) carries a small amount of gold and about 50 ounces of silver per ton.

The mineralized zone accompanying the Doddridge fault could be taken up either under replacement or under fissure deposition, since it is probably, a combination of the two. This zone has been stoped out 35 feet overhead but could not be examined because of bad timbers. The Doddridge winze, which sinks 160 feet to the granite, was examined as far as the water would allow. For a distance of about 80 feet below the main level, the rock of the fault zone was replaced by or filled with solid pyrite varying from 5 to 10 feet in thickness and extending laterally for 40 to 50 feet. However, this body of ore was too low grade to work.

#### CHARACTER OF THE ORE

The Ground Hog ore is of two general types, oxide and sulfide.

#### OXIDE ORES

The oxide zone extends down the dip of the quartzite for a distance of 500 to 700 feet. This zone formerly included some of the richest bullion pockets, but at the present time no valuable ore bodies are known in the oxidized

zone. The oxides were chiefly those of iron, and a small amount of manganese. The manganese oxide was, seemingly, limited to a few of the largest faults striking N. 40° - 45° E., such as the Cleveland fault.

#### SULPHIDE ORES

The sulphide ores are found below the oxidized ores and continue down the dip of the quartzite to the deepest faces in the mine. The sulfides are galena, sphalerite, bornite, copper-bearing pyrite, and pyrite. Of these the last is by far the most important, while the others occur sparingly in the small area near No. 3 and 4 South drifts and stopes. In the sulfide zone of the mine pyrite crystals (pyritohedrons) are very common. Cubes and octahedrons of pyrite were found in the lower levels of the Doddridge winze district. The pyritohedrons were not distorted. They occurred in considerable number and were exceedingly large. Some of the crystals were about 2 inches in diameter. No other crystal forms were combined with or imposed on the pyritohedrons. The cubes and octahedrons which were often combined were small, averaging 0.25 inches in diameter.

There were several faces of sulfide ore in the mine at the time the work for this report was done. A copper-bearing pyrite in a stope off No. 3 South drift contains consid-

erable ore, but it is of too low grade to be worked profitably. A sample of this copper-bearing pyrite ran 0.08 of an ounce in gold and 7.8 ounces in silver per ton, when assayed.

A large quantity of pyrite can be seen in the level 3 feet down the Doddridge winze. This also was said to have been low-grade ore. Several assays of the ore showed that it contained 1.2 ounces of gold and 4 to 6 ounces of silver per ton. There is a possibility of considerable good ore in this part of the mine, although a drainage of the Doddridge winze should be affected to develop the ore body. This would necessitate pumping the water to the surface and would involve ~~the~~ some expense.

The small face at the lower end of the Doddridge incline contains pyrite, both as a replacement of the porous quartzite and as fissure filling above, and was being worked by Mr. Ohmstead during the summer and fall of 1921. A trace of gold and about 50 ounces of silver per ton is an average of three assays for this face of ore. Although very little ore was in sight, a man could make good wages working at the small face on ore running \$50 to \$60 a ton.

#### MINERALOGY OF THE ORES

Regardless of their economic value, all the minerals found in the mine will be considered in this section. They

are arranged alphabetically under the name of the characteristic metal of each group. Primary minerals are differentiated from secondary minerals, but for a more complete discussion, the paragraphs on genesis and secondary sulphide enrichments should be considered.

### Copper

Chalcocite, cuprous sulphide,  $\text{Cu}_2\text{S}$ . Secondary chalcocite occurs in small quantity in stopes off No. 2, 3, and 4 South drifts. It is blue-black and granular.

Chalcanthite or Blue Vitriol, hydrated sulphate of copper,  $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ . Secondary chalcanthite fills narrow fissures along the main crosscut. It is a sky-blue mineral with a nauseous taste.

Chalcopyrite, copper-iron sulphide,  $\text{CuFeS}_2$ . Primary chalcopyrite occurs in considerable quantity in stopes off No. 3 and 4 South drifts and at the face in No. 3 North drift. It is massive and brass-yellow.

Copper-bearing pyrite, sulphide of iron with a variable amount of copper,  $\text{FeS}_2$ . Although all of the pyrite in the mine probably carries some copper, the pyrite in the area between the Nottingham incline and the Doddridge incline along the Main crosscut carries the most copper. It is massive and brass-yellow.

Covellite, copper sulphide,  $CuS$ . It occurs in small amounts in the stope off No. 2 South as a thin coating on copper-bearing pyrite. It has an indigo-blue color.

#### Gold

Nuggets of gold have been found in the oxidized zone in the Forgy Bullion hole, which is located in the Nottingham (right) incline about 225 feet above the main crosscut, in the Baldwin and Oneal Bullion place, which is located 300 feet down the Doddridge incline, and in the Woods and Henderson Bullion shoot 200 feet down the same incline. Gold in quantities from a tract to 1.6 ounces per ton was found in the oxidized iron ores in various parts of the mine. Traces of gold were found in most of the sulphide ores of the mine. Tests of some of the highest grade gold ores gave no indication of tellurium, although it might easily be missed because of the small quantity of gold in the ore (2.25 ounces per ton).

#### Iron

Limonite, ferric oxide with water,  $2Fe_2O_3 \cdot 3H_2O$ .

Brown and yellow limonite occurs in almost every ore body in the oxidized zone.

Pyrite, iron disulphide,  $\text{FeS}_2$ . Pyrite occurs both granular and massive as a replacement deposit and as open fissure deposition.

Turgite, hydrous ferric oxide,  $2\text{Fe}_2\text{O}_3 \cdot \text{H}_2\text{O}$ . A red, earthy turgite occurs with the limonite in the Forgy incline.

### Lead

Galena, lead sulphide,  $\text{PbS}$ . Fine to medium grained galena occurs in No. 3 and 4 South drifts about 100 feet above or southwest of the stopes in small quantities in open fissure filled veins.

### Silver

Most of the pyrite in the mine carries silver. Some of it runs 60 ounces of silver to the ton. Galena also carries a considerable amount of silver (50 ounces to the ton). Oxidized ores on the contrary carry very little silver (2 - 5 ounces). Silver, probably, occurs in the form of silver sulphide, argentite,  $\text{Ag}_2\text{S}$ .

## Zinc

upper third of the mine, or stated before, the oxide zone extends from the surface down the dip of the quartzite for a distance of 500 to 700 feet. The sulphide ores, chiefly Sphalerite or zinc blende, zinc sulphide  $ZnS$ . Crystals of sphalerite are found associated with galena and copper bearing pyrite in the open fissure veins in the small area on the main crosscut between the Doddridge and Nottingham inclines.

## Non-Metallic Gangue Minerals

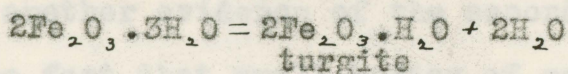
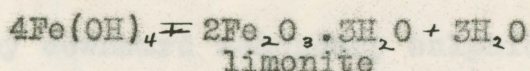
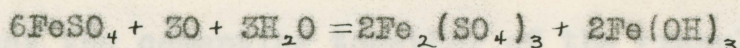
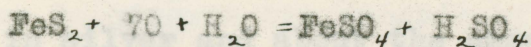
Barite, barium sulphate,  $BaSO_4$ . Barite or "heavy spar" is found encrusting the sphalerite and copper-bearing pyrite in the center of the unfilled portion of the open fissure veins in the main crosscut district.

Quartz, silica,  $SiO_2$ . Quartz in the form of quartzite, forms the walls of the replacement and open fissure deposits. Quartz encrustations are also found coating the pyrite in the open fissure ore bodies.

## Oxidation and Secondary Enrichment

Oxidation of the sulphide ores has taken place in the

upper third of the mine, or as stated before, the oxide zone extends from the surface down the dip of the quartzite for a distance of 500 to 700 feet. The sulphide ores, chiefly pyrite, have been changed to limonite and in a few places to turgite. The chemistry of the oxidation is relatively simple and is best shown by the reactions which take place:



From a number of assays on the oxide and sulphide ores, the following data were obtained:

1. Oxide carries little silver - 4 to 8 ounces per ton.
2. Oxide ore averages from 0.6 to 1.2 ounces of gold per ton.
3. Sulphide ore carries considerable silver - average is 50 ounces of silver to the ton.
4. Sulphide ore contains very little gold - average is a trace to 0.4 ounce per ton.
5. Sulphide ore varies widely in tenor.

Conclusions drawn from the data are:

1. Oxidizing processes leached out the silver content.
2. Oxidizing processes did not leach the gold but tended to concentrate it by leaching the other minerals in the ore bodies.
3. Rich sulphide ore bodies suggest secondary sulphide

enrichment, especially since the sulphides carry high silver and low gold.

Another evidence of the secondary sulphide enrichment is the fact that the loose, granular, sandlike replacement deposit of the ore-bearing bed is low in silver and gold, while the same ore deposit, when compact and firmly cemented, runs high in silver and about the same in gold. This would suggest that the cementing together of the granular ore was affected by downward secondary sulphide enrichment.

Still another evidence of the secondary sulphide enrichment is the fact that small bodies of secondary chalcocite, covellite and probably bornite occur in the stoped area of No. 2, 3 and 4 South drifts. Thin films or coatings of covellite were found covering crystals of pyrite in addition to granular to massive chalcocite associated with pyrite. Although these secondary minerals may not have been transported far, inasmuch as the area in which they are found is not far from the oxidized zone, nevertheless the secondary minerals indicate sulphide enrichment.

Evidence for the concentrating of the gold into bullion pockets and shoots, such as the presence of manganese, was not found. It is probable, therefore, that the pockets of gold were formed by a leaching away of all other materials in the ore deposits except the gold, rather than by enrichment. This theory is supported by the assays, showing that the gold was not subject to leaching while the silver was leached out and deposited lower down as secondary sulphide

enrichment.

### GENESIS OF THE ORE

A few general facts about the ore deposits are:

1. The ore occurs in three horizons, the granite and

In order to discuss the genesis of the ores, it is necessary to consider the structure of the region. This will be done in a very limited and general way.

In the Redcliff district Paleozoic sediments, overlying granite, gneiss, and schist, dip 15° northeast. The sediments are broken by a number of faults which may be classified roughly, into at least two systems. The faults of one system strike northeast, those of the other system strike northwest. Many of these faults continue into the granite, especially the larger northeast faults. An intrusion of quartz porphyry occurs in the form of a sheet between the Leadville limestone and the Weber shales. This intrusive sheet varies laterally in thickness, being from 50 to 200 feet thick in the Redcliff district. The Ground Hog mine is located in the earliest of Paleozoic sediments and is about 200 feet above the granite. A generalized section of this district is:

1500' Wyoming formation Triassic?

1500' Maroon formation Upper Pennsylvanian

3000' Weber formation Lower Pennsylvanian

80' Porphyry

170'	Leadville Limestone	Devonian-Mississippian
30'	Parting ? Quartzite	Devonian?
325'	Sqwatch quartzite	Cambrian
	Granite and gneiss	pre-Cambrian

A few general facts about the ore deposits are:

1. The ore occurs in three horizons, the granites and gneisses, the Cambrian quartzite, and the Leadville limestones.
2. The ores in the three different horizons are closely related, as to mineral composition.
3. Where the ore occurs in one horizon, it seems also to occur in the other horizons.
4. The porphyry seems to be present wherever valuable ore deposits occur.
5. No ore is known above the porphyry sheet.
6. There is no appreciable amount of metals or metallic minerals in the porphyry.
7. The porphyry affected very little metamorphism in the shales and limestones above and below it.

In order to formulate a theory for the deposition of the ore, it is necessary to fit it to all of these general facts.

In the writer's opinion only one theory will coincide with all of the facts in the case. That is, the minerals were deposited from an ascending hot solution. The ascending solution was hot and possibly alkaline because of the kind of material replaced by it, particularly quartzite and granite. The solution stopped its upward journey with the porphyry

which acted as a barrier. Fissure filling occurred in the granite and fissure filling and replacement occurred in the quartzite, because a particular bed offered easy impregnation and because a particular hard and dense bed overlay the easily replaced bed. Replacement, in the main, occurred in the limestone beds, because of the ease of replacement and because of the intrusive barrier above the limestone formation. Certainly this hypothesis will fit all the conditions listed. A question might be asked here: Why were the solutions hot and why did they carry minerals? Inasmuch as some of the igneous activity of the region was manifested by an intrusive sheet, it is logical to believe it connected with a larger mass of igneous rock below the surface an unknown distance. In this case it would be necessary for the magma to have been close enough to the surface so that it could be reached by meteoric waters which took up heat and a portion of the metals and then because of the temperature found its way upward in the faults and fissures. It is probable that magmatic waters and vapors assisted in the carrying of the metals upward and it is possible that the ore deposition had a magmatic origin. In case the ore was due entirely to magmatic deposition, the magma would not have to approach so near to the surface as would be necessary in considering meteoric waters the carrying agent. The minerals were deposited along the fissures and in beds which were more porous and readily replaced. Finally the ore-bearing solutions were stopped by the sheet of porphyry intruded between the Leadville limestone and the Weber formation.

Other hypothesis have been advanced for the deposition of the ore. One of them is that the ore-bearing solutions came from the sheet of porphyry. In this case, why is ore not found in the beds of limestone immediately above the porphyry? Another hypothesis might be that the ores were leached out from the overlying sediments by meteoric waters. In this case it would be logical to consider the igneous sheet as a barrier but with the upper side of the porphyry as the most likely place for deposition.

If then, the hypothesis that the ores were deposited from ascending solutions coming from a deep-seated source is accepted, it is a relatively easy task to differentiate between the periods of deposition. From fissure filling, it is readily seen that the pyrite was deposited first, then sphalerite, then a gangue of either quartz or barite. Hand specimens taken from the mine very conclusively prove this point. In a few fissures, it seems that there was a second deposition of pyrite after the sphalerite was deposited.

#### TENOR OF THE ORE

The tenor of the Ground Hog ore deposits is extremely irregular. For that particular reason averages are of little value. From assays of samples, which were collected in the mine, the following data were compiled.

Sample No.	Location	Character	Mineral	Oz. Au. per T	Oz. Ag. per T
232	250' down: Forgy incline.	Brown oxide and vein quartz.	Limonite: Quartz	0.38	5.44
234	200' down: Pool in- cline to face.	Yellow- brown, muddy oxide.	Limonite:	0.11	3.05
239	400' down: Raymond incline	Brown earthy oxide	Limonite: pyrite silica	0.115	37.10
240	400' down: Raymond incline	Brown earthy oxide	Limonite: pyrite silica	0.12	37.05
170	On Cleve- land Fault opposite main cross- cut.	Red oxide	Turgite Pyrite	0.21	25.55
6	300' down: Doddridge incline	Oxide	Limonite: Silica	0.06	8.09
229	In Dis- mant cross cut off the Forgy incline	Mixture of brown and red oxide	Limonite: Turgite: Silica	0.22	2.15
171	On Cleve- land fault opposite main cross cut	Brown to black oxide	Limonite: Pyrite	0.04	11.75

Sample No.	Location	Character	Mineral	Oz. Au. per T	Oz. Ag. per T
162	300' down Doddridge incline	Red oxide	Turgite Limonite	2.12	2.00
227	450' down Raymond incline	Sulphide	Pyrite Sphalerite	trace	15.64
203	200' above main cross cut in No. 3-4 South drifts	Sulphide	Galena	0.72	34.30
201	At junct- ion of 3- 4 South drifts	Sulphide	Galena	0.15	17.92
8	Doddridge dump	Sulphide	Pyrite	1.48	5.63
164	600' below portal & 150' NW Doddridge incline	Sulphide	Pyrite	0.65	4.26
158	Stope in drift No. 2 South	Disseminat- ed sulphide in breccia	Pyrite	0.31	2.80
174	At end of short drift on Cleveland fault be- low main crosscut	Sulphide	Pyrite	0.35	5.00

Sample No.	Location	Character	Mineral	Oz. Au. per T	Oz. Ag. per T
209	25' above main level in stope off No. 3 South drift	Sulphide	Pyrite Bonnite Chalcoelite	0.16	17.25
207	35' above main level in stope off No. 3 South drift	Sulphide	Pyrite (copper bearing)	0.66	13.25
167	No. 3 North drift	Sulphide	Pyrite	0.45	7.50
154	Main crosscut 100' from Doddridge incline	Sulphide	Pyrite (copper bearing)	0.20	4 0.40
184	Face at lower end of Doddridge incline	Sulphide	Pyrite	0.64	6.17
193	45' below main level off Doddridge winze	Sulphide	Pyrite	1.21	3.95
190	35' below main level off Doddridge winze	Sulphide	Pyrite	1.14	5.00

Sample No.	Location	Character	Mineral	Oz. Au. per T	Oz. Ag. per T
197	20' NE of: Doddrige: winze	Sulphide	Pyrite	0.40	5.32
181	Ohmstead face	Sulphide	Pyrite	trace	23.25
182	Compact ore from Ohmstead face (low er part)	Sulphide	Pyrite	0.14	56.85
179	Ohmstead stock pile	Sulphide	Pyrite	0.17	25.12
159	200' down: main cross cut from Doddrige: incline	Sulphide	Pyrite	0.38	5.10
153	North of Doddrige: incline region below main crosscut	Sulphide	Pyrite	0.05	45.17
168	No. 3 & 4: South drifts	Sulphide	Sphalerite	trace	37.08
221	Face of Badger incline 900' below entrance	No ore sample of wall rock	Silica	none	none

It must be remembered that these samples are largely waste material left by the miners and that high values should not be expected from them. In general the waste oxides carry very little silver. This has been explained by leaching in connection with the oxidation. The sulphide ores range in value from almost valueless to \$60.00 a ton. In this case the high values are partly explained by secondary sulphide enrichment and are otherwise explained by the fact that the primary deposition of the ore is extremely irregular in content of gold and silver.

Because of the expensive mining conditions, the pyrite must carry about \$40.00 - \$50.00 a ton in gold and silver to be considered ore.

### C O N C L U S I O N

The Ground Hog mine is fairly well worked out, very little paying ore having been left in accessible places. As mentioned before the oxide zone extends down the dip of the quartzite 500 to 700 feet. It is in the oxide zone that the bullion shoots and pockets of gold nuggets were found. These shoots were originally the pyrite-replaced porous bed which had been oxidized, and then most of the material except the gold had been leached away. It is certain that almost every square foot of the oxide zone

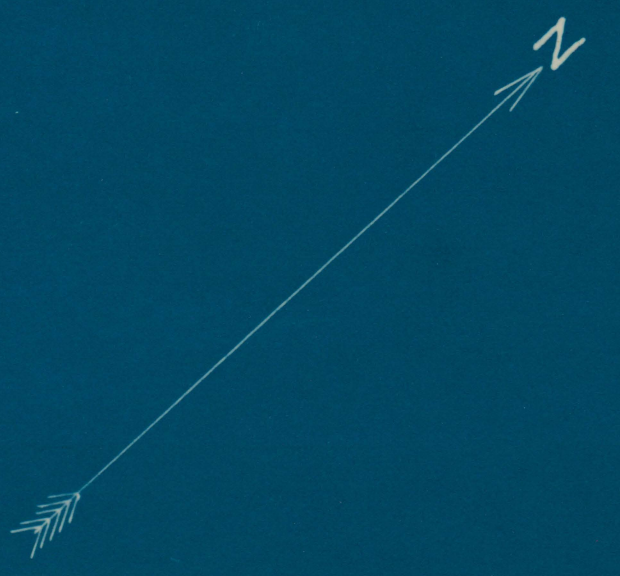
has been examined.

The zone of secondary sulphide enrichment borders the oxide zone and extends down the dip a variable distance. From the samples assayed and from the mine workings themselves, the secondary sulphide zone would seem to extend about 100 feet below the main crosscut. It seems that this zone has also received careful examination and prospecting, with one or two possible exceptions. The Doddridge winze area might bear further development, inasmuch as it is on the border of the secondary zone and as it seems to contain considerable pyrite, which carries about \$25.00 in gold and silver. I was told that in the granite at the bottom of the winze, a solid vein of low grade pyrite 3 feet in width extends further into the granite.

The primary zone which may be considered to extend from the secondary zone to and past the end of the workings contains considerable pyrite but is not of a quality that will stand working.

However, there is the possibility as in all mining properties that an ore shoot has been overlooked, and by careful development could again become a producer for at least a short time.

0  
100  
200  
300  
500  
Feet



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