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STRUCTURAL GEOLOGY AND ORE DEPOSITS

OF THE

RED CLIFF MINING REGION

RED CLIFF, COLORADO

BY

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A THESIS

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INTRODUCTION

LOCATION

The Red Cliff mining region is in the southeastern part of Eagle County, Colorado. The largest town in the region is Red Cliff, on the main line of the Denver and Rio Grande railroad, 293.9 miles from Denver. Pando and Belden are stations on the Denver and Rio Grande, one being south, the other north of Red Cliff. Gilman is on Battle Mountain above Belden.

Up to the present, the geology of only a portion of the region has been examined. The mines under consideration in this report are near Gilman and Belden, and are all apparently worked out. The mines at and near Red Cliff have not been investigated. The Empire Zinc Company's mines, which contain the largest known bodies of ore in the region, were not examined for this report.

ACKNOWLEDGMENTS

This paper serves the combined purpose of a report to the Colorado Geological Survey and a thesis. The writer is under obligation to Professor R. D. George and Professor

R. D. Crawford for the assignment of an interesting problem, and for helpful suggestions in writing the report. To Professor Crawford, the writer is especially grateful for direction in the field and for criticism of the manuscript. The cheerful cooperation of the other members of the field party, Messrs. Ellis A. Hall, Philip Andrews, and W. O. Thompson, is much appreciated.

REMARKS ON GENERAL GEOLOGY

The oldest rocks in the region are gneisses and schists of pre-Cambrian age intruded by granites and other rocks. The sands which were later metamorphosed to form the Cambrian quartzite were not laid down on the gneiss surface until after a considerable period of erosion. The appearance of the contact, a fairly regular plane, suggests that the region was peneplained before the Cambrian sediments were deposited. Overlying the Cambrian are Devonian limestones; Mississippian and Pennsylvanian limestones, sandstones, and shales; and younger undetermined sediments. A porphyry sheet of considerable area has intruded the Paleozoic rocks very close to the Mississippian - Pennsylvanian contact. Mountain glaciation has modified the surface and left deposits of glacial debris.

S T R U C T U R A L G E O L O G Y

Since only a portion of the region has been surveyed, not all of the structural features have been examined, and the data at hand are not so complete as they will be after another season in the field. The following features are briefly discussed below: regional metamorphism, folding, faulting, and igneous intrusion.

REGIONAL METAMORPHISM

The oldest rocks of the area consist of gneisses and schists with irregular intrusions of granite and other igneous rocks which exhibit little or no effects of metamorphism. The nature of the rocks, which were profoundly changed previous to Cambrian time to form the present gneisses and schists, has not been determined.

FOLDING

So far as observations go, the region has apparently been subjected to at least two periods of folding. All of the rocks which existed previous to Cambrian time were folded, profoundly altered, and eroded at the surface before the Cambrian sediments were laid down. All the sedimentary rocks of the area, identified up to the present writing, are Paleozoic and dip almost uniformly 5° to 16° to the northeast. Whether this is a monocline or one limb of a geosyncline remains to be determined.

FAULTING AND FISSURING

Thus far, few great faults have been determined in the area. Surface indications of displacement are not numerous, and most of the faults mapped were disclosed in underground workings.

In size, the faults range from small displacements where evidence of movement is scarcely discernible to large faults where the brecciated zone is several feet in width. Among the mines obtaining most of their ore from the vein material which filled these large fault fissures may be mentioned Bleakhouse No. 3, Bleakhouse No. 2, and the Ben Butler. In none of these has the amount of displacement been determined. All of the workings in Bleakhouse No. 3 are in the quartzite; in the other two mines they are in the granite.

In the large faults, where the displacement cannot be measured because of the character of the wall rock or the limited evidence available, and where the amount of gouge and brecciation is considerable, it seems not unreasonable to suppose that an oscillatory movement has taken place, i.e., the same wall of the fault has moved in opposite directions at different times.

Traces of slickensided surfaces are still to be seen in some of the large faults, but in many cases this evidence of faulting has been obliterated by weathering. Several samples that ran high in gold and silver were obtained from mineralized gouge which varied from a fraction of an inch to several inches in thickness. The brecciated zone varies in width even more than the gouge. In some faults, breccia is lacking, the only evidence of displacement being the gouge or scant traces of slickensiding; in others, the brecciated zone extends the entire width of the tunnel, varying from three to six feet.

The transverse faults in the granite are much more striking and more easily determined than the bedding faults in the quartzite. In the latter rocks, the only evidence of a dislocation is the gouge along the bedding plane, which is itself the fault surface. Usually, the fault may be traced underground from the point where it appears in the back to the point where it disappears in the bottom, provided that the tunnel is driven in the direction of dip. Where the tunnel is along the strike, even less of the fault may be seen.

Tunnels have been driven in the granite on some of the faults which approach 90° in dip. In many places, the ore has been stoped out, revealing the dimensions of the fault but not the direction of movement. In some instances, the fault is not a single dislocation but appears to be a number of closely spaced breaks. A single large fault sometimes forks, and the tunnel follows the branch containing more mineralized material.

Approximately three-eighths of a mile southwest of Blodgett's ranch house on Homestake Creek is an ill-defined fault in the quartzite which was traced by the slickensided displaced beds for 300 feet northeast along the strike. Beyond this point, the disturbed beds are obscured by glacial drift, but the more easily eroded and weathered fault zone has given rise to a depression in the surface which was followed to Eagle Canyon. There the beds are again exposed and show abnormal dips. A narrow porphyry dike, which was traced for 500 feet, coincided with the fault zone. The intruding magma had, seemingly, availed itself of the zone of weakness.

Diagrams which were made of all the faults and fissures of any magnitude in six of the large mines revealed two general directions of strike, northeast and northwest. For the most part, the strike is northeast. Numerous smaller faults seen at the surface and in shallow tunnels in Eagle Canyon agree in direction with the above-mentioned faults.

While most of the faults have a high angle of dip, many being vertical, the bedding faults in the quartzite and limestone have low dips in accordance with the strata in which they occur.

IGNEOUS INTRUSION

Up to the present, the igneous intrusions located are not numerous, and no large body has been found with which the genesis of the bulk of the ore may have some connection. Nor can the intrusive rocks be accurately named until thin sections have been made and examined under the microscope.

Near Camp Bryan, a small exposure of what seems to be a dike of gray porphyry has been mapped. Not far from this is a larger, red granite dike the limits of which are beyond the area which was being mapped at the time it was found. Both of these are intrusive in the gneiss and schist. No traces of contact metamorphism are evident.

On the west side of Eagle Canyon, approximately half a mile north of Peterson Gulch, is a light-colored felsitic intrusion very close to, if not coincident with, the gneiss - quartzite contact. In the gneiss, just below this point, is a dark-colored granitic dike. Neither intrusion can be traced far because the outcrops are obscured by glacial drift.

Along the east side of Eagle Canyon are many outcrops of a gray to yellow felsitic porphyry sheet, intrusive in the limestones and shales. Outcrops are frequently continuous for some distance, and correlation with similar exposures at intervals not widely separated is not difficult. Numerous prospect holes in the intrusion have aided in mapping. The porphyry has been traced at intervals along Eagle Canyon from Gilman to a point eight miles south.

O R E D E P O S I T S

In none of the mines under consideration in this report has oxidation been so thorough that practically no sulphides may be found; consequently it will be necessary to discuss the sulphides and oxidized ores together.

Therefore, wherever such terms as "ore" or "ore deposit" are used, they will refer to all types of ore minerals.

GENERAL DESCRIPTION OF THE ORE DEPOSITS

All the ore bodies examined are epigenetic, and are of two general types, namely, fissure-vein and replacement. Subsequent exploration may reveal other types.

FISSURE - VEIN DEPOSITS

Most of the ore in the pre-Cambrian gneiss, schist, and granite is found in fissures. While there is no evidence of movement along some of the fissures, others are packed with several inches of gouge and show good brecciation, thus indicating faulting. In the superjacent Cambrian quartzite, faulting across the bedding is more easily detected than in the gneiss and schist. In at least two places, faults were found at the contact between the quartzite and the pre-Cambrian rocks.

The veins of solid sulphide material vary in width from a fraction of an inch to several inches. The brecciated zones in fault fissures are frequently several feet in width but irregularly mineralized. In many cases, the veins are somewhat widened by replacement of the wall rock. Instead of a single vein, there may be a number of small, approximately parallel fissures which have been filled with metalliferous material. Some of these fissures coalesce and form a wider vein which, farther on, again branches.

For the most part, the fissures strike northeast, N. 45° E. being a fair average; a subordinate number strike northwest. The dip of the fissures varies from 20° to 90°, the greater number approaching 90°. About as many fissures dip northwest as southeast.

One of the best examples in the region of a fissure-vein deposit is the Bleakhouse No. 2 mine. The tunnel is driven on a large fault fissure in the granite. A specimen of ore from the wall at one point shows what seems to be the primary texture of a filled fissure. A rough banding is developed parallel to the walls of the altered granite and the order of deposition is pyrite, sphalerite, galena. A few small, well-developed quartz crystals appear on the surface of the galena. The sulphides are fairly coarsely crystalline, the galena showing good crystal faces. Elsewhere along the same fault are small veins of mixed zinc blende and galena. Fine flakes of pyrite are disseminated through the wall rock adjacent to the veins.

REPLACEMENT DEPOSITS

In the granite and gneiss, the widening of vein deposits by replacement is of minor importance. The best examples of metasomatism are to be found in the quartzite and limestone, and seem to be associated with large faults and fissures which are transverse to the bedding or with apparently minor bedding faults. Here, entire beds or groups of beds have been replaced, usually by pyrite, less often by sphalerite or galena. In some instances, a more or less intimate mixture of two or three of these sulphides is the replacing material.

As evidence of replacement, several features may be mentioned. In the Cambrian quartzite, where the ore bodies are frequently tabular and of considerable lateral extent without having great thickness, the ore may consist of pyrite which has entirely replaced a particular bed of quartzite, while the beds immediately above and below the ore are only sparingly mineralized. These shoots follow the dip of the quartzite,- approximately 10° to 15° N.E. Such structures as bedding, jointing, and small fissures are faithfully preserved. Nearly complete crystals are often found in the country rock.

CHARACTER OF THE ORES

Conclusions as to the character of the ores are based on the examination of eight mines in a restricted area near Bell's Camp, Gilman, and Belden. None of the mines was producing at the time of examination, and the samples which were qualitatively analyzed are remnants of the ore and can not be considered as an indication of the general run of the mine. Ores from the following mines are considered below:

Ben Butler tunnel
Bleakhouse No. 2 mine
Bleakhouse No. 3 mine
Polar incline
Rocky Point incline
Garbutt mine
May Queen mine
Potvin mine

Under the heading "Other minerals determined", in the tables which follow, the minerals are listed in the order of their abundance; but not all of the minerals in each sample have been determined.

ORES CONTAINING CONSIDERABLE CERUSSITE

Sample Number	Wall Rock	Description of Sample	Ounces Gold	Ounces Silver	Other Minerals Determined
180	quartzite	decomposed, mineralized wall rock	0.05	10.47	cerussite, quartz, limonite
179	quartzite	decomposed wall rock	0.07	11.47	cerussite, quartz, limonite
170	limesti	ore from ore bin	?	9.30	limonite, cerussite

180 Rocky Point Incline

179 Rocky Point incline

170 May Queen mine

ORES CONTAINING CONSIDERABLE GALENA

Sample Number	Wall Rock	Description of Sample	Ounces Gold	Ounces Silver	Other Minerals Determined
111	granite	vein material	trace	14.80	pyrite, galena, sphalerite
103	quartzite	gouge and vein material	0.09	33.35	galena, pyrite, oxides of manganese

111 Bleakhouse No. 2 mine

103 Bleakhouse No. 3 mine

ORES CONTAINING CONSIDERABLE MANGANESE

Sample Number	Wall Rock	Description of Sample	Ounces Gold	Ounces Silver	Other minerals Determined
121	quartzite	replaced wall rock; vug material	trace	7.90	quartz, limonite, pyrolusite, cerargyrite
156	limestone and shale	mineralized streak in shale	0.48	8.57	oxides of manganese, and limonite
174	quartzite	mineralized wall rock	0.62	12.90	pyrite, limonite, quartz, pyrolusite

121 Polar incline

156 Potvin mine

174 Rocky Point incline

ORES CONTAINING CONSIDERABLE PYRITE

Sample Number	Wall Rock	Description of Sample	Ounces Gold	Ounces Silver	Other Minerals Determined
110	granite	mineralized wall rock and vein material	0.05	16.17	pyrite, sphalerite, galena, cerussite, cerargyrite
174	quartzite	mineralized wall ro rock; much jointed	0.62	12.90	pyrite, limonite, quartz, pyrolusite
111	granite	vein material	trace	14.80	pyrite, galena, sphalerite
112	granite	gouge, and fault breccia	trace	5.77	pyrite, limonite, kaolin
99	quartzite	replaced wall rock	trace	11.80	pyrite, quartz, limonite, melanterite
103	quartzite	gouge and vein material	0.09	33.35	galena, pyrite, oxides of manganese
119	granite	gouge, breccia, and vein material	0.20	1.15	pyrite, limonite, melanterite, gypsum
155	limestone	mineralized band in wall rock	?	15.55	pyrite, limonite, selenite,

110	Bleakhouse No. 2 mine	99	Bleakhouse No. 3 mine
174	Rocky Point incline	103	Bleakhouse No. 3 mine
111	Bleakhouse No. 2 mine	119	Ben Butler tunnel
112	Bleakhouse No. 2 mine	155	Potvin mine

ORES CONTAINING CONSIDERABLE SPHALERITE

Sample Number	Wall Rock	Description of Sample	Ounces Gold	Ounces Silver	Other Minerals Determined
110	granite	mineralized wall rock and vein material	0.05	16.17	pyrite, sphalerite, galena, cerussite, cerargyrite
111	granite	vein material	trace	14.80	pyrite, galena, sphalerite
107	granite	fault gouge and vein material	0.04	0.25	sphalerite, pyrite, limonite, oxides of manganese

110 Bleakhouse No. 2

111 Bleakhouse No. 2

107 Bleakhouse No. 2

ORES CONTAINING CONSIDERABLE LIMONITE

Sample Number	Wall Rock	Description of Samples	Ounces Gold	Ounces Silver	Other Minerals Determined
174	quartzite	mineralized wall rock	0.62	12.90	pyrite, limonite, quartz, pyrolusite
155	limestone	mineralized band in wall rock	?	15.55	pyrite, limonite, selenite
156	limestone and shale	mineralized streak in shale	0.48	8.57	oxides of manganese, limonite
170	limestone	ore (from ore bin)	?	9.30	limonite, cerussite, melanterite, pyrolusite
154	limestone and shale	mineralized shale	trace	11.35	limonite, kaolin, selenite, pyrolusite

174 Rocky Point incline
155 Potvin mine
156 Potvin mine
170 May Queen mine
154 Potvin mine

ORES CONTAINING CONSIDERABLE QUARTZ

Sample Number	Wall Rock	Description of Samples	Ounces Gold	Ounces Silver	Other Minerals Determined
121	quartzite	replaced wall rock; vug material	trace	7.90	quartz, limonite, pyrolusite, cerargyrite
123	quartzite	mineralized wall rock; vug material	0.17	3.87	quartz, limonite, pyrolusite
179	quartzite	decomposed mineralized wall rock	0.07	11.47	cerussite, quartz, limonite
180	quartzite	decomposed mineralized wall rock	0.05	10.47	cerussite, quartz, limonite
174	quartzite	mineralized wall rock	0.62	12.90	pyrite, limonite, quartz, pyrolusite

121 Polar incline
123 Polar incline
179 Rocky Point incline
180 Rocky Point incline
174 Rocky Point incline

The chief values of the ores from the above mines are in their gold and silver content. Other mines of the district have produced manganese and zinc in paying quantities. The gold is usually associated with pyrite and limonite; and, whenever much more than a trace is found, some manganese mineral, probably pyrolusite, is present. Though silver occurs with the same minerals, the best ores from mines in the quartzite and granite contain, in addition, some lead, frequently as galena, less often as cerussite. The higher silver values appear to be in the sulphides.

As is evident, none of the ores examined were pure sulphide ores; all were from the zone of at least partial oxidation. Consequently, whether oxidation has made these particular deposits in the oxidized zone richer or leaner has not been determined.

The tenor of the ores varies widely. Rarely more than 0.1 ounces of gold was found in the ores assayed, the chief value being in silver which runs from a trace to 33 ounces per ton. One sample from a fault in Bleakhouse No. 3 mine assayed 33 ounces silver and 0.09 ounces gold per ton. The best gold ore, a sample from the Rocky Point incline, showed 0.62 ounces gold and 12.90 ounces silver per ton. Both of these mines are in the quartzite. In Bleakhouse No. 2, one sample from a large fault fissure in the granite contained 0.05 ounces gold and 16.17 ounces silver per ton. Elsewhere in this same fissure, a sample showed no gold and only 0.13 ounces silver per ton. Samples from mines in the limestone varied from extremely small values to fair ores. One sample from the Potvin mine assayed 0.48 ounces gold and 8.57 ounces silver per ton.

It is exceedingly difficult to estimate the size of the ore bodies that formerly existed in these mines, now abandoned. Many of the old workings are caved and cannot be investigated. Nor is it possible to tell how much of the material removed was gangue.

It is reported that ore to the value of $345,000 was taken out of Bleakhouse No. 3. In view of the size of the workings, this does not seem excessive.

Not all of the Rocky Point incline has been investigated, but from the size of the stopes observed it is safe to infer that a very large amount of ore was removed.

DESCRIPTION OF ORE AND GANGUE MINERALS

Most of the ore minerals and gangue minerals listed below were found in specimens from the larger mines of the district. Not all of the mines which have shipped and are shipping ore have been examined, however, and other minerals not described here may occur in the region. The occurrence of each mineral will be noted and a brief description given.

ALUMINUM

<u>Aluminum Sulphate</u>. In altered granite in the Ben Butler tunnel are traces of a sulphate of aluminum.

GOLD

Gold is present in both the sulphide and oxidized zones and small quantities in mines in all parts of the district. It is probably present as native gold but can be detected only by the fire assay.

IRON

<u>Limonite</u>, hydrous sesquioxide of iron, $2Fe_2O_3 \cdot 3H_2O$ - iron 59.8 per cent. In the oxidized ores where pyrite has been altered, limonite is abundant. Mixed with quartz, it is one of the chief ore minerals in mines in the quartzite.

<u>Melanterite</u>, hydrous ferrous sulphate, $FeSO_4 \cdot 7H_2O$ - sulphur trioxide 28.8 per cent, iron protoxide 25.9 per cent, water 45.3 per cent. Magnesium and manganese sometimes replace part of the iron. Pulverulent melanterite is frequently present in small quantities as a decomposition product of pyrite.

<u>Pyrite</u>, iron disulphide, FeS_2 - iron 46.6 per cent, sulphur 53.4 per cent. Pyrite occurs in vein deposits with other sulphides and as the metasome in replacement deposits where it is often massive. Fine crystals and even large cubes and pyritohedrons are not uncommon. Pyrite is the commonest mineral in the sulphide zone.

LEAD

Cerussite, lead carbonate, $PbCO_3$ - lead 77.5 per cent. Cerussite is sparingly present in the oxidized zone in the Rocky Point incline and the Garbutt mine. Some specimens were also found on the dump of the May Queen mine. The Rocky Point is in the quartzite; the other two are in limestone.

Galena, lead sulphide, PbS - lead 86.6 per cent. Galena was found in only two of the mines examined, Bleakhouse No. 3 and Bleakhouse No. 2. In both instances, the sulphide was part of the vein filling a large fault fissure and was accompanied by other sulphides. In Bleakhouse No. 3, the lead was in the form called "steel galena"; in No. 2, fairly large crystals were developed. All of the galena is probably argentiferous, as some of the highest grade silver ores assayed are those that contain considerable lead sulphide.

MANGANESE

Manganese occurs in most of the ores in the form of a sootlike powder or more or less intimately mixed with limonite. Presumably, the mineral is pyrolusite, but no specimens were found which were large enough and sufficiently pure for analysis.

SILVER

Cerargyrite, silver chloride, AgCl - silver 75.3 percent. Even the best ores are so lean that it is difficult to isolate the precious metals or the minerals that contain gold or silver in the formula. Cerargyrite occurs in the Rocky Point incline and in Bleakhouse No. 2; it may be present in other mines in extremely small quantities. Cerargyrite was determined by dissolving in ammonium hydroxide and again precipitating the silver as a chloride with nitric acid.

Native Silver, Ag. Native silver is believed to occur disseminated invisibly in galena in the Bleakhouse No. 3 mine, and in pyrite and limonite in the Rocky Point incline.

ZINC

Sphalerite, zinc sulphide, ZnS - zinc 67 per cent. Sphalerite occurs as vein matter with galena and pyrite in Bleakhouse No. 2 and Bleakhouse No. 3.

GANGUE MINERALS

Barite, barium sulphate, $BaSO_4$. Nearly perfect tabular crystals of barite were found in pieces of the wall rock on the dump of the Gilman tunnel.

Calcite, calcium carbonate, $CaCO_3$. Calcite may be found in numerous mines in both replacement and fissure-vein deposits. It is present as limestone and alters by replacement to pyrite, sphalerite, and quartz.

Dolomite, calcium magnesium carbonate, $(Ca,Mg)CO_3$. Massive dolomite constitutes some of the magnesian limestone. Very little crystalline dolomite may be seen.

Gypsum, hydrous calcium sulphate, $CaSO_4+2H_2O$. Gypsum is produced by the decomposition of pyrite where lime is present. Clear, transparent portions of crystals of selenite were found in the Potvin mine associated with pyrite, limonite, and pyrolusite in a gray to black shale. Elsewhere, gypsum occurs as pulverulent or earthy material in the oxidized zone.

Kaolinite, hydrous aluminum silicate, $H_4Al_2Si_2O_9$. Impure kaolinite is mixed with the gouge and brecciated material in faults. It results from the decomposition of potassium feldspars.

Quartz, silicon dioxide, SiO_2. Quartz is present in some form in most of the mines. As fine granular quartz, it is the predominant mineral of quartzite. Small, well-developed crystals were found as one of the last minerals to be deposited on the walls of a fissure in Bleakhouse No. 2 where most of the vein material consisted of metallic sulphides. Quartz is a replacing mineral, and is, in turn, replaced by metallic and non-metallic minerals.

ALTERATION OF THE ORES

When surface waters bearing oxygen and carbon dioxide enter an ore body, the minerals are attacked and chemical and physical changes occur. Since metallic minerals are more profoundly affected than non-metallic minerals, the chemical reactions that take place are somewhat intricate. As a result, the ores in the oxidized zone may be made richer by a removal of less valuable or worthless material; or they may be made poorer if the ore minerals are converted into soluble compounds which are carried down below the ground water level in solution.

Pyrite oxidizes readily and furnishes sulphuric acid, which attacks other minerals and produces soluble sulphates. Both ferric and ferrous sulphates yield limonite.[1] Hydrous ferrous sulphate crystallizes as melanterite on the surface of the pyrite. Ferric sulphate acts also as an oxidizing agent. Lead sulphide may be converted to lead carbonate; lead sulphate may form intermediately. Zinc sulphate waters will attack limestone and deposit zinc carbonate, the more soluble calcium sulphate going into solution.[2]

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[1] Ries, H., Economic Geology, p. 479.

[2] Emmons, W. H., The Enrichment of Ore Deposits: Bull. U. S. Geol. Survey, No. 625, 1917, p. 377.

That similar processes have gone on in the mines under discussion seems reasonably certain. In the zone of partial oxidation, the primary sulphides of iron, lead, and zinc may still be found together with their derivatives: oxides, hydrated oxides, sulphates, and carbonates. Where oxidation has been more complete, only such minerals as limonite, pyrolusite, cerussite, kaolin, gypsum, and melanterite are present. In some mines, places are found that are intermediate in thoroughness of oxidation. Oxidized ores may predominate, but good patches of unaltered pyrite, the most abundant sulphide, persist.

Whether, in general, oxidation has enriched or impoverished the ores in the oxidized zone has not been determined. The best values in gold were obtained from samples of more thoroughly oxidized material; the best silver ores appear to be sulphides.

In none of the mines examined was a lean zone found above, passing downward into one of greater richness underlain by a primary sulphide zone. Nowhere does a leached ferruginous gossan occur above an apparently enriched vein where veinlets of richer ore occur in leaner material. If secondary sulphide enrichment occurred in any of the deposits, the evidence has been removed.

ORIGIN OF THE ORES

As mentioned previously, the mines examined by the writer are those in which at least partial oxidation has occurred. From mines where small patches of slightly altered sulphides may be found in fault fissures, evidence points to an original deposition of metallic sulphides in these fissures. Such evidence is briefly discussed below.

A rude banding occurs in Bleakhouse No. 2 mine, where most of the apparent mineralization is in one fault fissure in the granite. The order of deposition of the sulphides in one instance in this mine is pyrite, sphalerite, galena; at another point in the same drift, sphalerite and galena completely fill a small fissure by crustification, the last mineral to be deposited being galena. These three minerals are among the common primary sulphides deposited from hot ascending solutions.[1], In the instance mentioned above, the sample was from a fault fissure in the pre-Cambrian rocks. There are fault fissures in the overlying Cambrian quartzite which seem to be similar in every respect; and in at least two places, faults were found at the contact. In other mining regions, galena, sphalerite, and pyrite may be concentrated in deposits as a result of the circulation of cold ground water of meteoric origin, but such deposits do not commonly carry gold and silver.

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[1] Crawford, R. D., Geology and ore deposits of the Monarch and Tomichi Districts: Bull. Colo. Geol. Survey, No. 4, 1913, p. 223.

In view of the character of the minerals, the method of occurrence, and the presence of gold and silver, it is tentatively suggested that the ores owe their origin to hot solutions which ascended from a deep-seated body of magma.

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