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MOLYBDENUM DEPOSITS OF COLORADO

WITH GENERAL NOTES ON THE MOLYBDENUM INDUSTRY

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LETTER OF TRANSMITTAL

State Geological Survey,
University of Colorado, November 27, 1918

Governor Julius C. Gunter, Chairman, and Members of the Advisory Board of the State Geological Survey.

Gentlemen: I have the honor to transmit herewith Bulletin 14 of the Colorado Geological Survey.

Very respectfully,
R. D. George,
State Geologist.

III

CONTENTS

ILLUSTRATIONS

Molybdenum Deposits of Colorado

With General Notes on the Molybdenum Industry

INTRODUCTION

Soon after it was declared that a state of war existed between the United States and Germany, the Colorado Geological Survey was asked to cooperate with Federal officials in determining the extent of the undeveloped molybdenum resources of Colorado.

A notice was at once sent to all the papers of the state, in which information was asked for concerning molybdenite and other minerals which were then, or might later be, needed for war purposes. A questionnaire was mailed to prospectors, mine owners, assayers and others, who would be likely to know about the required minerals, and the writer spent approximately three months in the field during the summer and autumn of 1917 examining molybdenite properties that were reported to the Survey through various mediums of information.

It seemed necessary to get certain data with as little delay as possible, and the examination of the various prospects was, therefore, brief and of a reconnaissance nature, but it was sufficient to show that Colorado has very large molybdenum resources, although all the ores are low grade.

Many reports of molybdenite prospects were received at the Survey office after the field work was finished in 1917, and those properties which seemed to be the most promising were examined during the summer of 1918.

Purpose of the Report

It is the purpose of this report to present a brief statement of the occurrence of molybdenum; to show the present condition of the molybdenum industry; to describe the molybdenite properties of Colorado so far as they are now known; and to indicate the areas in this state that should be prospected.

Acknowledgments

To acknowledge individually all who have given information, or who have extended courtesies of one sort or another, would be a pleasure, but it is one which the writer must, with reluctance, forego, for more than 100 people have responded to requests for information, and it is obviously out of keeping with this report to specifically mention each one. To all who have in any way contributed to this report, the author is extremely grateful.

To acknowledge all the sources of material from which the statements regarding the occurrence, properties, uses, etc., of molybdenite are derived, is also too great an undertaking for this report. Standard works like Dana's Mineralogy are therefore not referred to in the statements that follow. However, when material has been drawn from special articles, whose distribution may be limited, they are acknowledged in the footnotes or in the text.

Dr. Horton's bulletin, Molybdenum: Its ores and their concentration, U. S. Bureau of Mines Bull. 111, 1916, has been drawn upon freely in the preparation of this report.

CHAPTER I

MOLYBDENUM

History

Molybdenum was discovered in 1778 by the Swedish chemist Scheele, and Bergman described its isolation by Hjelm four years later.

Until recently it was regarded as a "rare metal," and as such it was little used for industrial purposes. A small amount has long been used for various purposes in chemical laboratories, and ammonium molybdate has been widely used to detect phosphorus in steel works.

During the past 10 or 15 years many experiments have been made with molybdenum, for industrial purposes, and particular attention has been given to various mixtures that would give tougher, harder, and acid or heat-resisting steels. These experiments have apparently advanced further in Europe than in America. It was not until the present war was imminent that the demand for molybdenum was at all strong on either continent. Almost as soon as the demand quickened slightly, the production was largely increased and at the present time the supply greatly exceeds the demand.

Physical Properties

Pure molybdenum is a heavy, silvery white metal, which is ductile, malleable, and may be both polished and welded. Its hardness is about 5; its atomic weight is 96.0; and its melting point as given by the Bureau of Standards[1] in circular 35 is equaled by only 4 or 5 elements.

The following table gives extracts from this circular to show the melting points of molybdenum and some of the other elements:

[1]Bureau of Standards Circular 35, 2nd ed., p. 2, revised Jan. 1, 1915.

MELTING POINT OF VARIOUS ELEMENTS

Element	C.	F.
Copper	1083	1981.5
Iron	1530	2786
Platinum	1755	3191
Boron	2200-2500	4000-4500
Molybdenum	2500(?)	4500
Osmium	2700(?)	4900
Tantalum	2850	5160
Tungsten	3000	5430
Carbon	3600	6500

The specific gravity of molybdenum is usually given as 9 or 9.01, but Fink[1] gives it as 10.02, and shows that after it has been worked, like zinc, copper, tungsten and other metals, its specific gravity increases. Thus the specific gravity of molybdenum, before drawing, was 10.02. After drawing a wire of 3.75 mm. diameter it was 10.04, and when drawn to 0.038 mm. it was 10.32.

In common with the increase in specific gravity with working, it is shown by Fink[2] that the tensile strength of molybdenum and other metals is increased the more they are worked.

COMPARATIVE TENSILE STRENGTH OF MOLYBDENUM, TUNGSTEN AND STEEL WIRE

Wire	Diameter in thousandths of inch	Diameter in mm.	Pounds per square inch	Kilograms per square mm.
Molybdenum	5.0	0.125	200,000 to 260,000	140 to 182
	2.8	0.070	230,000 to 270,000	161 to 189
	1.5	0.038	270,000 to 310,000	189 to 217
Tungsten	5.0	0.125	460,000 to 490,000	322 to 343
	2.8	0.070	480,000 to 530,000	336 to 371
	1.5	0.038	550,000 to 600,000	385 to 420
Hard-drawn piano wire	3.0	0.075	507,000	356

1Fink, C. G., Ductile tungsten and molybdenum. Trans. Am. Electrochemical Soc., vol. 17, 1910, pp. 229-233.
2Fink, C. G., loc. cit.

Chemical Properties[1]

Molybdenum is insoluble in dilute acids except nitric acid. It is soluble in concentrated sulphuric acid.

Under ordinary conditions of temperature and humidity, pure molybdenum does not tarnish. If heated for a long time in air to dull-red heat molybdic oxide appears on the surface of the metal in the form of a white coating. At a temperature of 1,500 C. the metal takes up carbon and becomes very hard. When in the form of a coarse powder, molybdenum is readily attacked by fluorine at ordinary temperatures, by chlorine at dull-red and by bromine at cherry-red heat.

Molybdenum unites with varying proportions of oxygen to form oxides; with sulphur to form sulphides; with oxygen and sodium, potassium, lead, ammonium, calcium, barium, etc., etc., to form molybdates of these elements. Bromides, iodides, chlorides, etc., of molybdenum are formed under certain conditions, and more complex compounds formed from these simpler ones, such as bromolybdic chloride, are known. Molybdenum also unites with boron, carbon, phosphorus and silicon, and with many other elements.

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[1]For a full discussion see Roscoe and Schorlemmer, A Treatise on Chemistry, vol. 2, "Molybdenum."

CHAPTER II

MOLYBDENUM MINERALS AND ORES

In the following list are the names of the known minerals that contain molybdenum, with the composition of each and the percentage of metallic elements of those that have been thoroughly studied. The first three are common; the others are rare.

MOLYBDENUM MINERALS

Mineral	Composition	Percentage of Metals	
Molybdenite	MoS_2	Mo. 59.95	
Wulfenite	$PbMoO_4$	Mo. 26.16	Pb. 56.4
Molybdite	$Fe_2O_3.3MoO_3.7\frac{1}{2}H_2O$	Mo. 39.60	Fe. 15.40
Powellite	$CaMoO_4$	Mo. 48.00	
Ilsemannite	$MoO_2.4MoO_3$ (?)	Mo. 68.18	
Belonesite	$MgMoO_4$ (?)	Mo. 52.08	
Pateraite	$CoMoO_4$	Mo. 43.84	Co. 26.94
Achrematite	$3(3Pb_3As_2O_8.PbCl_2), 4(Pb_2MoO_5)$	Mo. 3.40	Pb. 78.58
Eosite	Vanado-molybdate of lead	Not determined.	

MINERALS IN DOUBT[1]

Molybdurane	$UO_2.UO_3.2MoO_4$
Knightite	Phosphate of molybdenum
Molybdoferrite	$FeMoO_4$

MOLYBDENITE

Molybdenite, molybdenum sulphide (MoS_2) is the most important ore of molybdenum. It is a primary constituent of many granites[2] and other acidic rocks.[3]

Molybdenite looks very much like crystalline graphite, for which it is often mistaken. It is also rather easily confused with lead, or gray copper, by one who is uninformed. In some instances when it occurs in small flakes it has been mistaken for silvery mica, with which it is quite commonly associated.

1Horton, F. W., Molybdenum, etc., U. S. Bureau of Mines Bull. 111, 1916, p. 16.

2Clark, F. W., The Data of Geochemistry. U. S. Geol. Survey Bull. 330, 1908, p. 273.

3Hillebrand, W. F., Distribution and quantitative occurrence of vanadium and molybdenum in rocks of the United States. U. S. Geol. Survey Bull. 167, 1900, pp. 49-55.

The color of molybdenite is typically blue or lead gray, but it varies somewhat. Some flakes are a bright silvery gray, while in very fine-grained aggregates which coat fractures it is almost black. In distinct crystals molybdenite has a metallic luster, but in fine-grained or amorphous aggregates the luster is sub-metallic to earthy. It is soft, has a greasy feel, soils the fingers when handled and marks paper readily. On white paper it leaves a blue-gray mark, which if rubbed thin has a distinctly greenish tinge. This is a very distinctive test, and usually is all that is needed to identify the mineral. Its specific gravity is about 4.8.

Molybdenite crystallizes in the hexagonal system. The crystals are often horizontally striated. A radiated structure is also common. The crystals have one nearly perfect cleavage (basal). Laminae produced by this cleavage are flexible, but not elastic. The size of the flakes varies from a small fraction of an inch to several inches in diameter.

Tests

There are many tests for molybdenite, but only a few of the simpler ones will be given here.

1. The physical test given above, *viz.*, rubbing a streak thin and getting a green tinge on pure white paper, is usually sufficient, if flakes one-fourth of an inch or more in diameter can be procured for the test.

2. Powder some of the mineral and heat it strongly in an open glass tube. Sulphur fumes (detected by the odor) will be given off and a pale yellow finely crystalline residue of molybdenum trioxide will be left.

3. Heat some of the powdered mineral on charcoal with a blowpipe in an oxidizing flame. Sulphur fumes are given off and a coating of molybdenum oxide, yellow when hot and white when cold, is left. If this coating is touched with the reducing flame a beautiful azure-blue color appears.

4. Dissolve some of the powdered mineral in nitric acid, evaporate to dryness, add a drop or two of sulphuric acid, again evaporate to dryness, let the residue stand and a deep blue color will finally appear.

5. Powder some of the mineral, dissolve in nitric acid, evaporate to dryness, cool, add a drop of ammonium hydroxide (ammonia

water) and then a drop of hydrogen peroxide. If molybdenum is present a cherry-red to pinkish-yellow color will appear, depending upon the amount of molybdenum there is present.[1]

Occurrence of Molybdenite

Molybdenite is found chiefly in quartz veins in granite, pegmatite, acidic intrusives, gneisses and schists. It is much less commonly associated with intermediate and basic intrusives which cut granites or other acidic rocks.

Crook[2] gives the following rocks in which molybdenite is found: Conglomerate (Switzerland), granular limestone (Hessen, Ungarn), contact of marble and pyroxenite (California), serpentine (Tirol), garnetite (Hessen), amphibolite schist (Finland), chlorite schist (Switzerland, Sweden), gneiss (Baden, Mahren, France, Norway, Connecticut), basalt (Sardinia), pyroxenite (Canada), gabbro (Harz), syenite (Norway), granite (Schlosien, Bohmen, Bayern, England, Norway, Ceylon, Tasmania, New South Wales, Victoria, Canada, United States).

In the same reference Crook also gives a list of minerals with which molybdenite is associated. These are: apatite, arsenopyrite, barite, bornite, biotite, cassiterite, chalcopyrite, fluorite, garnet, gold, hornblende, magnetite, muscovite, oligoclase, orthoclase, pyrite, pyroxenite, pyrrhotite, rutile, scapolite, scheelite, silver, sphalerite, tourmaline, tremolite, wolframite, zircon.

To this list Umpleby[3] adds the following: Chalcocite, cuprite, hubnerite, manganese oxides.

Heintze[4] records these additional minerals: Beryl, dolomite, lollingite, phlogopite, talc.

Several additional minerals are recorded by Horton.[5] These are azurite, bismuthinite, chrysocolla, native copper, epidote, limonite, malachite.

Hess[6] notes that erythrite, autunite and vanadium and several other of the minerals mentioned above, occur with molybdenite and molybdite in a vein near Placerville.

1Melikoff, P., A new reaction for molybdenum. Eng. and Mining Journal, vol. 96, 1913, p. 836.

2Crook, A. R., Molybdenite at Crown Point, Washington. Bull. Geol. Soc. America, vol. 15, 1904, pp. 283-288.

3Umpleby, J. H., Geology and ore deposits of Lemhi County, Idaho. U. S. Geol. Survey Bull. 528, 1913, p. 73.

4Heintze, Carl, Handbuch der Mineralogie, Bd. 1, pp. 410-418.

5Horton, F. W., Molybdenum: Its ores and their concentration. Bureau of Mines Bull. 111, 1916, p. 9.

6Hess, F. L., Vanadium deposit near Placerville, Colo. U. S. Geol. Survey Bull. 530, 1913, p. 151.

WULFENITE

Wulfenite, lead molybdate ($PbMoO_4$) is second in importance to molybdenite as an ore of molybdenum, but its occurrence is very much more limited, and it is found in commercial quantities in comparatively few localities, none of which are in Colorado. It is always associated with ores of lead, and is especially likely to be associated with vanadinite and pyromorphite.

Wulfenite usually occurs as a yellow, orange or orange-red mineral, in thin square plates. Sometimes its color is greenish, brown, or gray. Its crystals may be thick pyramids or almost cubes, rather than thin plates. It has a bright resinous or adamantine luster. In thin pieces it is translucent. The hardness is slightly less than 3. It is easily scratched with a knife but not by the thumb nail. The streak is white, and the specific gravity is 6.7-7. It occurs usually in more or less perfect crystals, or crystal crusts, but sometimes in massive, or granular forms.

Tests

Fuse with sodium carbonate (soda) or charcoal. A globule of metallic lead appears.

The addition of strong hydrochloric acid to the powdered mineral gives a green solution. If this solution is much diluted and tin is added, it becomes deep blue and finally brown.

Occurrence

Wulfenite occurs in commercial quantities in Mexico, Spain, Arizona, New Mexico, and California. It is reported from many other regions, where it is associated with lead ores.

MOLYBDITE

For many years molybdite was regarded as synonymous with molybdic trioxide (MoO_3) which is obtained artificially by oxidizing molybdenite. Schaller[1] demonstrated that natural molybdite contained iron and water and that it has the composition $Fe_2O_3 \cdot 3MoO_3 \cdot 7\frac{1}{2}H_2O$.

Schaller[2] also showed that the analyses of various samples of pure molybdite agreed very closely with the theoretical composition derived from this formula. The theoretical composition is: MoO_3 59.42 per cent, Fe_2O_3 22.01 per cent, H_2O 18.57 per cent.

[1]Schaller, W. T., Mineralogical notes. Series 1, U. S. Geol. Survey Bull. 490, 1911, pp. 84, 87 and 88.
[2]Schaller, W. T., loc. cit., pp. 87-88.

Molybdite is an alteration product of molybdenite, with which it is very commonly associated near the surface of the ground. It is also found in open fractures, where ground water has been active in molybdenite deposits. It occurs as a yellow powder or as yellow, silky, fibrous or radiated crystals. When in the powder form it resembles carnotite, or tungstic oxide. Its luster is silky, pearly or earthy. Its streak is yellow, and its specific gravity is 4.5.

Tests

When heated on charcoal it fuses and leaves a coating of minute yellowish crystals. If this coating is heated for an instant in the reducing flame it turns deep blue, and with continued heating it becomes dark red.

On heating the mineral in a closed tube water is given off and the mineral takes a dark-blue color, which becomes lighter upon further heating. For further tests see Schaller[1] or Horton[2] who gives Schaller's tests.

POWELLITE

Powellite is a calcium molybdate with the formula $CaMoO_4$. It is a white or grayish mineral, which breaks into small glistening scales. These are soft, and adhere to the skin like talc when crumbled between the fingers. The mineral is formed by the weathering of molybdenite, after which it is a pseudomorph. Scheelite may occur with the mineral, but Schaller[3] believes that the mixture is mechanical, and not a chemical combination.

The specific gravity of powellite is about 4.25.[4] It has a resinous luster, and an uneven fracture.

It is decomposed by nitric and hydrochloric acids. It has been reported in the United States from Texas and Nevada.

ILSEMANNITE

The composition of ilsemannite is believed to be $MoO_2.4MoO_3$. It is a blue-black cryptocrystalline mineral which is soluble in water, giving a deep blue solution. Upon evaporating the solution, dark blue crystals appear. The mineral is reported from the Cripple Creek district,[5] and from Idaho Springs.[6]

1Schaller, W. T., loc. cit., pp. 85-86.

2Horton, F. W., Molybdenum: Its ores and their concentration. U. S. Bureau of Mines Bull. 111, 1916, p. 12.

3Schaller, W. T., loc. cit., pp. 81-83.

4Schaller, W. T., loc. cit., p. 83.

5Lindgren, Waldemar, and Ransome, F. L., Geology and gold deposits of the Cripple Creek district, Colo.: U. S. Geol. Survey Prof. Paper No. 54, 1906, p. 124.

6Horton, F. W., loc. cit., pp. 15-16.

BELONESITE

This mineral is believed to be a magnesian molybdate ($MgMoO_4$). It is white, and is transparent in thin flakes. It is insoluble in acids but fuses readily in salt of phosphorus, and less easily in borax. It has been reported only from Italy, where it occurs in rock fragments, enveloped in the lava flow from Vesuvius of 1872.

PATERAITE

Pateraite is an impure black mineral reported from the Elias mine, Joachimsthal, Austria, where it is associated with uranium. Its composition is $CoMoO_4$.

ACHREMATITE

Achrematite is a complex mineral having the composition represented by the formula $3(3Pb_3As_2O_8.PbCl_2)4(Pb_2MoO_5)$. It has a sulphur-yellow to orange, or red color, when fresh, but in mass is liver-brown due to the presence of limonite. If heated on charcoal it fuses, gives arsenic fumes and odor, and finally yields a lead coating on the charcoal and globules of lead. It is reported from the mines of Guanacere, Chihuahua, Mexico.

EOSITE

Eosite is supposed to be a vanado-molybdate of lead, of the composition and formula $Pb_3V_2MoO_4$, although its exact composition has not, according to Horton,[1] been definitely established. It occurs as minute octahedral crystals of the tetragonal system on pyromorphite and cerussite at Leadhills, Scotland. Its hardness is 3 or 4. Its color is deep aurora-red and its streak is a brownish orange-yellow.

Tests

When heated in a closed tube the mineral darkens, but regains its color on cooling. When fused with potassium bisulphate it gives a slightly yellow color to the mass, while hot, but on cooling it turns first reddish brown and finally brownish orange-yellow. The fused mass, when dissolved in water and boiled with metallic tin, colors the solution a faint greenish-blue. If a small fragment of the mineral is placed on a glass plate and treated with hydrochloric acid, followed by the addition of alcohol, and then evaporated, a

[1]Horton, F. W., loc. cit., pp. 14-15.

blue or bluish-green coating is formed with a green precipitate on the edges.

DOUBTFUL SPECIES

Horton[1] cites molybdurane, molybdoferrite and knightite as doubtful minerals, whose "existence as distinct species is problematical." The provisional formula of molybdurane is given as $UO_2.UO_3.2MoO_4$, and that of molybdoferrite, $FeMoO_4$. Knightite is said to be a phosphate of molybdenum.

PRODUCTION OF MOLYBDENUM

The following countries have considerable quantities of molybdenum ores, and most of them have produced concentrates in commercial amounts: Australia (New South Wales, Queensland, and Tasmania), Bolivia, Canada, Chile, German East Africa, Germany, Japan, Mexico, Norway, Peru, New Zealand, Rhodesia, Spain, Sweden, United States. Of these, Australia, Canada, Norway, Spain, the United States, and possibly Germany, are the chief producers.

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[1]Horton, F. W., Molybdenum: Its ores and their concentration. U. S. Bureau of Mines Bull. 111, 1916, pp. 16-17.

CHAPTER III

FOREIGN MOLYBDENUM DEPOSITS

AUSTRALIAN DEPOSITS

For many years Australia, from the two states Queensland and New South Wales, was the world's largest producer of molybdenum. Queensland is the larger producer of the two. The following table shows the production of these two states:

PRODUCTION OF MOLYBDENITE IN AUSTRALIA[1]

Year	Queensland Tons	New South Wales Tons
1900	11	
1901	*26	
1902	39	15
1903	10	29
1904	21	25.25
1905	63	19.40
1906	106.25	32.65
1907	66.75	21.65
1908	89	8.45
1909	93.75	28.15
1910	106	47.50
1911	99.5	20.65
1912	102.66	56.55
1913	66.33	78.80
1914	77.75	61.40
1915	97.50	31.70

1916 (estimated) for the two states 140 tons.

*Includes some wolfram and bismuth.

Andrews[2] states that, in Queensland, wolfram, molybdenite and bismuth occur together in all the mines, although the main tin deposits of north Queensland do not have the other minerals present. He further states that: "All the important deposits of the mineral in question (molybdenite) occur in northern Queensland."

1Andrews, E. C., The molybdenum industry of New South Wales. New South Wales Geol. Survey, Bureau of Mines, Min. Res. No. 24, 1916, p. 22.

2Andrews, E. C., loc. cit., p. 17.

Mr. Andrews quotes Mr. Ball in describing the geology of these deposits as follows:

All these deposits occur on or within a few hundred feet of the contact of the granite and the rock it intruded, exceptions to this rule being only apparent. Thus, when a deposit is found in the granite distant from a covering rock, it is easy to show that the intruded rock has formerly existed at no great elevation above the present surface; and when the deposit is found in sediments unassociated with the granite, it can mostly be shown that the latter lies at comparatively shallow depths below the surface.

The deposits when occurring in granite are peculiar in shape, being typically bent and contorted tubes or pipes, the origin of which is not perfectly clear, beyond that they have been produced in the solidifying magma by the escaping gases and solutions.

He notes further in the same reference that the veins of molybdenite in southern Australia, which produce negligible amounts of molybdenite, are believed to be of igneous origin.

Andrews[1] summarizes the geology of the New South Wales deposits as follows:

The greater portion of the molybdenite from this Australian state is won from New England, in the northeast, and from Whipstick, in the southeast.

The deposits occur as follows:

A. Pipes or cylindrical masses of tortuous form.
- (a) Quartz pipes.
- (b) Pegmatite pipes.
- (c) Granite pipes.
- (d) "Mica-garnet" pipes.
- (e) "Garnet" pipes.

B. Aplitic segregations.

C. Pegmatitic veins.

D. Quartz veins containing feldspar.

E. Quartz veins.
- (a) In greisen within the peripheral areas of coarse, sandy granite.
- (b) In aplites or tin-granites of fine texture.
- (c) In coarse basic granites.
- (d) In sandy granites, fine and coarse in texture.
- (e) Networks of veins in quartz-porphyry.

F. Contact deposits, containing abundant garnet, wollastonite, amphibole, actinolite, quartz, with a little pyrrhotite and pyrites.

As late as the beginning of 1916 only a little work had been done on the problems of concentrating the low-grade ores of Australia, and the lack of modern plants has kept down the produc-

[1]Andrews, E. C., loc. cit. p. 16.

tion. Hand picking, crude methods of crushing and saving the coarse flakes by hand picking and sieving, are the methods in use at the smaller mines. Small plants, with a capacity of from 5 to 25 tons a day of 3 shifts each, are described by Andrews.[1] These are based on some form of oil or water flotation.

The same author,[2] in discussing the outlook for the industry in New South Wales, states that many of the owners of small properties, which have no large showings of ore, are not pushing their production, but are waiting for concentration methods to be perfected which shall be both cheap and efficient. He estimates that eventually it will "be possible for New South Wales to produce hundreds of tons a year of high-grade molybdenite concentrate from the pipes, seams, and veins above mentioned."

MOLYBDENUM DEPOSITS OF NORWAY

Norway has produced about the same amount of ore as has New South Wales. The average annual production of molybdenite concentrates (probably about 75 per cent MoS_2) between 1902 and 1913 was about 30 tons.[3] About 75 tons of concentrates of similar grade were produced in 1914, and 87 tons in 1915.[4]

Extracts by Mr. Claudet[5] from the translation of a paper published by Dr. Otto Falkenberg give the main facts of the geology of the Norway deposits.

The most important discoveries in Norway are at Knabeheien near Kvinas Valley, north of Flekkefjord. The occurrences are associated with granite and partly granite-gneiss. They appear to some extent in intimate association with massive pegmatite, and specially at the boundary of the pegmatite with the surrounding granite. In other places one can best speak of molybdenite-bearing quartz-rock, and finally there are occurrences of ore direct in the granite without any accompanying kind of vein matter. This last is, however, usually of little extension and seems to be confined to small veins which intersect the granite. Owing to its intimate association with the pegmatite, the want of a distinct line between the vein and the surrounding granite, together with the appearance of fluorspar, the author considers these occurrences to be formed, at any rate partly, from pneumatolytic origin in connection with the ascending ore-bearing solutions. Their formation is to be considered as the last effect of the granite eruptions. * * * The ore-bearing zones are intersected by several diabase dykes, running approximately E-W, having a width up

1 Andrews, E. C., loc. cit., pp. 10-13.
2 Andrews, E. C., loc. cit., pp. 190-191.
3 Horton, F. W., loc. cit. p. 29.
4 Claudet, H. H., Notes on molybdenite operations in Norway. Can. Min. Inst. Bull. 51, July, 1916, p. 610.
5 Claudet, H. H., loc. cit., p. 611.

to five meters. They do not appear to have any special influence on the ore's occurrence. The diabase dykes can be followed for several kilometers. This ore-bearing zone is about one kilometer broad and has a longitudinal extension from north to south of about twenty kilometers. A further continuation is not out of the question as the same granite continues also beyond the present known ore-bearing zone, but is little explored. A red granite variety, whose red colour is owing to large orthoclase crystals, must be considered as quite unmetallic.

Claudet[1] states that the deepest workings are only about 100 feet, vertically, in depth, and that in many places the ore has disappeared at shallow depths. In some cases the veins themselves disappear; in others, they simply become barren.

He further notes[2] that, although there are considerable amounts of mica, pyrite, and chalcopyrite, and some pyrrhotite with the molybdenite, the concentration of the ores has not been a particularly difficult matter, and that by the Elmore process, molybdenite ores as low grade as 0.4 per cent to 0.5 per cent MoS_2, containing other sulphides and mica, have been concentrated up to from 70 per cent to 75 per cent MoS_2 in one operation.

"With an ore containing 0.8 per cent. to 1.0 per cent. MoS_2 over 80 per cent. recovery and a concentrate varying from 75 per cent. to 85 per cent. MoS_2 is obtained in practice, but when the mill feed is very low the results will correspondingly suffer."

Mr. E. R. Woakes[3] states that the war demand, coupled with unrestricted prices, has caused an abnormal expansion of the molybdenite industry in Norway. He gives a list of 18 promising deposits, all in southern Norway. Of these 5 are undeveloped, 5 are producing, but have no concentrating plants, and 8 have mills, all of which use the Elmore vaccum process.

According to Mr. Woakes, the cost of producing a ton of 75 per cent concentrates is $2,500. He believes that Norway can produce 100 tons a year of the metal molybdenum for many years, if the price stays above $19.00 a unit for the concentrates.

Norway has an abundance of undeveloped water power, which is soon to be utilized in the manufacture of ferro-molybdenum.

1Claudet, H. H., loc. cit., p. 612.
2Claudet, H. H., loc. cit., pp. 610, 612-614.
3Woakes, E. R., Molybdenum industry in Norway. (Extracts from a paper in Bull. 160, I. M. M.) Eng. and Min. Journal, vol. 105, No. 11, 1918, pp. 499-502.

CANADIAN MOLYBDENITE DEPOSITS

In 1911, Dr. T. L. Walker[1] stated that up to that time there had been no regular production of molybdenum ore in Canada. He also stated[2] that the recorded production of Canadian ore between 1886 and 1909 was only 90 tons. Between 1909 and the first of the year 1915 there seems to have been no commercial production. In the latter year, however, due to the European demand, 28,600 pounds of molybdenite was produced.[3] The next year 159,000 pounds of molybdenite was produced,[4] while in 1917 the production had increased to 271,530 pounds.[5]

These figures show the stimulus on the industry caused by the war.

Dr. Walker,[6] in 1911, cited 12 localities in Canada that appeared promising. Since that time a large amount of prospecting has been done and many important locations have been made, especially in Quebec, Ontario, Manitoba, and in British Columbia.

Drysdale[7] states that Mr. Johnston, mineralogist of the Geological Survey, gives a list of 60 different localities in Canada where molybdenite occurs. "Of these 20 are in British Columbia, 18 in Ontario, 15 in Quebec, 3 in Nova Scotia, 3 in New Brunswick." Of these, 2 in British Columbia, at least 1 in Manitoba, 1 in Quebec and 3 in Ontario, appear to be particularly promising, and will be briefly described in order to present some idea of the character of the deposits and the probable Canadian production.

British Columbia Deposits

The Canadian Mining Journal for August 1, 1916, p. 361, quotes a Spokane newspaper report of a statement by Mr. Arthur Lakes, Jr., as follows:

About 13 miles from Anyox, on Alice Arm, the Stilwells, of Seattle, Washington, are equipping a molybdenum mine with a 50-ton flotation plant, which is expected to begin operations on August 1. This is probably the largest known deposit of molybdenum in the world, and as the ore occurs in quartz its metallurgy presents no problems. The owners

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1Walker, T. L., Molybdenum ores of Canada. Canada Department of Mines. 1911, p. 57.

2Walker, T. L., loc. cit., p. 15.

3McLeish, J. S., Preliminary report on the mineral production of Canada during the calendar year 1915. Mines Branch, Ottawa, p. 15, 1916.

4McLeish, J. S., Can. Min. Journal, vol. 38, No. 6, 1917, p. 122.

5McLeish, J. S., Can. Min. Journal, vol. 39, No. 5, 1918, p. 72.

6Walker, T. L., loc. cit., p. 57.

7Drysdale, C. W., Notes on the geology of the "Molly" molybdenite mine, Lost Creek, Nelson Mining Division. Can. Min. Inst. Bull., Nov., 1915, pp. 872-880.

have been awarded a contract by the Munitions Board for one hundred tons of the metal in concentrate containing not less than 60 per cent molybdenum at $1.00 a pound, or $20.00 a unit. From what I have seen of the ore, I believe they will not experience any difficulty in producing the grade of concentrate required, and they should clean up $200,000 on the contract.

Another British Columbia deposit which shows considerable promise was described by Drysdale[1] in 1915. The following quotations will show his conception of the geology and the value of the deposit:

The Molly mine is situated on Lost Creek, on the old Dewdney Trail, about 15 miles by wagon road from Salmo. It is at present being opened by a Vancouver syndicate. The property includes a group of four Crown Granted claims—"Molybdenum No. 1," "Molybdenite," "Bromyrite," and "Bromyrite King." The claims were located July 15, 1913, by S. N. Ross, H. E. Bennett, and J. A. Benson.

PRODUCTION.—Since discovery, 50 tons of molybdenite ore have been shipped from the property. The first car of 24 tons was shipped by the owners to Denver, Colorado, on October 1, 1914. The average run of the shipment was 16.586 percent molybdenite and 822 pounds of the ore averaged as high as 30.175 percent MoS_2. Specimens of ore of this grade assayed 2½ ounces in silver with a trace of copper and gold. Selected samples assayed from 52 percent to 80 percent MoS_2. At that time the shippers were paid for 85 percent of the MoS_2 contents at the low rate of 20 cents per pound. On March 10, 1914, the property was leased to G. H. and J. P. Bell of Salmo, who proceeded to actively develop it; and on April 9, 1915, shipped one car of 24 tons to Denver, Colorado. The shipment ran 12.26 percent MoS_2, and 90 percent of the MoS_2 content was paid for at the rate of 50 cents per pound. In addition, two tons of ore samples, which assayed 9.5 percent MoS_2 and sold for $1.00 per pound of MoS_2 content, were shipped by the owners to New York. Several thousand tons of milling ore of about probably 4 percent MoS_2 lie on the mine dumps. During the spring of 1915 the property was bonded for $100,000 by a Vancouver syndicate, which continued the development of the mine, intending, should conditions warrant, to presently install a small concentrating plant on the property.

GEOLOGY OF THE ORE DEPOSIT.—Like so many Cordilleran ore deposits, that of the Molly mine is associated with the upper border of a large intrusive mass or batholith of granitic rocks which have been laid bare by erosion. * * * The ore zone appears to be about 10 feet thick, as exposed in the main open cut at the west border of the cupola stock. The granite below the ore zone becomes more massive, blocky, and coarser in grain. Whether the molybdenite ore persists into the diagonally jointed granite or is only confined to the platy jointing still remains to

[1]Drysdale, C. W., loc. cit., pp. 876, 877, 879.

be seen. The granite, however, for considerable distances from the ore zone is impregnated with molybdenite and much of it might be milled profitably.

* * * * * *

The geological structure, the small amount of mica in the ore, which contains also only traces of copper, and the existence of a sufficiently ample water supply, are factors favorable to the provision of a mill to treat the lower grades of molybdenite ore. By thus raising the percentage of molybdenite through concentration to, say, 95 percent MoS_2, not only the highest prices would be obtainable, but also a more widespread market and sale for the product made possible.

Manitoba Deposits

There are several undeveloped deposits in Manitoba. One, at Falcon Lake, has been described by J. S. De Lury.[1] At the time he wrote there had been no commercial development of the deposit.

The mineral occurs in large crystals and masses, in dikes of pegmatite, which lie in the Keewatin schists parallel to and adjacent to the contact of the schist and masses of intrusive red granite. In describing the occurrence and value of the molybdenite, Mr. De Lury says:

> The showings were much better in some openings than others. At one point, where a shot had been put in exposing about one square yard of fresh pegmatite, the crystals of molybdenite were exposed, which taken together, it was judged, would weigh from one-half to one pound. In the blasting out of seven or eight cubic yards of the dyke-rock, twenty or twenty-five pounds of loose crystals and masses were gathered, while in the large unbroken blocks of rock piled on the dump, could be seen many more.
>
> The prominent type of occurrence of the molybdenite is in large crystals and lamellar masses, which could be readily hand-picked into an almost pure product. There is another type which, if found in sufficient quantity, would be of economic importance: the fine-grained variety as found in aplite.

Mr. De Lury believes that the content of the ore is from one or two-tenths of one per cent to one per cent of molybdenite, but that better values may be uncovered with further prospecting.

Ontario Deposits

Mr. A. L. Parsons,[2] in a preliminary report on the molybdenite deposits of Ontario, thus summarizes the geology of the deposits in Ontario:

1De Lury, J. S., Molybdenite at Falcon Lake, Manitoba. Can. Min. Journal, vol. 38, No. 23, 1917, pp. 460-462.

2Parsons, A. L., Molybdenite deposits of Ontario. Can. Min. Journal, vol. 38, No. 11, 1917, p. 231.

With but few apparent exceptions to the rule, the molybdenite of eastern Ontario is intimately associated with pegmatite dikes in the gneisses and crystalline limestone, probably of Grenville age. In case limestone is present, it is usual to find that the pegmatite is not directly in contact with the limestone, but is separated from it by a band of pyroxenite, which is presumably due to a chemical reaction between the pegmatite and the limestone. Where this pyroxenite is present it usually carries the greater part of the molybdenite, and with it considerable quantities of pyrite and pyrrhotite. In certain instances brown and black mica replace part of the pyroxene. When limestone is absent and the pegmatite has introduced gneissic rocks, the pyroxenite band is seldom present and the molybdenite is in the normal pegmatite, but in only one case did the writer find an outcrop where no trace of pyroxene was to be seen. In the more normal pegmatite deposits tourmaline is frequently associated with molybdenite, and in certain instances the pegmatite becomes more siliceous until it appears to be an ordinary quartz vein. The deposits at Net Lake, near Timagami, District of Nipissing, appear to be an exception to the pegmatitic origin of the deposits. At this place the molybdenite is present in a series of gash veins of quartz, which contain in addition small quantities of gold and copper, the latter being in the form of chalcopyrite. Whether these veins are pegmatitic in origin is not definitely known, though such an origin has been suggested for some of the gold veins at Porcupine. In case the pegmatitic origin for this deposit can be shown, the deposits of eastern Ontario may all be grouped together as being associated with pegmatite.

Renfrew County seems to be the most promising. The International Molybdenum Company, Limited, and the Renfrew Molybdenum Mines Company, Limited, as well as some individual operators, are developing certain deposits, as indicated by the following extracts from Mr. Parsons' report:[1]

Brougham Township.—Lots 35 and 36, con. XIV. An open cut about 10 by 70 feet has been excavated by Legree Bros., Dacre, in a micaceous pyroxenite. About 8 tons of ore, running possibly 3 percent MoS_2, together with possibly 400 pounds of pure flake, had been taken out and laid aside for shipment. The property merits further prospecting, and the ore should be shipped to prevent loss by oxidation.

Lots 76 and 17, con. XI., and Lot 17, con. X. Owners of mineral rights, International Molybdenum Company, Limited. Development work is being carried on under the superintendence of J. C. Murray. From 20 to 30 men are employed. The molybdenite is in a series of parallel pegmatite-pyroxenite dikes, and at the time of the writer's visit the work had all been by stripping and open cuts. More than 200 tons of concentrating ore have been shipped from this property. The writer was informed that a shaft was started after his visit.

Lots 7, 8 and 9, con. XI., and lot 8, con. XII. The Renfrew Molybdenum Mines, Limited, under the superintendence of Charles Spearman, are working on a low-grade pyroxenite, which lies between Grenville

[1]Parsons, A. L., loc. cit., pp. 231-232.

limestone and pegmatite. Several carloads of concentrating ore have been shipped from this property. A drift about 60 feet long and a cross-cut about 90 feet in length have been driven into this deposit and two holes have been put in with a core drill. The deposit as exposed is about 600 feet long and 40 feet wide, and apparently offers a large tonnage of concentrating ore. Preparations were in progress for the erection of a mill, and two more boilers were being installed. It is proposed to use the Elmore (flotation) concentrator in the mill. Preparations were being made for the sinking of a shaft.

Lot 15, con. XI., known as the Connelly-Chown property. Two pits have been sunk on a couple of narrow pegmatite dikes of apparently the same character as those on the adjoining claims, which are worked by Mr. Murray.

Griffith Township.—Lots 31 and 32, con. V., and lot 31, con. IV. Owner, W. J. Spain, New York City. Manager, George R. Gray, Dacre. The molybdenite is in two dikes of pegmatite and pyroxenite in gneiss and crystalline limestone, separated by about 10 feet of gneiss. The two dikes together give a width of about 25 feet of working ore. The molybdenite occurs in extremely large flakes, some of them being more than a foot across. Masses of nearly pure molybdenite, weighing as much as 50 pounds, have been taken out. A mill has been erected and was nearly ready for work. As much of the flake molybdenite as possible will be picked out on picking belts, and the remainder, after passing through the rolls, will go to a Hooper pneumatic concentrator.

Lyndoch Township.—Lot 5 and 6, con. VII. Jamieson mine, operated by the International Molybdenum Company, Limited. Idle at the time of the writer's visit and workings filled with water. There were 57 sacks of low-grade ore ready for shipment and a few small piles of ore to be cobbed. This is looked upon as one of the promising properties.

Quebec Deposits

There are important deposits of molybdenite in the Ottawa Valley, north and west of Ottawa. Of these the "Moss" mine, in Onslow Township, 3 miles from Quyon and 35 miles from Ottawa, has become a large producer. The property was located in 1915, and purchased by the Canadian Wood Molybdenite Company, in March, 1916. During the remainder of 1916 and 1917 the mine is said to have produced about 300,000 pounds of molybdenite. In 1916 it was probably the largest producing molybdenite mine in the world. In 1917 the property was purchased by an American syndicate, the Dominion Molybdenite Company. This company has done a large amount of prospecting with the diamond drill, and has enlarged the mill at the mine from a capacity of 50 tons a day to 200 tons a day. The Wood water flotation machines, which are said to have given fair satisfaction, have been replaced by the Callow oil flotation cells.

The geology of the Ottawa Valley, and particularly the "Moss" mine deposits, has been described by M. E. Wilson[1] and E. Thompson.[2]

It is peculiarly interesting that pyroxenite in considerable quantities is intimately associated with the molybdenite.

Thompson[3] divides the deposits of the region into three types, as follows:

1. Associated with slightly more basic segregations in the granites, syenites, or gneisses of the Laurentian.

2. In intimate association with pyroxene in the "contact pyroxenite" of the Grenville series, or in the partially digested rock of this process of silicification.

3. In pegmatite dikes.

The articles are too long to quote here, but the authors show that in spite of the seemingly unusual occurrence of the "Moss" mine ore with pyroxene, it is probably not so unusual after all, when all the conditions have been studied, and that the molybdenite was deposited by pneumatolytic action in one of three ways: (a) accompanying the formation of pegmatite dikes; (b) the intrusion of acidic rocks, granite, or syenite, into sedimentary or metamorphic rocks; or (c) the segregation of slightly more basic rocks from their parent masses, accompanied by fracturing and possibly followed by pegmatitic action. The "Moss" mine deposit seems to be of the latter type.

CONCENTRATION

The ore is being concentrated at the mines mentioned above in British Columbia and Quebec, also at Hull, Quebec, and at Renfrew and Mt. St. Patrick, Ontario. The Mines Branch at Ottawa has for some time been conducting a custom concentrating plant for the convenience of prospectors and small mine owners, but this was to be discontinued July 31, 1918.[4]

The concentrates are being reduced, and molybdenum powder, ferro-molybdenum, and ammonium molybdate are being manufactured at the plant of the International Molybdenum Company at Orillia, Ontario.

[1] Wilson, M. E., Molybdenite deposits of Quyon District, Quebec. Can. Min. Journal, vol. 29, No. 5, 1918, pp. 78-80.
[2] Thompson, E., A pegmatitic origin for molybdenite ores. Economic Geology, vol. 13, No. 4, 1918, pp. 302-313.
[3] Thompson, E., loc. cit., pp. 305-313.
[4] Can. Min. Journal, vol. 29, No. 3, 1918, p. 33.

It is apparent, from a review of the literature of the subject, that Canada has very large molybdenite resources, and it is evident that this country will be an important factor in furnishing the world's supply of molybdenum.

GERMAN DEPOSITS

There is little information at hand concerning the German molybdenite deposits. A note in Engineering and Mining Journal, volume 100, October 9, 1915, page 589, states that the German mines near Halle, on the Saale, have been enlarged and improved and will be able to supply the whole European steel industry, when peace is restored.

CHAPTER IV

UNITED STATES MOLYBDENUM DEPOSITS—EXCEPT COLORADO

Horton[1] gives a list of the following states from which one or more deposits of molybdenite have been reported:

Alaska, Arizona, California, Colorado, Connecticut, Idaho, Maine, Massachusetts, Minnesota, Montana, Nevada, New Hampshire, New Jersey, New Mexico, New York, North Carolina, Oklahoma, Oregon, Pennsylvania, Rhode Island, South Carolina, Texas, Utah, Vermont, Washington and Wyoming.

Wulfenite[2] is reported from: Arizona, California, Colorado, Massachusetts, Montana, New Mexico, Nevada, New York, South Dakota and Utah.

Six western states,[3] namely, Arizona, California, Colorado, Montana, New Mexico and Washington, have many molybdenite deposits, some of which are now producing. In addition there are deposits of considerable promise in Utah, Nevada and Maine.

In 1915[4] the United States produced 91.0 short tons of molybdenum, most of which came from Arizona and Colorado, but small lots were shipped from Texas and Utah.

The larger operating companies or individuals in 1915 are given by Hess[5] as: The Arizona Rare Metals Co., Col. Epes Randolph, The Duquesne Mining and Reduction Co., The Leviathan Mines Co. and the American Molybdenum Co., all working in Arizona; The Pingrey Mines and Ore Reduction Co. and the Primos Chemical Co., of Colorado. The Arizona Rare Metals Co. and Col. Epes Randolph produced wulfenite concentrates from the Mammoth Mine 48 miles northeast of Tucson, and from the Yuma Mine 14 miles northwest of Tucson, respectively. All the others produced molybdenite ore.

In 1917 Hess[6] reported that:

1Horton, F. W., Molybdenum: Its ores and their concentration. U. S. Bureau of Mines Bull. 111, 1916, pp. 86-88.

2Horton, F. W., loc. cit., pp. 89-90.

3Horton, F. W., loc. cit., pp. 44-85.

4Hess, F. L., Molybdenum. U. S. Geol. Survey, Mineral Resources of the United States for 1915, part 1, pp. 807-812.

5Hess, F. L., loc. cit., pp. 807-808.

6Hess, F. L., Our Mineral Supplies. The Rarer Metals. U. S. Geol. Survey Bull. 666-U, p. 10.

The principal deposits of molybdenum ores known are on Chalk and Bartlett mountains and Quandary Peak, in Summit County, and near Empire, on the east side of Red Mountain, Colorado; in Copper Canyon, on the east slope of the Hualpai Mountains, Mohave County; at the old Yuma mine, Pima County, and at the Mammoth and Collins mines, Pinal County, Arizona; and near Emigrant and at other places in Montana. Many smaller deposits on which less development work has been done, occur in practically all the Rocky Mountain and Pacific slope states.

Some of the deposits, such as the wulfenite-bearing veins at the Yuma, Mammoth and Collins mines and the molybdenite deposits in Copper Canyon, Arizona, are now (1917) being actively exploited.

It has been impossible for the writer to get reliable statistics of production since 1915, but it is understood that in 1916 and 1917 Arizona produced large amounts of wulfenite and molybdenite concentrates, and that early in 1918 some of the companies were holding thousands of pounds of concentrates that could not be marketed at what was regarded as a fair price.

Colorado, as shown in another part of this report, is capable of producing large quantities of ore, and it would therefore appear that for the present the demand is likely to be exceeded by the immediately available supply, in this country.

For purposes of comparison with Colorado deposits, brief extracts of reports on the geology of several molybdenite deposits of the United States will be given. Since Colorado does not now have, and is not likely to have, commercial wulfenite deposits, no mention of the geology of those deposits will be made.

ARIZONA MOLYBDENITE DEPOSITS

Dr. Horton[1] describes the occurrence a the Leviathan mines, Copper Canyon, Mohave County, as follows:

The Leviathan properties consist of a group of six claims located on two approximately parallel veins knowns as the "Whale" and the "Copper Wonder." These veins traverse a granite country rock and consist of white quartz carrying molybdenite and chalcopyrite as the principal ore-forming minerals. * * * The "Whale" vein, which is the larger of the two, varies in width from 6 to 40 feet, and the "Copper Wonder" vein from about 2 to 20 feet.

The molybdenite occurs in amorphous and finely crystalline form in thin veinlets and irregular masses throughout the quartz, and as a fine crystalline powder and as nuggets in vugs and cavities in the veins. Much of it is somewhat intimately associated with chalcopyrite, and in only a few places could the writer obtain specimens that were free from copper. * * *

[1]Horton, F. W., loc. cit., pp. 52-54.

The country rock is a medium-grained gray granite consisting of quartz, feldspar (orthoclase, microcline and plagioclases varying from albite to labradorite), biotite, muscovite and small amounts of the usual accessory minerals, zircon and apatite. * * *

The analyses of 22 samples of the ore are given as 2.73 per cent MoS_2 and 1.71 per cent copper, and the writer concludes:

The outcrop of the "Whale" vein is so exceptionally well defined and so wide and the molybdenite and copper contents of the vein, as indicated by sampling of the outcrop and workings, are so regular and persistent that the writer considers the property a most promising one notwithstanding the unfortunate association of copper with the molybdenite.

CALIFORNIA DEPOSITS

Mr. F. C. Calkins[1] has described an occurrence of molybdenite near Ramona, San Diego County, California, as follows:

The dominant rock about Ramona, as well as westward to the foot of the mountain range, is one that would commonly be called a biotite granite. * * * Microscopic study shows that the rock is not a typical granite, inasmuch as the alkali feldspar is very subordinate to the soda-lime feldspar.

This granitic country rock is cut by many dikes of aplite. * * *

The molybdenite occurs in one of the aplite dikes, which trends north-northwest and has been traced about 1,500 feet southward from the brink of the gorge of Santa Maria Creek, on whose south wall it is exposed. Its width varies from less than 50 to about 200 feet. The molybdenite is very unevenly distributed through the rock. The greater part of the dike is barren or nearly so. * * *

The molybdenite is clearly an original constituent of the aplite, to which it is confined. Its occurrence in the coarser parts of the rock indicates that the coarse crystallization and the mineralization were both due to local concentration in the magma of the more mobile constituents. To its mode of origin is due its uneven distribution.

MAINE MOLYBDENITE DEPOSITS

The following is an extract from Hess's[2] description of the geology at the property of the American Molybdenum Co., at Cooper, Maine:

The prevailing rock is a comparatively fine-grained light-gray biotite granite, which weathers to a pinkish color. It is much broken by three prominent sets of joints. Two of these strike about northeast, one dipping 45° or less to the northwest, the other from 45° southeastward to vertical. The third set is older than the other two and runs nearly north and south with an almost vertical dip. Many of the joints of this third set have been filled with thin dikes of rather quartzose pegmatite

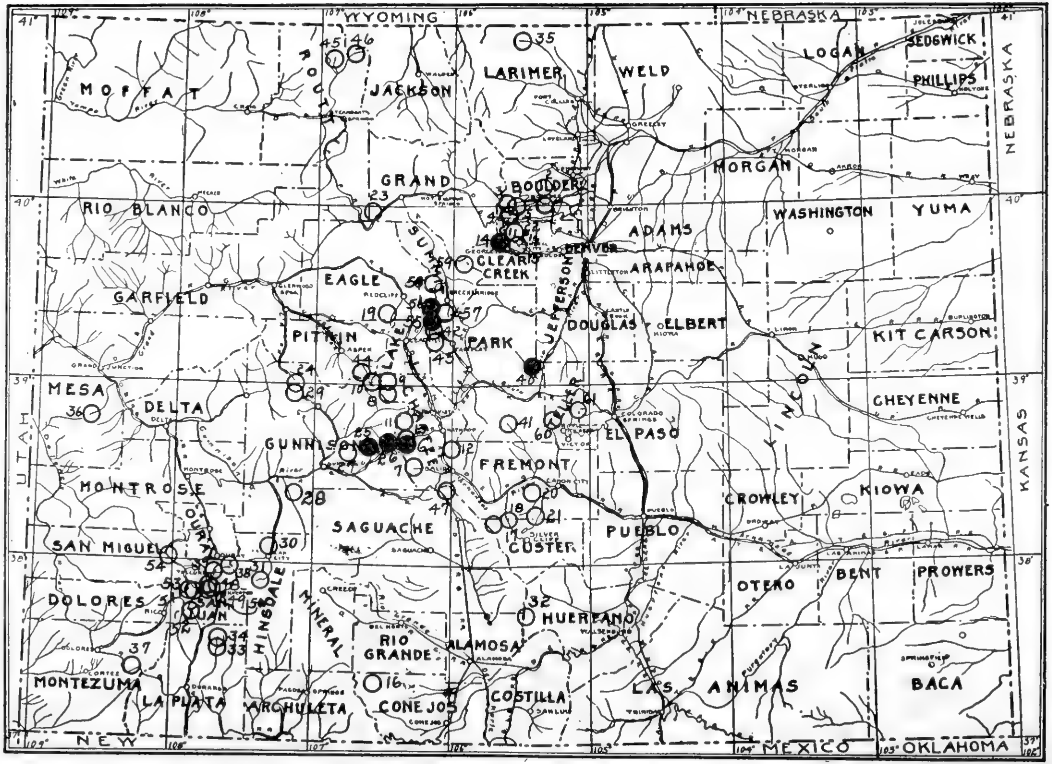
[1]Calkins, F. C., Molybdenite near Ramona, San Diego County, California. U. S. Geol. Survey Bull. 640-D, 1916, pp. 74-75.

[2]Hess, F. L., Some molybdenum deposits of Maine, Utah and California. U. S. Geol. Survey Bull. 340, 1907, p. 232.

from one-half inch to three inches thick. Ordinarily the most quartzose phases occur where the dike has narrowed to its smallest proportions, and at many such places molybdenite forms crusts in which the flakes lie in radical groups of considerable beauty. Between the molybdenite and the walls of the dike there is a thin layer of quartz and feldspar, the latter on the wall itself, but at some places in crystals so small as to escape casual examination. In width the molybdenite flakes commonly range between one-sixteenth inch and an inch, but may fall short of or exceed these limits. It is said that segregations occur weighing 10 to 12 pounds. In wider parts of the dikes feldspar is a conspicuous constituent, but molybdenite is more sparsely distributed and seems inclined to segregate in the middle of the dike.

From this list of occurrences of molybdenite in the United States and in other countries it is evident that the majority of the richest known deposits are associated with granitic rocks, particularly pegmatites.

MOLYBDENUM DEPOSITS OF COLORADO



Scale approximately 80 miles to the inch. The clear circles indicate regions where molybdenum occurs. The shaded circles indicates deposits from which ore has been produced. In many cases several deposits are included under one number.

CHAPTER V

THE MOLYBDENUM DEPOSITS OF COLORADO

The following list includes all the molybdenum deposits in Colorado that have been reported to the Survey.

This list is followed by descriptions of the larger deposits.

The numbers in the first column of this list agree with the location numbers on the accompanying map. It should be noted that several deposits may be included under one location number.

BOULDER COUNTY

No. Location	Name of Property	Owner
1—Magnolia	Mountain Lion	Robert Kermack, Boulder.
2—Jamestown		Chas. Mohr and others, Jamestown.
3—Caribou	Red Warrior Group	W. C. Bryant, M. B. Wray and Geo. Bartels, Nederland.
4—Eldora	Mogul Tunnel	Spencer Mtn. Tunnel Co., Eldora.
5—Cardinal	Boulder County	Cardinal Co., Cardinal.

CHAFFEE COUNTY

6—Brown's Gulch	California	Molybdenum Mines Co., Denver.
7—Huffman Park near Garfield	Nest Egg	C. M. Morgan and G. M. Hendricks, Garfield.
Same Location	Royal Purple	J. and E. A. Huffman, Poncha.
8—Winfield Dist.	Banker	Lessees W. B. Brooks, Leadville, P. S. Smith, Denver, Horace Hopkins, Greeley.
Winfield Dist.	Uintah	Same (Owners).
Winfield Dist.	North Point	R. T. Matthews, Granite.
Winfield Dist.		R. T. Matthews and J. W. Ady, Granite.
9—Twin Lakes Dist.	Molybdenum	Wm. Frederick and Fred Olson, Twin Lakes.
10—Twin Lakes Dist.	X Ray and Whale	Wm. Mock, Leadville.
Twin Lakes Dist.	Climax	Earle Whited and C. G. Bilt, Twin Lakes.
11—So. Cottonwood Creek	Geneva	G. K. Hartenstein and H. C. McLean, Buena Vista.
12—Turret	Independence	R. S. Stratton, Lessee, Turret.
13—Alpine	D. M. D.	J. H. Dermitt, Buena Vista.

CLEAR CREEK COUNTY

No. Location	Name of Property	Owner
14—Dailey Dist.	Urad	Primos Chemical Co., Boulder.
15—Near Central City	Clifford	Leopold Sternberger, Central City.

CONEJOS COUNTY

No. Location	Name of Property	Owner
16—Platora	Merrimac	A. E. Reynolds, Denver.

CUSTER COUNTY

No. Location	Name of Property	Owner
17—Rito Alto Peak	Grab	J. M. Duckett, Hillside.
Rito Alto Peak		E. F. Stacy, Hillside, R. J. Knight, Canon City.
18—Hillside		E. F. Stacy, R. A. Dissmore, Hillside.

EAGLE COUNTY

No. Location	Name of Property	Owner
19—Mount Whitney		W. G. McKay and John Popovitch, Red Cliff.

FREMONT COUNTY

No. Location	Name of Property	Owner
20—9 mi. S. Parkdale	Copper Girl	Greenhorn Mtn. Copper Mining Co., Canon City.
21—12 mi. N. E. Westcliffe	Liberty Bond	K. L. Eldred and B. F. Young, Canon City.

GILPIN COUNTY

No. Location	Name of Property	Owner
22—Apex	Gray Eagle	John Goldberg, Apex, Eugene Stevens and Geo. Holland, Boulder.
Apex		John Smith and Will Converse, Apex.

GRAND COUNTY

No. Location	Name of Property	Owner
23—Radium		H. S. Porter, Radium.

GUNNISON COUNTY

No. Location	Name of Property	Owner
24—Treasury Mtn.		John O'Toole, 410 Ideal Building, Denver.
25—Lamphere Lakes		Geo. Carter and Herman Hudler, Ohio.
26—Gold Hill	Molybdenum	Wm. McKinley and A. L. Pearson, Pitkin.
Gold Hill	Bon Ton	Lessee, Penn. Rare Metals M. and D. Co., Pitkin.
Gold Hill	Emma H.	H. Stephens Ehrman, Pitkin.
Gold Hill	New Discovery	A. L. Pearson, Pitkin, and Mr. Carpenter, Tin Cup.
27—Cross Mountain		William Waugh, Gunnison.
28—Spencer		Pat Trainer, Iola.
29—Paradise Pass		Charles Daniels, Salida

HINSDALE COUNTY

No. Location	Name of Property	Owner
30—4 mi. North of Lake City	I. D. A.	Robert Wagner, Lake City.
31—Sherman		John Gavin, Lake City.

HUERFANO COUNTY

32—Mosca Pass		Not Located.

LA PLATA COUNTY

33—East Silver Mesa	Oregon	C. M. Ayers, Durango.
34—Vallecito Basin		John Bloom, Durango.

LARIMER COUNTY

35—St. Cloud Dist.	Iron King	E. F. Bartlett, Cherokee Park.

MESA COUNTY

36—Unaweep Canyon		R. U. Gavette, Grand Junction.
Unaweep Canyon		R. Collinson, Whitewater.

MONTEZUMA COUNTY

37—Near Mancos		Allard Mining Co., La Plata.

OURAY COUNTY

38—Engineer Mtn.		Fred Richter, Ouray.
39—Ironton	Irene	G. C. McGee, Ironton.
Ironton	Jumbo	J. Davis and Gus Bruner, Ouray.

PARK COUNTY

40—Lake George	Red Skin	Lessee, U. S. Rare Minerals Co., Denver.
Lake George	Apex	J. O'Driscoll and associates, Colo. Springs.
41—Guffey	Crescent	Alfred Dell, Guffey, and F. M. Woods Inv. Co., Colo. Springs.
42—West of Alma		E. E. Van Epps, Red Cliff.
West of Alma	White Swan	E. O. Nippert, Alma.
43—West of Alma	Humbug	Geo. W. Shelton, Alma.

PITKIN COUNTY

44—Near Red Mtn.	Greenhorn	F. E. Kendrick and associates, Leadville.

ROUTT COUNTY

45—Farwell Mtn.		Farwell Mtn. Cu. Co., Montreal.
46—Slavonia Dist.		G. H. Frantz, Clark.
Slavonia Dist.		D. M. Wilt, Clark.
Slavonia Dist.		M. A. Hoskinson, Oak Creek.

SAGUACHE COUNTY

No.	Location	Name of Property	Owner
47	Near Alder		Wm. Merideth, Alder.

SAN JUAN COUNTY

No.	Location	Name of Property	Owner
48	Chattanooga	Gold Finch and Hidden Treasure	Lee Tinsley and Taylor McGrew, Chattanooga.
49	2 mi. S. of Chattanooga	Liberty Bond	E. J. Holman, A. D. Malchus and R. J. Hoffman, Silverton.
50	Near mouth S. Mineral Creek	Black Diamond	J. P. Eaker, Silverton.
	Bear Mountain		Edward Hollingsworth, Silverton.
51	Head of S. Mineral Cr.		Not Located.
52	Cascade Basin		Not Located.

SAN MIGUEL COUNTY

No.	Location	Name of Property	Owner
53	Ophir	Molybdenite Queen	Colo. Molybdenum Mining Co., Ophir.
54	Placerville	Evans Claims	

SUMMIT COUNTY

No.	Location	Name of Property	Owner
55	Climax	Many Claims	Climax Molybdenum Co., Climax.
	Climax	Denver No. 2	Molybdenum Products Cor., Denver.
	Climax	Rare Metal Group	Pingrey Mines and O. R. Co., Leadville.
	Climax	Molybdenum Group	C. J. Senter, Leadville.
56	Kokomo	Bryant Claims	Joe Bryant, Kokomo.
	Kokomo		Kokomo Milling Co., Kokomo.
57	Quandry Mtn.	Salamander and Blue Valley	R. J. A. Widmar and A. C. Howard, Breckenridge.
58	Uneva Lake		
59	Montezuma		Clyde Drolsdraugh and John Sullivan, Montezuma.

TELLER COUNTY

No.	Location	Name of Property	Owner
60	Near Dome Rock		Lafe Fyfe, Cripple Creek.
61	North of Pike's Peak		Wm. Smith, Cripple Creek.

BOULDER COUNTY

The Mountain Lion Mine

The Mountain Lion Mine at Magnolia, Boulder County, is owned by Robert R. Kermack, and leased to M. A. Long, both of Boulder. It is situated about seven miles from Boulder. The property is close to the Keystone Mine, and within the limits of the village of Magnolia.

The mine is 350 feet deep and has drifts at the 100, 200, 300 and 350-foot levels. At the time it was visited no work was being done, and the shaft was partly full of water.

The country rocks are pre-Cambrian gneiss and schist cut by many masses of intrusive granite, and by pegmatite dikes. Messrs. J. H. Horry and M. A. Long, both of whom have worked in the mine, say that molybdenite occurs only on the lower levels, where it is associated with massive white quartz and small amounts of chalcopyrite and is found in and on the borders of a large pegmatite dike. The best showing is on the 350-foot level, where the dike, which has been cross-cut for 16 feet, shows small amounts of molybdenite all the way along. Wherever it occurs, the ore is very pockety and no safe estimate of the available supply can be made. In 1916 Mr. Horry shipped about 1,200 pounds to Denver for sampling and treatment. This ore was hand sorted, and selected from what was regarded as a rich streak, 10 feet long and 20 inches wide. The ore assayed 2 per cent MoS_2. Most of the molybdenite is coarsely granular. Some individual flakes are an inch in diameter and from one-half to three-quarters of an inch thick. Most of the mineral, however, occurs as small thin flakes, sparsely scattered through the quartz gangue.

The probabilities for developing a commercial body of molybdenite here are not regarded as good. No other molybdenite deposits are known in this region.

JAMESTOWN DEPOSIT

Mr. Charles J. Mohr, of Jamestown, Colorado, reports that he and associates have molybdenite claims near Jamestown, which show a large vein of low-grade ore. There is said to be a 60-foot tunnel on the property, which is all the development that has been done. No ore has yet been shipped. Samples and assay returns were requested but have not been received.

CARIBOU DEPOSIT

Messrs. W. C. Bryant, M. B. Ray and George Bartels, all of Nederland, have molybdenite in the Bighorn Shaft, which is on one of the ten claims of the Red Warrier Group, situated about two miles north of Caribou on the northeast slope of Haystack Mountain.

The property can be reached by a poor but passable road from Caribou, or by a trail about three-quarters of a mile long from the Silver Lake Mine, which may be reached by a fairly good wagon road from Hill, a station on the Denver, Boulder & Western Railroad.

The Bighorn Shaft is 90 feet deep. At the bottom there are two drifts on the vein, each about 30 feet long.

The country rock is garnetiferous quartz mica schist into which have been intruded many masses of coarse, gray biotite granite.

A strong quartz vein cuts the country rock. It is said to vary from 1½ to 7 feet in width. It dips vertically and strikes N. 45° E. The vein carries a great deal of pyrite. In fact, if it were near the railroad it might be successfully worked for pyrite. There are also said to be small values in gold and silver.

At the time the mine was visited the vein could not be examined in place, for there was a good deal of water in the shaft, which had accumulated during several months' time when the mine had been standing idle. The vein material on the dump was carefully studied. Molybdenite, in very fine grains, is disseminated all through the quartz. In some fractures the molybdenite content is high and rich specimens can be obtained, but the average of all the molybdenite-bearing quartz is from one-half to three-fourths of one per cent.

The mine is well equipped with a 15-horsepower wood-burning boiler, a double 4 by 6 cylinder hoist, and a good shaft house. There are comfortable log cabins near. Plenty of fire wood is close at hand, and water is not far distant.

OTHER LOCALITIES

Lindgren[1] has noted the occurrence of molybdenite in the Boulder County Mine, and also in the Mogul Tunnel, Spencer Mountain, near Eldorado. On the dump of the Mogul Tunnel he found deep blue stains, believed by him to be ilsemannite.

CHAFFEE COUNTY

The California Mine

The California Mine is owned by The Molybdenum Mines Co., whose office is in the Evans Block, Denver, Colorado.

The mine is situated near the head of Brown's Gulch, on the north side of the creek, at an elevation of 12,500 feet. It is

[1]Lindgren, Waldemar, Gold and tungsten deposits of Colorado. Economic Geology, vol. 2, 1907, pp. 456-458.

19 miles from Nathrop, which is the nearest station on the Denver & Rio Grande Railroad, and it is 5 or 6 miles south of Alpine, a station on the McElmo-Buena Vista division of the Colorado & Southern Railroad. From Nathrop or Salida the property is reached by a good wagon road as far as Centerville, thence a poor wagon road 5 miles to the Beaver dams in Brown's Gulch, and from there by a rough mountain trail 6 miles long. At present there is neither road nor trail all the way to the mine from Alpine, but a road 4 or 5 miles long follows a gulch south from Chalk Creek to a point within 1 or 2 miles of the camp. This road now reaches almost to the vein, where it outcrops in the first valley north of Brown's Gulch, and it may be of importance if the mine is finally developed, as it is likely to be, from the Chalk Creek side.

In July, 1917, the company owned four claims, namely, the California, California No. 2, Nevada and Nevada No. 2.

DEVELOPMENT

All the development work, with the exception of some shallow surface cuts and location shafts, has been done on the California Claim. In the summer of 1917 the workings consisted of: an open cut with a 50-foot drift on the vein; an inclined shaft 50 feet deep, near the open cut, but apparently not on the vein; a cross-cut tunnel, that was started 50 feet vertically below the open cut and was run 98 feet to the vein; and drifts from this tunnel, one 30 feet westerly on the vein and another 126 feet to the east. Small stopes, only 2 or 3 feet above the normal roof of the tunnel, have been run for 75 feet, on the east drift. Mr. W. B. Lowry reported in June, 1918, that since July, 1917, the drift has been continued on to the east 15 feet to a fault, and 130 feet beyond, where the vein was recovered.

GEOLOGY

The ore occurs in a fissure vein in Pomeroy quartz monzonite. This rock has been described by Professor Crawford,[1] as follows:

> The rock is pinkish-gray to bluish-gray, and carries a great number of small, bluish-gray plagoclase crystals which frequently show twin striations on lustrous cleavage faces. In the hand specimen may also be seen pinkish to white orthoclase, chloritized hornblende, a few biotite

[1]Crawford, R. D., Geology and ore deposits of the Monarch and Tomichi Districts, Colorado. Colorado Geol. Survey Bull. 4, 1913, pp. 79-80.

crystals, and occasional pyrite grains. With the aid of a strong lens quartz may be seen intergrown with the orthoclase. Near the east border of the larger area the rock is finer in texture, decidedly porphyritic, and carries a larger proportion of quartz. Along the east border also, wherever this porphyry is exposed on the ridges, as at Pomeroy Pass, it is much stained by red and brown oxides of iron.

The gangue minerals are quartz, beryl, some white mica and a little pyrite.

The vein varies from 18 inches to 3 feet in width. Its average dip is 80° N. 18° W., but it straightens up in many places to almost 90°. It seems to be a strong vein. It holds its course well and according to Mr. W. W. Rogers, superintendent at the mine, it has been followed by float on the surface for a mile or more. Work done since the writer's visit to the property in 1917 shows that at a distance of 141 feet from the cross-cut the vein is faulted, and that the east side is displaced 30 feet to the north.

Two ores of molybdenum, molybdenite and molybdite, occur in the vein. The latter is more abundant in the upper workings, but is found in considerable quantities at the main tunnel level. Molybdenite is found everywhere that the vein has been opened. The richest ore is near the walls, but there are rich streaks and vugs scattered all through the vein. In these rich streaks, and along the walls, chunks of solid molybdenite from 1 to 2 inches thick, and from 6 inches to 2 feet in length, are of common occurrence. The molybdenite is entirely crystalline, the flakes being as a rule from one-eighth to one-half an inch in diameter. The intimate association of pure white quartz crystals, some of which are 12 inches long, with opaque or clear beryl (aqua marine) crystals, and molybdenite is an interesting phase of the occurrence of this ore. Much of the richest ore is found with beautiful specimens of beryl. In many places pockets are found between masses of beryl and quartz crystals from which it is possible to dig out with a candlestick 20 or 30 pounds of practically pure molybdenite and molybdite. While the vein as a whole is strong, there are rich and lean streaks all through it. On this account it is very difficult to get fair average samples without shooting down, and sampling a large amount of ore. The difficulty of proper sampling is increased by the fact that the country rock is mineralized for several inches more or less from the vein proper. It is noticeable that there is considerably more pyrite with molybdenite in the country rock than in the vein.

TREATMENT

The ore taken from the mine is trammed by hand to the sorting room at the entrance of the tunnel, where it is cobbed, hand sorted, screened and sacked. The value of the hand sorted material varies, but is said to average between 20 and 30 per cent MoS_2. The screenings which pass a 10-mesh sieve run from 2 per cent MoS_2 up. The sacks of ore, which weigh from 75 to 100 pounds each, are packed on burros from the mine to the wagon road at the Beaver dams. From there they are hauled by wagon to Nathrop, and shipped by rail to Denver.

The company, for a time, conducted a small chemical plant in which they reduced the ore to molybdenum trioxide and ammonium molybdate. Only test lots of ore were so treated and the work was not resumed after a fire in the fall of 1917 destroyed the company's mill equipment.

IMPROVEMENTS, TIMBER AND WATER

There is a comfortable log cabin near the mine, which accommodates 8 or 10 men, and a log shop and sorting room at the entrance of the tunnel.

Timber line in Brown's Gulch is at 12,000 feet. There is plenty of timber suitable for mine use and building purposes within three-fourths of a mile of the camp.

There are springs within 100 yards of the camp, which furnish all the water needed for ordinary living and mine use. Half a mile away and 300 to 400 feet below the mine there is a strong, permanent stream.

FUTURE DEVELOPMENT

Stoping ground above the present tunnel level is limited to a maximum of 200 feet east of the cross-cut. In the west the drift will run out of the hill to the surface within 200 feet of the cross-cut. While the writer has not been over all the ground, it is his belief that the property could best be worked by going in from Alpine and drifting on the vein from the northeast. It would give more stoping ground, and the distance to a railroad would be much less than from the present camp.

It is of course evident that this property is not likely to become a large producer, but it should be an attractive proposition to some one who wishes to mine and mill a small quantity of relatively high-grade ore which is free from copper and other injurious impurities.

HUFFMAN PARK DEPOSITS

Huffman Park lies just at the foot of the east slope of Mount Etna, in the Monarch Mining District, about 4 miles northwest of Garfield. Garfield is on the Monarch-Salida branch of the Denver & Rio Grande Railroad, and is 20 miles west of Salida. The train service is irregular, but averages 2 or 3 times a week from Salida, during the summer. An automobile stage makes the round-trip daily, between Monarch or Garfield and Salida. There is a good road between Salida and Garfield. From Garfield to the head of Huffman Park the road is rough and steep, but ordinarily passable for wagons. In the Park there are two molybdenite claims, the Royal Purple and the Nest Egg.

The Royal Purple Claim

About one-fourth of a mile N. 25° E. of the cabin farthest up the gulch is the Royal Purple Claim which is owned by J. and E. A. Huffman of Poncha Springs. There are two veins here which are nearly parallel and which strike N. 55° E.

There is an open cut and shallow shaft on the east one of these veins. The country rock is Princeton quartz monzonite[1]—a light gray, or nearly white rock, which contains considerable pale pink or white orthoclase, bluish gray plagioclase, and small amounts of quartz.

A 6-foot vein is exposed which contains considerable molybdenite in a 6 or 8-inch streak on the hanging wall. Most of the mineral is found as distinct grains, from one-tenth to one-fourth of an inch in diameter, scattered through the vein. Some, however, occurs as facings in cracks in the vein and in the country rock. A little molybdite is found in the vein. Much pyrite is associated with the molybdenite, but no copper is present.

The vein could not be fully studied on account of the large amount of snow in the cut, but judging by what could be seen and by the ore on the dump, the grade of the ore is too low to allow its being mined and milled at a profit.

[1]Crawford, R. D., Geology and ore deposits of the Monarch and Tomichi Districts, Colorado. Colorado Geol. Survey Bull. 4, 1913, p. 138.

A short distance northwest of the first vein, at an elevation of 11,850 feet, is a second quartz vein in the same country rock. This vein is three feet wide. It contains many thin facings of molybdenite and some that is rather coarsely granular. An average sample of ore from the dump assayed 0.96 per cent MoS_2. Pyrite, but no copper, occurs in this vein.

There is plenty of water near this property, and there is good wood and timber not more than half a mile away.

The Nest Egg

The Nest Egg Claim, owned by C. M. Morgan and G. M. Hendricks, both of Garfield, is situated on the east slope of Mount Etna, above Huffman Park, at an elevation of 12,150 feet. A rough, poor trail leads up from the Park to this claim.

The country rock is Princeton quartz monzonite[1] and Pomeroy quartz monzonite.[2]

There are several small open cuts on the Nest Egg ground. At the main opening two faults cross. One dips 27° N. 20° E., and the other 85° N. 35 E. Along the junction of these faults, and on the hanging walls of both, there are bunches of molybdenite, which are entirely crystalline and occur in bright, silver-gray, thin, radiating flakes. These flakes impregnate the country rock for a distance of two feet or more from the fault planes, and fill many vugs which cannot be detected until the rock is broken open. Some work has been done at and near the junction of the faults, and at a distance apart of ten feet the country rock is mineralized from one fault to the other.

The ore is entirely free from all other metallic minerals, and can be concentrated easily. It is probable that a 1 or 2 per cent grade of ore could be sorted out without difficulty. The extent of the deposit, however, is in doubt. There is a great deal of slide rock in the region, and the veins have been exposed, only locally in the shallow cuts. If more work near the surface proves that the veins are continuous for some distance, it would probably be desirable to start a cross-cut tunnel considerably lower down the slope of the mountain where it would be easier to get timber and water. The relief is high, and more extensive development would be a comparatively easy matter.

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[1]Crawford, R. D., loc. cit., p. 138.
[2]Crawford, R. D., loc. cit., p. 134.

WINFIELD DISTRICT

In the Winfield District only a little development has been done, but there are several deposits of molybdenite worthy of further investigation.

Winfield is an old, almost deserted mining camp situated at the forks of Clear Creek, about 14 miles west of Granite, which is the nearest town on the railroad. There is a fairly good automobile road all the way from Granite. Clear Creek furnishes an amount of water sufficient for extensive mining or milling operations. There is also a large amount of timber close at hand. The topography is mountainous and the relief is high. Altogether the environment is entirely favorable for mining and milling, provided that further prospecting proves the existence of ore bodies of sufficient size and value

There are two regions in this district where there are very good surface indications of molybdenite. These are on the mountains immediately east and west of the south branch of Clear Creek, within two miles of Winfield. Four groups of claims have been located and they will be described in order, beginning with those farthest west.

North Point and Eastern Star Claims

These claims are owned by R. T. Mathews of Granite. They lie on the ridge which extends east from Virginia Peak, between Fortune Basin and the north branch of Clear Creek. Both are 600 by 1,500-foot claims. They trend northeast and southwest and lie side by side. The slopes of the ridge both to the north and south are steep. The elevation at about the center of the ridge is 12,200 feet.

Coarse gray biotite granite is the only country rock in the region. It is cut on this ridge by not less than 14 quartz veins, the smallest of which are 6 inches, and the largest about 2 feet, in width. All the veins run nearly north and south, and are practically vertical. Four of them, each about 1 foot wide, lie close together and show some very good-looking float. Samples broken from surface outcrops assayed 1.22 per cent MoS_2. The average molybdenite content of the four veins is estimated to be not less than 1 per cent and probably 1.5 per cent. There is some pyrite and a little molybdite with the molybdenite, but no copper.

This property is wholly undeveloped. The opportunities for tunneling at a considerable depth are very good and it is believed that the ground should be thoroughly prospected.

The Uintah Lode, and Others

Messrs. Horace Hopkins of Greeley, W. B. Brooks of Leadville, and Philip S. Smith of Denver, have located a group of 13 or more claims just northeast of the Mathews ground.

Several veins outcrop on this ground. The country rock and the occurrence of the ore are the same as just described, except that the ore does not seem to be so high grade in these veins as in the Mathews deposit. Since there has been no work done on this ground, one cannot, with assurance, predict what the values will be. As in the case of the Mathews claims, there are good tunnel sites on the claims, and prospecting would be easy and should be done.

The Banker Mine

This mine is situated about two miles south of Winfield, on the south fork of Clear Creek, at an altitude of 10,400 feet. It is owned by a corporation consisting largely of Pennsylvania people, and is now leased by Messrs. Hopkins, Brooks, and Smith.

The mine has not been worked for several years. There is a good deal of water in it, and in 1917 the air was so bad that no examination could be made by the writer.

There are said to be 44 claims in the Banker group. Most of the development work has been done through one big tunnel, but there are several shafts and small tunnels which have been used for surface prospecting.

There was at one time a splendid equipment at the mine. It included two 100-horsepower boilers, a large compressor, machine drills, etc., etc., with good buildings for offices, and bunk houses, and small cabins for the married employees. Some of the machinery has been dismantled by looters, but it would not be a very expensive matter to refit it if operations at the property should be resumed. There is plenty of water only a few yards from the tunnel and wood for mine timbers and fuel is close at hand.

The main tunnel is 3,700 feet long and has cut several veins. One vein 19 feet wide was cut at a depth below the surface of 1,200 feet and at a distance of 2,400 feet from the entrance of the tunnel. This was drifted on for 1,200 feet to the northeast. A large amount of material said to have come from the vein in question was studied on the dump. The gangue is pure white massive quartz. Scattered irregularly through it, but chiefly in layers near the walls, is molybdenite, most of which occurs as fine, dark lead-gray grains, and aggregates sheet-like in form. The richest streaks are on the vein walls and in the country rock near the walls, where with silvery mica and pyrite there is some very high-grade ore. Considerable bismuthinite was found on the dump in a white quartz exactly like that which contains the molybdenite, and in one instance bismuthinite and molybdenite were found together. It is not known whether or not such an association is common. It was, of course, impossible to get samples that would give any definite idea of the value of the ore that may be produced. Much of the vein undoubtedly carries practically no ore, but there are pockets and streaks on or near the contact of the vein and country rock, which will assay 10 or 15 per cent MoS_2. It would, therefore, seem advisable to reopen the mine and prospect the vein.

Ady and Mathews' Claims

About one mile northeast of the Banker Tunnel, on the east side of Winfield Peak, at an elevation of 12,200 feet, J. W. Ady and R. T. Mathews, of Granite, have located claims on what may be a continuation of the molybdenite vein in the Banker group.

The country rocks are coarse gray feldspathic granite, and a finer even-grained gray granite, not so rich in mica as is the coarser one. A quartz vein outcrops for several hundred feet on the northeast side of Winfield Peak. Where the float is not covered by mantle rock it shows a good deal of molybdenite. The dip of the vein cannot be accurately determined, but it seems to be practically vertical. The strike is N. 75° E. It is not possible to be sure of the width or length of the vein. It seems to split up more or less into stringers, with a rather well-defined mineralized zone 10 or 12 feet wide. According to Mr. Mathews it has been followed back to the southwest, half way to the Banker Tunnel, and northeast several hundred feet, but altogether it was not followed for more than 500 feet by the writer. Specimens which represent the average value of the ore exposed at the surface of the ground, assayed 2.037 per cent MoS_2. No development work has been done. The situation of the claims, on top of the mountain, half a mile or more from wood and water, is not conducive to easy development. After more prospecting has been done to determine the length and width of the vein, if the results are sufficiently encouraging, the property should be developed through tunnels started some distance down from the top of the ridge on which the claims are located.

Other Claims

Several other occurrences of molybdenite have been reported from the Winfield District, but so far as is known none has been developed.

Enough work has been done in this district to make it evident that there is considerable ore in the region, and the claims mentioned above should be thoroughly prospected, in order to demonstrate the value of the various deposits.

If sufficient bodies of ore are uncovered to make the project feasible, a concentrating mill should be built at or near Winfield to handle the product of the whole district.

TWIN LAKES DISTRICT

The Molybdenum Lode

The Molybdenum Lode, which is owned by William Frederick and Fred Olson, of Twin Lakes, is situated on Hope Mountain, at the head of Little Willis Gulch, at an elevation of 12,500 feet. It is reached by a rough, steep pack trail 5 miles long, from Twin Lakes postoffice. The nearest railroad station is at Granite which is 12 miles from Twin Lakes by wagon road. Granite is on both the Denver & Rio Grande and the Colorado Midland railroads.

The discovery shaft on this claim is located well up on the side of Hope Mountain, about 1,000 feet above the valley floor. The topography of the region is rough and mountainous. The maximum relief is not less than 2,000 feet.

The high relief is advantageous for tunnel sites, but, at present, mining at the discovery shaft is difficult, for the shaft is 1,000 feet above, and three-fourths of a mile away from wood and a permanent supply of water.

GEOLOGY

Not enough work has been done on this ground to permit an accurate estimate of the value of the deposit. Molybdenite occurs in many small quartz veins which are in a fractured granite zone, evidently on a fault. This mineralized zone is 10 to 15 feet wide. It strikes N. 50° E. Where the rock in place is not covered with talus and mantle rock molybdenite can be found on the surface of the ground for a distance of 30 or 40 feet. One opening 10 by 10 feet in length and breadth and 20 feet deep has been made in the deposit. Ore is shown on the walls and in the bottom of this cut, and apparently the best ore is at the bottom. It impregnates both the granite and the quartz veins, and occurs extensively as thick solid facings on the vein walls. According to Mr. Frederick, a sample clear across the best 5-foot mineralized zone assayed 2.5 per cent MoS_2. The writer's sample, which represents a grade of ore that could be cobbed out in considerable quantities, assayed 2.18 per cent MoS_2. It would be an easy matter to sort the ore more carefully and procure a 5 per cent grade, although the whole vein would probably not average more than one-half of 1 per cent. As is to be expected, so near the surface of the ground, there is a good deal of molybdite associated with the molybdenite. Pyrite, in considerable amounts, also is found all through the mineralized zone.

Since this property is relatively inaccessible, it is not likely that it will be developed at present. If the demand for molybdenum increases, however, it would be advisable to prospect this ground thoroughly, for there are very good surface indications of ore.

Collins Claim

George Collins, who lives 10 miles up Lake Creek from Twin Lakes postoffice, has a prospect on the north side of and 100 feet from the stream about 300 yards above the junction of the creeks at the mouth of Sayre Gulch.

The only development so far is a hole 10 feet long and 6 feet deep. A 2½-foot quartz vein is exposed which carries a little molybdenite with considerable pyrite. The country rock is granite and gneiss. The vein dips 60° N. 37° W. The showing is not at all promising.

X-Ray and Whale Claims

Messrs. William Mock and Fred St. Clair, of Leadville, have claims on the crest of the continental divide on the west side of west Sayre Gulch, about 14 miles from Twin Lakes postoffice.

The X-Ray Claim crosses the divide at an altitude of 12,300 feet and is about one mile from the head of the gulch.

The country rock is medium-grained gray granite. Molybdenite occurs with pyrite in a quartz vein which is 6 to 8 feet wide. The vein stands vertically and strikes S. 65° W. The ore is very pockety. Occasional rich bunches are found, but most of the vein is barren. About 400 feet below the top of the divide, on the west side, a prospect tunnel, now caved, was driven in a distance of 20 feet. At the breast, according to Mr. Mock, the ore was of a very good grade.

The Whale vein crosses the divide 400 feet north of the X-Ray. This is also a white quartz vein in granite, which carries more or less molybdenite. The vein is 30 feet wide, strikes S. 45° W. and is vertical. Most of the vein appears to be barren, but in some places there is ore which runs 1 per cent or more MoS_2. The Whale vein has been followed down in Sayre Gulch and up on the east side, through a distance of more than 1,500 feet.

Both these properties are at present relatively inaccessible, although they could be easily developed by tunnels from Sayre Gulch. There is plenty of timber and water in the gulch. The vertical range from the creek in the bottom of the gulch to the top of the saddle where the Whale crosses the divide is about nine hundred feet. There is a poor wagon road half way up Sayre Gulch from Lake Creek, and it would not be a difficult matter to continue it to the head of the gulch.

The surface showings on these claims are not good enough to make them attractive prospects at this time.

Climax Claim

The Climax Claim, owned by Earl Whited and C. G. Bilt, of Twin Lakes, is located on the east side of South Lake Fork on Mount Ewing. The altitude at the discovery shaft is 11,650 feet, which is just the elevation of timber line in this gulch. The claim is about 12 miles from Twin Lakes postoffice, and is not far from "Three Cabins." There is a good road from Twin Lakes to within a mile of the property and an old wood road goes up from the valley nearly to the vein.

The country is mountainous, with beautiful glaciated valleys and high relief. The claim is about 850 feet vertically above the valley bottom, and a still greater distance below the top of the mountain. There is plenty of wood and water near at hand.

The country rock is gneissoid granite cut by a dark gray felsite porphyry rich in quartz phenocrysts. Small amounts of molybdenite, with much pyrite, occur in an 18-inch quartz vein which dips 55° N. 50° E. The vein is on the porphyry-granite contact and seems to be due to the intrusion.

Only a small amount of work has been done here. There are several shallow surface cuts and one opening that is 10 feet deep, about 6 feet wide and 15 feet long. The present development does not indicate that the vein is a strong one and it is not probable that it will ever be developed.

The Geneva Claim

Messrs. G. K. Hartenstein and H. C. McLean, of Buena Vista, own this claim, which is situated about 18 miles southwest of Buena Vista on the north side of South Cottonwood Canyon. The property is reached from Buena Vista by a good wagon road to Cottonwood Lake, a poorer road for the next 2 or 3 miles and a trail the rest of the way.

The relief is high, and the topography of the region is extremely rough and mountainous. The claim is located 400 or 500 feet above the bottom of the valley on the south side of Jones Mountain, at an elevation of 11,750 feet.

GEOLOGY

There is a great fault here which strikes approximately N. 20° E. A block of dolomitic limestone has been tilted up into a vertical position and is held between granite walls. The limestone block is about one-eighth of a mile wide and more than a mile long. The limestone is everywhere much brecciated and metamorphosed, but is most altered near the granite contacts. Secondary mica, serpentine, asbestos and calcite are found in the brecciated parts of the limestone. There are many small calcite veins which cross the fault block, and in these veins are considerable quantities of pyrite and very small amounts of molybdenite. Varying but rather small amounts of chalcopyrite accompany the other sulphides. The molybdenite is very pockety. Some of the richer streaks are a foot or more across, but these are not common. There seem to be no continuous veins, and the grade of the ore that has been found is so low that it is doubtful if there will be much work done on this claim.

Plenty of water and good wood are close at hand, and cabins have been built on the ground to accommodate miners who took out considerable silver ore from a higher shaft on this claim. The ore is said to have been worth $100.00 a ton. It soon played out, however, and no work has been done on the property for some time. There are altogether 800 or 1,000 feet of workings at the main tunnel level.

ALPINE

D. M. D. Claim

The D. M. D. Claim is located about three-fourths of a mile in an air line north of Alpine, a station on the Buena Vista & McElmo branch of the Colorado & Southern Railroad. The claim is owned by J. H. Dermitt and Maud Davis, of Buena Vista.

The property is on the south slope of a very steep side hill at an elevation of 10,500 feet. It is reached by a good trail from Alpine.

A tunnel 200 feet long crosses two quartz veins, both of which are small. The country rock is Princeton quartz monzonite. In the veins are chalcopyrite, pyrite and a little galena. Mr. Dermitt states that the vein can be followed for nearly half a mile and that it carries an average value of 1½ per cent molybdenite. The writer's samples, which were carefully taken from the only veins exposed, failed to show more than traces of molybdenite.

TURRET DISTRICT

Molybdenite has been reported by Mr. A. E. Moynahan, former deputy state mine inspector, from the Independence Tunnel in the Turret District. The ore is said to occur in mica schist and gneiss. It is understood that the deposit is of small extent and that the ore is low grade.

CLEAR CREEK COUNTY

The Primos Chemical Company's Mine

This property is in the Dailey Mining District on the southeast slope of Red Mountain, about 14 miles from Empire Station. It is reached from Empire by a good wagon or auto road which follows the Berthoud Pass road along West Creek for about one-half the distance, and continues along the creek valley after the Berthoud Pass road turns off to the north.

The property was visited by the writer in June, 1917. At this time no work was being done, operations having been suspended in the autumn of 1915.

The camp buildings are well situated on the side of the valley at the foot of the mountain, near abundant supplies of wood and water, at an elevation of about 10,200 feet. At the time the property was examined there were only two buildings at the lower camp. These were a large house in which were combined the compressor room, offices and comfortable living quarters for about twenty men; and a stable for draft and pack animals.

DEVELOPMENT

The mine workings at this time were as follows:

1. A tunnel just above the camp at an elevation of about 10,600 feet. This tunnel was driven in a cross-cut for about 180 feet, nearly due west. Then it was turned to N. 60° W. and driven on for 370 feet, to the breast. In the latter direction it follows a fissure for about 150 feet. Several small quartz and pyrite veins were cut, but no molybdenite was seen by the writer. The country rock is mainly hard, gray, coarse-grained granite which carries a small amount of biotite. About 100 feet from the mouth of the tunnel a considerable body of garnetiferous quartz-mica schist was cut.

2. Going up the hill, the next work was done just east of the trail at an elevation of about 10,900 feet. Here a tunnel was run for 30 feet, N. 75° W., across a contact of granite, and granite porphyry or coarse rhyolite porphyry. The dike strikes N. 15° E. and dips 65° S. 75° E. It contains many small grains of pyrite, but no molybdenite was seen here.

3. The main tunnel, from which most of the ore so far has been taken, is at an elevation of about 11,300 feet. The tunnel was started on the south side of a granite porphyry contact, and driven in a general westerly direction for about 600 feet, where it apparently cut the main vein, which is exposed high up the hill. From the 600-foot mark the tunnel becomes a drift for about 800 feet on the vein. Cross-cuts, most of which are from 10 to 20 feet long, have been driven out at short intervals from the main tunnel. There are also three stopes, each 50 or 60 feet long and about 100 feet high. Considerable molybdenite is shown in the tunnel and the stopes. It was not sampled, but is estimated to average 1 or 2 per cent MoS_2. The vein varies greatly in width but averages perhaps three feet.

4. About 500 feet above the main tunnel there are several surface cuts where the original locations were made. The three largest cuts open on a line which runs about N. 45° E. The cut farthest to the southwest opened a vein which strikes S. 80° W., and dips 63° N. 10° W. The vein is 3 or 4 feet wide and has been opened up for 15 feet. Considerable molybdenite and molybdite are shown. The next cut, about 60 feet to the northeast, is on a

vein which is nearly vertical and strikes N. 85° W. The vein has been opened for 40 feet, and a good grade of ore is exposed. The third cut, 40 feet northeast of the second, is about 20 feet long. Several quartz veins are exposed, but nothing so definite as in the middle cut. All these exposures seem to be part of one strongly mineralized zone, the richest part of which seems to center near Cut No. 2.

GEOLOGY

The country rock is chiefly coarse gray biotite granite which was intruded into pre-Cambrian garnetiferous quartz-mica schist. The granite in turn was cut by many dikes of a granite or rhyolite porphyry which apparently come from a large mass of the same rock that makes up the main part of Red Mountain. (This larger mass was not studied in detail, but the assumption is made, on the basis of the color, and the float washed down from above.) The porphyry consists of many large grains of colorless quartz and pale flesh-colored feldspar in a fine-grained light-green groundmass which is highly impregnated with small pyrite grains. The pyrite is present in such large amounts that the rock, when weathered, turns to a dark brownish or brick-red color, because of the oxidation of the iron.

Horton[1] describes the occurrence of the ore as follows: "The ore occurs in two forms—one consists of an alaskite (?) breccia in which the molybdenite occurs as occasional small flakes but more often in finely granular form associated with iron pyrite in the interstices of the breccia; in the other the molybdenite occurs in small veinlets and stringers running off into the alaskite-porphyry (?) country rock. The brecciated type of ore constitutes the vein material proper, * * *."

According to the writer's observations, which were somewhat limited, the ore occurs chiefly in small quartz veins, in the shattered granite and on the borders of the porphyry dikes. Many fissures occur nearly parallel to or at right angles to the direction of the dikes. Both the dike rock and the country rock are in places much brecciated, and the molybdenite occurs as fine separated grains or thick coatings with the quartz which has filled the fractures. The number of dikes which cut the granite, and their exact relationship to the ore bodies, were not learned, but there are at least three dikes exposed in the workings men-

1Horton, F. W., Molybdenum: Its ores and their concentration. U. S. Bureau of Mines Bull. 111, 1916, p. 65.

tioned above. In the upper surface cuts, all the ore seems to be northeast of a large porphyry dike which stands in a vertical position and strikes S. 25° E. In the main tunnel 500 feet below, the ore appears to lie on the southwest side of a dike which is also vertical and strikes about S. 65° W. at the portal of the tunnel, but turns to nearly due west as it enters the hill. No ore was seen near the third dike, which is just east of the trail between the two tunnels.

In the upper cuts considerable molybdite occurs with the molybdenite, but in the tunnels there has been no oxidation of the molybdenite and it is not present.

Most of the molybdenite is very finely granular. It occurs as dark blue-gray coatings which vary in thickness from that of thin paper up to one-half an inch or a little more. Many veinlets of quartz which may or may not carry molybdenite run off roughly at right angles to the main veins. These stringers vary from a few inches to several feet in length. Pyrite occurs wherever molybdenite is found, but no other metallic mineral was observed.

PRODUCTION

The present owners took over this property in November, 1914, when the first real development work was done. Between January 1st and the end of August, 1915, nearly all the development work indicated above was done. Horton[1] reports that during this time between 1,500 and 2,000 tons of ore, which averaged about 2 per cent MoS_2, was mined, packed down to the creek on mules, hauled to Empire in wagons and shipped from there by rail to Pennsylvania.

During the summer of 1917 the owners again began active work at the property. At the time of this writing, June, 1918, it is understood that an oil flotation concentrating mill with a rated capacity of 100 tons of ore a day has been completed and is in operation. An aerial tram has been built from the main tunnel to the mill and a new tunnel has been started at the foot of the mountain, which will open the veins at a depth of 1,600 or 1,800 feet below the upper surface cuts.

[1]Horton, F. W., Molybdenum: Its ores and their concentration. U. S. Bureau of Mines Bull. 111, 1916, pp. 66-67.

Clifford Mine

The Clifford Mine is located on the divide between Woodpecker and York gulches about two and one-half miles west of Central City. Leopold Sternberger, of Central City, is the owner of the property.

The country rocks belong to the Idaho Springs formation, which consists here of gneiss and biotite schist. The vein and its development are described by Bastin and Hill[1] as follows:

> The Clifford vein runs along the divide between Woodpecker and York gulches. About a mile south-southeast of Mount Pisgah it is opened by a shaft which could not be entered, but which is shown by mine maps to be an incline a little over 150 feet deep, with 300 feet of drifting on the 100-foot and about 400 feet on the 150-foot level.
>
> The country rock belongs to the Idaho Springs formation, and biotite schist is the only rock seen on the dump. On the surface the vein is not well exposed, but appears to strike N. 60° E. The drifts shown on the mine map strike about N. 59° E., and the vein dips steeply southeast. The ore in the bins consisted of white quartz cut by seams and stringers of dark quartz carrying galena, light and dark sphalerite, chalcopyrite and some pyrite. Most of the ore is siliceous, but some specimens carry barite, which is either embedded or implanted on the walls of vugs and which crystallized with the dark quartz and the lead and zinc minerals. Postmineral movement has crushed some of the ore, producing in some places a grayish gouge.

No reference is made to molybdenite in this report, but the writer examined the material on the dump and found considerable molybdenite with quartz. It occurs either as finely divided flakes or more commonly as amorphous coatings. It was of course impossible to judge the size of the vein from an examination of the surface material, but it seems probable that the veins are small, and they may be only quartz stringers in the Idaho Springs formation.

Specimens selected from the dump, which were probably of more than average value, assayed 1.87 per cent MoS_2. Some pyrite and limonite were found with the molybdenite, but no other metallic minerals were observed. As far as can be learned, no molybdenite has ever been shipped from this property.

There is not much good wood for mine timber nearby. Water is also scarce. The mine is easily accessible from Central City and it is hoped that when more work is done, some attention will

[1]Bastin, E. S., and Hill, James M., Economic geology of Gilpin County and adjacent parts of Clear Creek and Boulder Counties, Colorado. U. S. G. S. Professional Paper 94, 1917, pp. 317-318.

be given to the molybdenite, although it seems unlikely that, if there were commercial deposits there, they would remain undeveloped at this time.

CONEJOS COUNTY

PLATORA

Mr. H. A. Aurand, of the Colorado Geological Survey, examined this deposit in September, 1917, and the following statement is a résumé of his notes:

Platora is reached by stage, either from Del Norte or Monte Vista. The distance is 26 miles from the latter town.

A small quartz vein, which carries a little molybdenite, outcrops on the Merrimac Claim, between the Forest King and Mammoth mines. The vein is two inches wide, strikes N. 15°-17° W., and dips 90°. The wall rocks are granite and granite gneiss. On the surface the vein outcrops for 125 feet. It is believed that the same vein was cut by some of the upper drifts of the Merrimac, for ore of this character is found on the dump. The mine has not been worked for many years and the workings have caved badly. The deposit is too small to be of any commercial value.

CUSTER COUNTY

Knight-Stacy Claims

R. J. Knight, of Canon City, and E. F. Stacy, of Hillside, have claims that are situated on the side of Rito Alto Peak, about 11 miles from Hillside, at an elevation of 11,600 feet. Hillside is a station, about 12 miles from Texas Creek, on the Texas Creek and Westcliffe branch of the Denver & Rio Grande Railroad.

The property is reached by a good wagon road from Hillside to Stacy's ranch, and by a poor road and rough trail the remaining six miles to the claims.

The country rocks are fine-grained, gray diorite, and a coarser-grained, lighter-colored diorite or monzonite.

A quartz vein, which averages about one foot in width and which dips nearly vertically, strikes N. 35° W. There are no deep openings on the vein, but it has been exposed for several hundred feet by surface cuts. The vein matter consists of honeycombed quartz, pyrite, and molybdenite. The latter occurs in small crystals and in amorphous aggregates one-eight to one-fourth of an inch in diameter. Molybdenite impregnates the country rock to a slight extent. Many of the crystals of molybdenite show a marked radiated structure. Specimens of selected ore assayed 3.47 per cent. MoS_2. The whole vein, however, will probably not run 1 per cent. The ore is free from copper and from other undesirable impurities except pyrite. Some molybdite is found near the surface, but it will probably disappear with depth.

The claims are about 1,500 feet above the floor of the valley, and a corresponding distance above available wood and water. On this account development work will be expensive.

The Grab Claim

This claim is owned by J. M. Duckett, of Hillside. It adjoins the Knight-Stacy claims on the northwest.

A shaft, 50 feet deep, has been driven on the vein, and some ore has been shipped by leasors. The shaft was nearly full of ice when the property was visited by the writer in 1918, and the vein could not be examined in place, but it is believed to be an extension of the Knight-Stacy vein. Judging by the material on the dump, the occurrence and values of the ore are essentially the same, with one important exception, namely, considerable chalcopyrite was found on the Grab dump, and it is said to be rather thoroughly mixed with the ore. This, of course, detracts from the value of the ore, in so far as its molybdenum content is concerned.

Fine timber and abundant water for power or milling purposes are only about one-eighth of a mile away from the Duckett shaft.

In connection with both the Knight-Stacy and the Duckett properties there are very good opportunities for driving cross-cut tunnels at considerable depth, if future surface and near-surface development makes such action seem desirable.

It is believed, however, that, due to the difficulty of reaching the claims and to the present low-grade character of the ore, these properties will not be worked until the demand for molybdenum is much greater than at present.

The Stacy-Dissmore Claim

Messrs. E. F. Stacy and R. A. Dissmore, of Hillside, have a molybdenite claim that is situated about two miles southeast of Hillside.

The country rocks are coarse, pink biotite granite and an older quartz mica schist. On the contact of these rocks there are some rich patches of molybdenite which occurs in masses an inch or two across and half as thick. The absence of a vein and the irregular contact of the granite and schist are conditions adverse to the formation of workable ore bodies, and this deposit is not believed to be valuable.

EAGLE COUNTY

CROSS MINING DISTRICT

John Popovitch and W. G. McKay, of Red Cliff, have two molybdenite claims on Mount Whitney, about 18 miles from Red Cliff and about 2 miles north of Cross City. The claims are reached by wagon road from Red Cliff, 12 miles long, to Gold Park; thence by the Cross City wagon road, now almost impassable, for 5 miles. There is neither road nor trail the rest of the way to the claim, but the grade is easy and the construction of a road would not be difficult. The elevation at the discovery tunnel is 11,250 feet.

The country rocks are quartz mica schist and a micaceous gneissoid granite. Many quartz veins cut the schist, which is the dominant country rock.

A quartz vein, which is from 12 to 16 inches wide and which has a general trend of N. 30° E., has been opened by a surface cut and tunnel for a distance of 30 feet. The dip is nearly vertical. Molybdenite in crystals and fine-grained coatings occurs in the vein and on the borders of the vein and the country rock. Some ore, which runs 5 or 6 per cent, is found in pockets, but the average of the vein is slightly less than 1 per cent. Pyrite in rather small amounts occurs in the vein. No copper is present.

The development work is too meagre to allow safe predictions as to the future value of this property. The vein is not straight, but winds around more or less. It has been followed up the hill, however, for several hundred feet, and a shallow hole, 150 feet higher on the hill, shows some ore.

The relief is high and there is nearly 1,500 feet of stoping ground above the present tunnel level.

Wood and water are plentiful and are near at hand.

On the whole, the property is regarded as unworthy of more prospecting unless other mines are opened in the neighborhood, so that road building and other costs of developing the property are materially reduced.

FREMONT COUNTY

The Copper Girl Mine

The Copper Girl Mine is owned by the Green Horn Mountain Copper Mining Company, of which Ralph Fairchild, of Canon City, is the president and general manager.

The property is situated about 9 miles south of Parkdale, Fremont County, Colorado, between Copper and Bear gulches. The main tunnel is at an elevation of about 7,700 feet. The mine is reached by a good road for the first 5 miles from Parkdale, then a poor road which follows the bed of an intermittent creek for 2 or 3 miles, and a steep, difficult mountain road the last mile and a half to the mine.

There are two patented claims in the property—the Copper Girl and the Valley View.

The development work, all of which has been done in the Copper Girl Claim, consists of: (1) An upper surface cut, and a 30-foot incline, which extends down to the tunnel; (2) the main tunnel, which is 100 feet long; (3) a winze at the breast of the tunnel, which is down about 75 feet on a 25-degree slope; (4) two or three short cross-cuts at the tunnel level.

GEOLOGY

The country rocks of this region consist of an undifferentiated pre-Cambrian complex of schists, gneiss and granite. The whole complex is cut by many pegmatite dikes.

The ore in the Copper Girl occurs in strongly mineralized bands of quartz-mica schist. These bands contain a good deal of quartz whose origin was evidently contemporaneous with that of the metallic minerals which are associated with it. These mineralized bands conform to the dip and strike of the layers of schist. Near the breast of the tunnel two mineralized bands are exposed. Each band varies from 1 to 3 feet in thickness, and the individual bands are from 1 to 3 feet apart. Considerable chalcopyrite and some fine-grained flaky molybdenite occur in each band. Three carloads of ore are said to have been taken from this mineralized zone. The ore was sampled and assayed, and according to Mr. Fairchild, ran between 8 and 9 per cent copper.

The main body of molybdenite in this property occurs between the chalcopyrite bands described above. It is found in fine-grained flakes, impregnating the schist. The width of the richest streak of molybdenite averages about ten inches. Some chalcopyrite is scattered all through the molybdenite-bearing schist, just as some molybdenite is found in the richer chalcopyrite streaks.

According to Mr. Fairchild, two 100-pound samples of this ore from the molybdenite streak were sent to Henry E. Wood, Denver, Colorado, for analysis. One sample assayed 3.7 per cent MoS_2 and the other 4.3 per cent MoS_2. The writer's sample, supposedly of the same ore, ran 1.058 per cent MoS_2 and 3.54 per cent copper. This sample, however, was a small one and may not have correctly indicated the average value of the whole ore body.

DEVELOPMENT

Comparatively little ore of any kind has ever been taken from the mine. Probably the amount is less than 400 tons altogether. All of this has been copper. The development work has not yet gone far enough to allow a careful estimate of the amount of molybdenum and copper that is available, but, judging by the limited exposures, it seems to be evident that both are increasing in value as greater depths are reached.

The elevation above the tunnel level is not great enough to allow more than 200 or 300 feet of stoping ground. However, if future development in the mine warrants such a procedure, a crosscut tunnel can be run into the ore body from the bed of the creek.

There is not much permanent equipment at the mine, but in July, 1917, when the property was examined, there was a gas engine and compressor on the ground.

There is plenty of good pinon pine timber within half a mile of the property. The nearest water available for any purpose is at the foot of the hill, in Bear Gulch, a mile and a half away.

If processes are now available, as is now claimed by several manufacturers, for the economical concentration and separation of the molybdenite and chalcopyrite, it would seem that with the present, June, 1918, high price of molybdenum and copper, and with good management, the mine might be operated very profitably. Any separation process, however, must be very complete, for even a very small amount of copper is detrimental, when included with the molybdenum concentrates.

If a mill should be built for the concentration of this ore it should be located at Parkdale, where there is plenty of water, and where concentrates could be shipped via railroad directly from the mill.

The Liberty Bond Claim

The Liberty Bond Claim, owned by K. L. Eldred and B. F. Young, of Canon City, is situated about 12 miles north of Westcliffe and about the same distance nearly due east of Hillside, on the divide between Westfall Gulch and Grape Creek. The property is reached by a good wagon road for a distance of 10 miles from Westcliffe and a poor road the rest of the way.

The topography near the property is rough and hilly. The relief is low to the west, but increases rapidly toward the east. The elevation at the claim is 7,500 feet.

The country rocks of the region are pre-Cambrian gneiss and schist, and granite. In the immediately vicinity of the molybdenite prospect the rock is chiefly a more or less gneissoid, fine to medium-grained, gray or pink granite, which contains a little biotite. This rock is cut by a diabase dike, which strikes N. 10° W. and dips 85° N. 80° E. The dike is 6 or 8 feet wide and is highly brecciated, containing many granite and schist fragments, the largest of which are at least a foot long.

A shaft, said to be 75 or 80 feet deep, was sunk on this dike about 30 years ago. The walls have caved and it was possible to examine only 8 or 10 feet of the rock which is exposed above the fallen timbers.

There are no well-defined veins, but the ore occurs in thin flakes, from one-eighth to one-half an inch in diameter, associated with calcite and pyrite, in lenses and small, irregularly distributed masses on and near the contact of the dike and the country rock. An occasional grain of chalcopyrite is found with the pyrite, but it is unimportant. The molybdenum is almost wholly unoxidized.

It is impossible to fairly estimate the value of the ore from the limited exposure. Several tons of rock, which evidently came from the mineralized contact zone, was examined, as well as the rock in place. Samples were taken which were regarded as better than the average of the ore that could be sorted out from the dump, and the assays were not encouraging, for the tenure of the ore is less than one-half of 1 per cent of MoS_2. It is possible that the ore increases in value with depth, but the general occurrence of the molybdenite, in such broad, thin flakes, irregularly distributed without well-defined veins, makes it seem improbable that this property will become a large producer.

Timber, in the form of pinon wood, is available for mine purposes. There is no considerable body of water nearer than Grape Creek, which is 2 or 3 miles away.

GILPIN COUNTY

Gray Eagle Claim

The Gray Eagle Claim, owned by John Goldberg, of Apex, and Eugene Stevens and George Holland, of Boulder, is located about three-fourths of a mile northeast of the town of Apex, on the northwest side of Dakota Hill. The elevation at the claim is 10,500 feet, which is about 650 feet higher than the town. An old wood road extends almost up to the claim from Apex. The country is open and of high relief.

The property is almost wholly undeveloped. There is one opening, 17 feet deep and 10 feet long, on the vein, and several shallow trenches have been dug in order to determine the course of the vein.

The country rocks are coarse, gray granite and micaceous gneissoid granite, but only about 200 feet away these rocks are in contact with monzonite porphyry,[1] and the intrusions of the latter may have been responsible for the occurrence of the ore.

Little could be learned of the extent of the deposit, but the vein does not seem to be a strong one. The walls are poorly defined and the thickness is variable. In fact, the ore body is really a mass of quartz veinlets in gneiss and granite. These veinlets vary from 1 to 8 inches in thickness. They contain small amounts of molybdenite, which occur as distinct thin flakes, thick bunches of fine grains, and amorphous coatings on joint planes and fractured surfaces. Pyrite, muscovite, and molybdite are found with the molybdenite. No copper is present. Selected specimens of ore, which were better than average samples of the whole vein, but not better than could be easily hand sorted, assayed 2.13 per cent MoS_2.

It is believed that more work should be done in order to determine the size and value of this deposit.

There is plenty of wood near at hand. The nearest available water for mill purposes is at Apex, three-quarters of a mile away.

[1]Bastin, E. S., and Hill, J. M., Economic geology of Gilpin County and adjacent parts of Clear Creek and Boulder Counties. U. S. G. S. Professional Paper 94, 1917, p. 39.

Sure Shot Lode

About 300 feet above the Gray Eagle is another quartz vein, which cuts the monzonite porphyry. This vein is 18 inches wide. It consists chiefly of pure white quartz, which contains very small quantities of molybdenite. The vein has been opened by 4 shallow cuts and one 20-foot shaft. It probably is of no value.

GUNNISON COUNTY

QUARTZ AND TINCUP MINING DISTRICTS

In the vicinity of Gold Hill, 9 or 10 miles north of Pitkin, there are several veins which contain considerable molybdenite.

One large fissure vein, which has been traced more or less continuously for more than two miles, crosses Gold Hill in a northwesterly direction. Another vein is indicated by float in the timber south of Gold Hill and the creek. On top of Gold Hill there are still other outcrops which indicate that there are several veins only imperfectly exposed.

When the region was visited by the writer in the summer of 1917, his time was so limited that he was unable to work out the relationship of these various veins. His observations were sufficient, however, to allow the statement that there are several large bodies of low-grade ore in the Gold Hill region.

In addition to the observations made in the field, notes have been furnished the writer by Mr. R. St. John Cleary, Mr. K. E. Tillotson, Major H. Stephens Ehrman and Senator Wm. J. Candlish. The principal development of the molybdenite veins has been done on the following claims: The Bon Ton, the Molybdenite Group, the Emma H., the Ida May, the Monitor, and the New Discovery. All these properties, with the exception of the New Discovery, are on the good wagon road from Pitkin to Tincup. The nearest ones are 5 or 6 miles, and those farthest away are 8 or 9 miles from Quartz, a station 3 miles from Pitkin on the Alpine branch of the Colorado & Southern Railroad. The part of that road between Quartz and Gunnison is now operated by the Denver & Rio Grande Railroad, and a bi- or tri-weekly train schedule is maintained.

The total relief in this region, between Quartz Creek or the headwaters of Taylor River and the top of Gold Hill, is between 800 and 1,000 feet. Good timber in abundance is growing on all the claims, except parts of the New Discovery, Ida May and Monitor. Water is available within distances varying from a few hundred feet to one mile. All the groups of claims have good locations for tunnel sites.

The Bon Ton Group

There are 10 claims in this group which are owned by the Bon Ton Mine & Leasing Co., but now are under bond and lease to the Pennsylvania Rare Metals Mining & Development Co. Mr. K. E. Tillotson, of Pitkin, is the superintendent of the latter company.

DEVELOPMENT

This property has been developed by two tunnels. The lower one was started only a short distance from Quartz Creek and has been driven in a northerly direction for 800 feet. Several veins have been cut and one has been followed to the west for 200 feet. The upper tunnel is about 300 feet long. Several veins, some of which have good showings of molybdenite, were crossed. A few years ago several tons of this ore was mined, hauled to Pitkin and then concentrated by oil-flotation in a remade mill. This ore is said to have assayed from 1 to 3 per cent MoS_2.

GEOLOGY

The country rock is quartz monzonite and granite. The veins are several feet across. They consist chiefly of massive white quartz and contain a good deal of chalcopyrite and gold-bearing pyrite.

It is said by some people who are familiar with both properties that the Bon Ton vein is the same as the one which crosses the Molybdenite Group, just west of the Bon Ton ground. Others believe that the veins are different. The writer did not have time to make the necessary examination, even if it had been possible to enter the Bon Ton tunnel. There is certainly a pronounced difference, however, between the ore taken from the Bon Ton and the Molybdenite claims. The former consists of small crystals and thick facings of molybdenite, intimately associated with pyrite and chalcopyrite, in a white quartz gangue, while the ore from the Molybdenite claims contains less pyrite and chalcopyrite.

Copper, with some gold and silver, have been, so far, the chief products of the mine. Molybdenite has not been regarded as of commercial importance until very recently and practically no work has been done on the molybdenum veins.

EQUIPMENT

The property is said to have a good working equipment, which consists of: cabins, ore house, blacksmith shop, boiler house, boiler, engine blower, compressor, machine drills, etc. A recent report states that the company is building a small concentrating mill near the mine.

The Molybdenite Group

The Molybdenite Group, owned by Wm. McKinley and A. L. Pearson, of Pitkin, consists of four full claims, each 600 by 1,500 feet, and a fraction. The property joins the Bon Ton on the west and the claims extend nearly to the top of Gold Hill.

DEVELOPMENT

In July, 1917, there were several shallow openings on the vein, and one 50-foot cut, 20 feet deep at the breast. Only specimen material had been taken out.

During the autumn of 1917 and the following winter the property was worked under bond and lease by Messrs. W. J. Candlish, W. E. Kreamer, and C. W. Savery, of Denver. A tunnel was driven to cut the vein at a depth of 50 feet or more, and they drifted for 90 feet on the vein. Several carloads of ore were shipped to the Richardson-Candlish concentrating plant, 1610 Bryant Street, Denver.

GEOLOGY

The country rock is coarse gray quartz monzonite which weathers red or reddish brown due to the oxidation and hydration of the large amount of pyrite present. The vein seems to be a strong one. It averages 4 feet in width and dips 45° S. 10° W. In the exposures which were examined by the writer, molybdenite was found associated with a small amount of pyrite and considerable molybdite. The molybdenite occurs in two forms: first, as small flakes and crystals, filling vugs and impregnating the vein and country rock for several inches from the vein walls; and, second, as very fine-grained thick black facings which coat fracture planes in the vein. The latter form is the more important one of the two.

This vein which looked so promising at the surface proved to be very disappointing when it was prospected at some depth. The molybdenite was found to be greatly diminished in quantity and the whole vein is so impregnated with copper that it is valueless for ordinary purposes.

It may be desirable to do more work on this vein at another place to see if the copper is everywhere present in the same proportions, for it is possible that the valuable and detrimental metals are both pockety, although it is not probable that such pockets would continue through such a long distance as the copper seems to do where the drift was run on this vein.

The New Discovery Claims

The New Discovery Claims extend from near the top of Gold Hill diagonally down to the creek, at the foot of the north slope. They are believed to be on the Molybdenite and Bon Ton vein which crosses Gold Hill from the southeast. The property is said to be owned by A. L. Pearson, of Pitkin, and Mr. Carpenter, of Tincup, who have given an option on it to Messrs. Candlish, Richardson and Savery, of Denver. The claims can be reached from either Pitkin or Tincup, but more easily from the latter town, for there is neither road nor trail on the Pitkin side beyond the top of Gold Hill, while from the north one can drive almost to the property.

DEVELOPMENT

The claims are, so far, almost wholly undeveloped. The vein has been exposed by shallow surface cuts for 200 feet, and one 25-foot drift has been made.

In this region there are exceptionally good tunnel sites, and the development of the property without waste work will be an easy matter. If the vein proves to carry ore that is of the proper grade, it would undoubtedly pay to build a small concentrating plant near the creek at the foot of the hill. If this were done, the distance from the mine to the mill would be short.

GEOLOGY

The country rock here, as elsewhere in this region, is quartz monzonite which is like that already described. This is cut by a quartz vein 2 or 3 feet wide, which can be followed on the surface of the ground for 600 feet. The writer was unable to find any copper in the vein. There is some pyrite and considerable molybdite with the molybdenite. The occurrence of the ore is noticeable in that it is found chiefly in bands which are parallel to the dip of the vein. Some of these bands of nearly pure molybdenite are from one-eighth to one-fourth of an inch thick. Most of the ore occurs in this form, but considerable is found as small grains and crystals scattered through the vein. A sample which represents the grade that could be easily procured by rough sorting, assayed 1.05 per cent. molybdenite.

It is understood that this property will be prospected more thoroughly during 1918.

The Emma H.

On top of Gold Hill, at an elevation of 12,000 feet, about three-fourths of a mile west of the saddle where the road crosses the divide, Major H. S. Ehrman and his associates have three claims: The Emma H., Emma H. No. 2, and the Cloverdale Consolidated No. 2. These claims run in a general north-south direction, the south ends extending down toward Quartz Creek, well below timber line.

Most of the development work has been done on the Emma H, where there are a 45-foot inclined shaft, a 75-foot shaft and several open cuts.

A quartz vein about three feet wide with well-defined walls is exposed in the 45-foot shaft and in a cross-cut from that shaft. The ore is associated with considerable pyrite, but there is said to be no chalcopyrite in the vein. Parallel with the molybdenite vein and about 25 feet away there is another quartz pyrite vein which carries gold, silver and some galena.

No molybdenite has ever been shipped from this property, but it is probable that there is a considerable amount of low-grade ore available.

The Ida May Claim

This claim is now owned by Messrs. Peeters and O'Brien, of the Palace Grocery Company, Denver. It is situated right on top of Gold Hill near the saddle where the wagon road crosses the divide.

This property has been developed for tungsten (hubnerite) rather than molybdenite, for hubnerite is found in considerable quantities in a large quartz vein which strikes S. 30° W. Some molybdenite is found in this vein, and more in another which crosses the hubnerite vein not far from the road. When the property was examined, in July, 1917, it was not sufficiently developed to give any idea of the extent of the molybdenite deposit.

The Monitor Claim

About a mile from the top of Gold Hill on the road toward Tincup is the Monitor Claim which is owned by George Norwood and associates, of Pitkin.

Here, as in the other deposits on Gold Hill, the country rock is gray quartz monzonite. The Monitor Vein is probably the same as the Ida May. Hubnerite occurs in some rich streaks. One specimen assayed 27.46 per cent Wo_3. Small amounts of molybdenite, pyrite, and galena are also found in this vein.

Very little development work has been done and most of the old work has caved, so it is impossible to make any accurate estimate of the strength of the vein and the character and extent of the ore. The occurrence of molybdenite with its associate minerals is, however, interesting and it is entirely possible that paying quantities of both hubnerite and molybdenite will be found in this region. Both will undoubtedly be low-grade ores, but if the molybdenite is free from copper and the hubnerite free from phosphorus, as is the case with that tested by the writer, these minerals may be of considerable value to the owners of the claims.

LAMPHERE LAKES DEPOSIT

About seven miles due north of Ohio City there is a deposit of molybdenite, owned by Messrs. George H. Carter and Herman Hudler, of Ohio, Colo. This deposit is situated about 100 yards N. 60° E. of the outlet of upper Lamphere Lake at an elevation of 11,500 feet. It is reached by a wagon from Ohio, which is the nearest railroad station, or from Pitkin. From Ohio the road is very good as far as the foot of the mountain, a mile north of the Gold Links Mine. From this point on to the deposit the road is new and is rough, steep, and in many places on swampy ground.

The surrounding country is mountainous with high relief and rough topography.

GEOLOGY

The country rock in the immediate vicinity of the deposit is a light-colored, fine-grained pre-Cambrian quartzite which cuts pre-Cambrian gneiss and schist. The granite in turn is cut by many large white quartz veins. These are very variable in size and are peculiarly distributed through the country rocks. One great vein 60 feet wide seems to be the center of mineralization. It has been exposed for 150 feet along the strike. Veins extend out in all directions from this main vein. Part of the surface has been covered with a thin coating of glacial debris, but in many places this has been removed by prospectors. Altogether at least an acre of ground is known to be included in this net work of veins.

Along the borders of large and small veins alike, there are long, narrow, mineralized bands, which consist of iron-stained muscovite, molybdenite and molybdite. Most of the molybdenite occurs as crystals, but there are some fine-grained facings which cover an area of from 4 to 6 square inches. The crystals vary in size from the diameter of a common pin up to three-fourths of an inch across. There is a pronounced radiated structure in nearly all the crystals that have been examined.

DEVELOPMENT

To date, about a dozen surface cuts have been dug to show the nature and extent of the deposit. The largest of these is 40 feet long and nearly as wide. All are shallow.

Since the ore is found almost entirely in pockets, which are separated by lean streaks, it is impossible to get average samples from the whole deposit. Small amounts of relatively high-grade (that is, 2 or 3 per cent) ore could be produced by careful sorting. It is doubtful if the whole deposit would run more than one-fourth, or possibly one-half, of one per cent.

It seems evident that the deposit is in the form of a "pipe," similar to deposits in Australia. These may have considerable depth, and it is possible that prospect shafts on some of the most promising-looking veins might uncover ore of more value than that which appears at the surface.

A small amount of ore has been mined and shipped from this property, but apparently it was too low grade to pay. Unless prospecting along the lines indicated in the preceding paragraph should reveal more and better ore, it is improbable that this deposit will become commercially important.

There is plenty of wood close to the property, and the Lamphere Lakes make available enough water for any milling or mining operations that may be demanded in case ore is found in large enough amounts to make the deposit workable.

CROSS MOUNTAIN REGION

Mr. William Waugh, of Gunnison, reports molybdenite from Cross Mountain, in Taylor Park between Gunnison and Tincup.

Small specimens, said to come from this region, showed flaky molybdenite in quartz with no pyrite and no copper. The extent of the deposit and the grade of the ore are unknown.

SPENCER DEPOSIT

Mr. T. C. Moritz, of Paonia, has very kindly furnished the following notes regarding a deposit near Spencer:

"Near the old town of Spencer is a lead showing from 3 to 5 per cent molybdenum in granite. There is also good tungsten in this neighborhood. This deposit is about 12 miles south and west of Iola, on the east side of the Cebolla, in a gulch called Wild Cat Gulch. The molybdenum ore shows signs of copper."

This claim is said to be owned by Mr. Pat Trainer, of Iola.

The writer has not been able to get further information regarding this deposit.

PARADISE PASS DEPOSIT

Mr. Charles Daniels, of Salida, has a molybdenite deposit on Paradise Pass, about 12 miles northwest of Crested Butte, and 7 miles from the Smith Hill Mine.

The deposit was not visited by the writer, but according to Mr. Daniels there is a large deposit of low-grade ore here. A sample of the ore furnished by Mr. Daniels shows considerable very fine-grained molybdenite in a quartz vein. Considerable pyrite is found in the vein, but no copper. The country rock is said to be granite.

No development work has been done on this deposit, but there are numerous outcrops within the limits of the two 600 by 1,500-foot claims, which have been located by Mr. Daniels.

The elevation at these claims is about 11,500 feet. There is said to be plenty of timber and water near the property.

THE TREASURY MOUNTAIN DEPOSIT

On the southwest slope of Treasury Mountain, at an elevation of 11 500 feet, there are molybdenite claims which are owned by John O'Toole, of Denver, and C. S. Robinson, of Crested Butte. These claims are about nine miles southeast of Marble, and are reached by a poor trail that branches off from the electric railroad near the Yule Marble Quarries. A trail also leads to these claims from Crested Butte.

The region is rough and mountainous. The maximum relief is about 2,000 feet. There is considerable water in Yule Creek, and there is plenty of good timber within a short distance of, but somewhat below, the property in question.

GEOLOGY

This region was visited by the writer in July, but little could be learned of the ore bodies, for they are exposed only in small open cuts which were filled with snow at the time.

The country rock is pre-Cambrian gneiss, schist and granite. Molybdenite occurs as small flakes scattered through small white quartz veins, and also as thin seams or coatings in the fractured quartz. There are two veins here, one of which averages 10 inches and the other about 20 inches in width. Both strike nearly north and south. Specimens of the ore, which were furnished by Mr. Joe Barnes, of Marble, assayed 0.408 per cent MoS_2. It is probable that the veins are too small and the grade of the ore is too low to allow the development of a workable body of ore in a deposit which is as inaccessible as this one is, for it would be a very expensive and difficult matter to build a road to the region from either Marble or Crested Butte.

HINSDALE COUNTY

The I. D. A. Claim

Mr. Robert Wagner, of Lake City, has a molybdenum claim about 3 or 4 miles north of Lake City. The elevation of the claim is about 9,500 feet. It is situated about a mile west of the railroad.

The country rock is a dark-gray, fine-grained rhyolite, which is cut by quartz veins. One vein which contains some molybdenite strikes N. 55° E. and is vertical. Three open cuts aggregating 25 feet in length have been made on the vein. Small flakes of molybdenite and an occasional spot of molybdite are found, but the ore is not present in commercial quantities. Some pyrite is found in the vein.

The country is rough and the relief is very high.

There is no water which could be regarded as a permanent supply within half a mile of the deposit. There is fine timber in abundance, close at hand.

On the whole the showing at this deposit is not at all encouraging.

SHERMAN DEPOSIT

About 12 miles south of Lake City, near the old mining camp Sherman, there is an undeveloped molybdenite deposit owned by Mr. John Gavin, of Lake City.

The deposit was not visited by the writer, but it was described to him by Mr. Gavin.

The country rock is granite. This is cut by a large pegmatite dike which carries occasional large flakes of molybdenite. The ore is pockety and does not occur in large enough amounts to be commercially valuable.

HUERFANO COUNTY

MOSCA PASS

Mr. H. A. Aurand examined a molybdenite deposit at Mosca Pass and the substance of his notes follows: Mosca Pass can be reached from Hooper or Mosca, stations on the San Luis Valley division of the Denver & Rio Grande Railroad. The distance is about 25 miles from either station, and travel is very slow on account of the sand.

About 300 yards east of the pass and on the north side of the road is a small quartz vein ten inches wide, in pegmatite, which contains some molybdenite. The vein strikes N. 27° W. The dip is 90°. Two small openings have been made on the vein, but no real development work has been done. The proposition is believed to be too low grade to be of economic importance.

GRAND COUNTY

RADIUM

It is understood that there is a deposit of molybdenite near Radium, which is owned by Mr. H. S. Porter, of that town. The extent and value of the deposit are not known.

LA PLATA COUNTY

EAST SILVER MESA

Mr. C. M. Ayers, of Durango, reports molybdenite from his Oregon No. 1 and No. 2 claims, which are on East Silver Mesa, about nine miles from Needleton and within 2,000 feet of Lake Lillie. The claims join the Pittsburg Mine on the south. They are reached by a wagon road, five miles from Needleton, a station on the Durango-Silverton branch of the Denver & Rio Grande Railroad, to Chicago Basin, and by a good trail from there to the property.

The topography is mountainous, with high ridges and glaciated valleys. The relief is high. Timber-line in this region is at an altitude of about 12,000 feet, and the Oregon claims are 400 or 500 feet above timber-line.

Very little work has been done on these claims, and that has been on veins which contain lead and zinc. About a dozen shallow shafts have been sunk on quartz veins in the gray granite country rock, but the deepest one is 32 feet. Some four-inch quartz veins have been found which contain molybdenite. The mineral occurs in small bunches, facings, and single crystals. Assays of these four-inch veins gave an average of 2.1 per cent MoS_2, according to Mr. Ayers. Very small samples which he gave to the writer contained 1.156 per cent molybdenite. Mr. Ayers expects to do more development work on his ground during the summer of 1918. He already has a good cabin and a blacksmith shop on the property.

VALLECITO BASIN

About seven miles from Needleton, in Vallecito Basin, at an elevation of about 12,600 feet, there are said to be very good surface outcrops of veins which contain molybdenite on claims owned by John Bloom, of Durango. The vein is said to be entirely undeveloped. It strikes nearly due north and stands nearly vertically. Specimens given the writer by Josiah Moore, of Rockwood, showed white quartz vein material in gray granite. Bunches of flaky molybdenite from one-fourth to one-half inch thick are scattered through the quartz. Considerable muscovite is associated with the molybdenite. There is no pyrite and no copper. The size of the vein is unknown. It is said that there is plenty of wood and water half a mile away.

LARIMER COUNTY

ST. CLOUD DISTRICT

Small amounts of molybdenite have been found in the Iron King Mine, which is on Prairie Divide, about 4 miles south of Cherokee Park (St. Cloud) postoffice and about 40 miles northwest of Fort Collins. This property is owned by E. M. Bartlett, of Cherokee Park, and Mrs. L. M. Hill, of Denver.

The relief here is very low. Prairie Divide is a broad, nearly level plateau, which lies between two of the headwater branches of the Cache La Poudre River. The elevation above sea level is 8,000 feet.

The property is reached by an auto road from Fort Collins. All but the last four miles of the road is very good.

The country rock in this region is an even-textured, medium-grained biotite granite, which contains an abundance of pink orthoclase.

There are two shafts on the property, but both were full of water. Consequently, only a superficial examination of the deposit could be made. According to Mr. Bartlett, one shaft is 35 feet deep. At the bottom there is a 10-foot drift, which runs N. 60° W. on the strike of the vein. Chalcopyrite, sphalerite, large quantities of magnetite and traces of molybdenite are found in the vein. A few feet west is a 45-foot shaft, with a 25-foot drift at the bottom. This is on the contact of granite and a coarse pegmatite dike. Molybdenite is found as small, irregular grains, and aggregates in pockets in the pegmatite. Some of the individual flakes are half an inch in diameter, but most of them are much smaller.

One hundred yards south of the Iron King is the Copper King group, owned by Mr. Bartlett, P. J. McIntyre, and associates, of Denver. This is a copper property, which contains some sphalerite and traces of molybdenite.

The molybdenite in both of these properties occurs in too small amounts to be of commercial value.

MESA COUNTY

In June, 1918, R. C. Coffin, of the Colorado Geological Survey, examined molybdenite claims in Unaweep Canyon, which are owned by R. U. Gavette, of Grand Junction, and R. Collinson, of Whitewater. Mr. Coffin placed his notes and a complete set of specimens of the ore and the country rock at the disposal of the writer, and the following statements are based on these data:

The Gavette Claim

Mr. Gavette's claim is located 29 miles from Whitewater, near the Casto ranch, on the north side of Unaweep Canyon, at an elevation of 7,500 feet.

The rocks in the immediate region of the deposit consist of pre-Cambrian schists, which carry considerable quartz and mica or hornblende, hornblendite and pegmatite dikes of later, but undetermined age that cut the pre-Cambrian complex in a general east-west direction. The hardness of these dikes is much greater than that of the country rock and they form conspicuous geologic and topographic features. The dikes range from 1 to 50 feet in width, and some of them can be traced for 5 miles.

Molybdenite is found in a dike of coarse, gray biotite granite, which runs at right angles to the general trend of the pegmatite dikes. The outcrop has been traced for 200 feet, but the conditions are such that the vein may extend for a much greater distance. The width of the dike varies from 2 to 5 feet. Short stringers leave the main dike and pinch out in the country rock. Most of the molybdenite is found near the contact of the dike and the country rock.

The molybdenite occurs chiefly in isolated crystals and small masses, which range in size from one-fourth to one-half an inch in diameter. At the time Mr. Coffin examined the property there had been practically no work done on the deposit, and the samples, which were from the surface, showed only very low-grade ore. In a letter written soon after this examination, Mr. Gavette stated that he was down four feet on the vein and that he had uncovered some very good ore.

The Collinson Claim

The claim owned by Mr. Collinson is about two miles northeast of the Gavette property. This deposit is also on the north side of Unaweep Canyon, and is at an elevation of about 7,700 feet. It is about 1,200 feet above the bottom of the valley.

The country rock here is essentially the same as that at the Gavette claims, except that there is rather more granite in the vicinity of the Collinson property.

The vein is composed of coarsely granulated white quartz. Occasional flakes of molybdenite are found in the vein, but the surface showing is not at all encouraging. The vein strikes N. 30° W., and is vertical. It can be traced for more than one mile. Its width varies from 12 to 18 inches.

Both of these claims are well situated, not far from the Whitewater-Gateway stage road. There is plenty of water near at hand, and the lateral streams that flow into Unaweep Canyon could be utilized for hydro-electric power purposes if there were a demand for the power. Timber is also available, and in general the natural conditions favor cheap development if ore bodies of sufficient size are found to warrant their exploitation.

MONTEZUMA COUNTY

Mr. H. H. Brown, of the Allard Mining Company, has reported molybdenite from Giles Mountain, near Mancos.

The specimens he submitted show fine-grained molybdenite and molybdite in what appears to be a quartzite. The samples, it is estimated, will run 2 or 3 per cent MoS_2. No work has been done on this deposit, and its extent and value are not known.

OURAY COUNTY

IRONTON DEPOSITS

The Irene

Messrs. G. C. McGee, of Ironton, and A. E. Ackerson, of Ouray, have a molybdenite claim, the Irene, which is situated about half a mile north of Ironton, 400 feet above and parallel to the creek.

The country rock is the Silverton volcanic series. It is cut by a quartz vein, which is from one to two feet wide, and which carries pyrite, traces of gold and silver, 7 per cent lead and small amounts of molygdenite. The vein dips at a high angle to the west and strikes north and south. The molybdenite is fine-grained, and is intimately mixed with quartz. Considerable molybdite is found in soft streaks in the vein, especially along the walls. It is highly mixed with quartz.

The vein has been opened by a tunnel for 50 feet. The vein is very variable in thickness and the ore in the vein is also variable in amount. Samples of the whole vein are said by Mr. McGee to have assayed 1 per cent molybdenite, but samples furnished by him to the Survey only assayed 0.364 per cent. MoS_2. On account of so small a vein, and ore of this grade, it is probable that the vein cannot be successfully worked for the molybdenite alone. If the lead ore is rich enough and a suitable process devised for the economical separation of the lead and molybdenite, it may be that the property can be worked at a profit.

The Jumbo No. 2

This claim is located near the creek, about one-fourth of a mile west of Ironton. There is a tunnel, 150 feet long, which runs S. 70° W., and 50 feet from the portal a drift 120 feet long has been run to the northwest along an alleged molybdenite vein. The streak which is supposed to carry the ore is only 2 or 3 inches wide, and in it no molybdenite is to be seen. There is a little molybdite and probably some molybdenite that cannot be recognized in the hand specimen, but the assay returns are only 0.338 per cent for the molybdenite present.

Other Regions

Molybdenite has been reported from Poughkeepsie Gulch and from Sneffels and other regions near Ouray, but, so far as is known, no active prospecting has been done for it, except at Ironton.

CORNER OF OURAY AND HINSDALE COUNTIES

ENGINEER MOUNTAIN DEPOSITS

Near the junction of Ouray, San Juan, and Hinsdale counties, on Engineer Mountain, Fred Richter, of Ouray, has a claim in which there are traces of molybdenite. According to Mr. Aurand, who examined the property, there is not enough ore available to make the deposit worthy of further investigation.

PARK COUNTY

LAKE GEORGE DEPOSITS

Molybdenite has been reported from several properties a few miles north of Lake George, the most important of which are the Boomer, the Apex, and the Redskin mines. The latter is the only one which has been developed for molybdenum. The others are said to have small amounts of molybdenite present with copper ores.

The Redskin Mine

This property is located near Tarryall Creek, about eight miles north of Lake George, a station on the Colorado Midland Railroad. The country is rough and the relief rather high. The elevation at the mine is about 8,600 feet.

At the time the writer visited the property, in July, 1917, the mine was nearly full of water and no underground examination could be made. The following notes, therefore, are derived from data collected on the surface, and from statements made by officers of the U. S. Rare Minerals Company.

This company, whose offices are in the Gas and Electric Building, in Denver, has a three-year lease on the property. It took over the property in June, 1918, and immediately proceeded to put up cabins and mine buildings, and to install a compressor, hoist, and other necessary mine machinery. At this time there was one shaft, 150 feet deep, and a little drifting, which, with a small amount of surface work, represented the only development work done. The company has driven the shaft another 100 feet or more and has done some more drifting.

The geology of the region could not be completely worked out from the surface, but the country rock seems to be coarse, pink, feldspathic granite, which has intruded gray biotite granite and quartz-mica schist. Along the borders of the intrusive pink granite are deposits of molybdenite, which in some cases thoroughly impregnates the quartz-mica schist. The ore is very discontinuous, occurring in pockets and bunches, some of which are quite rich. Samples taken from the mine have assayed as high as 10 per cent MoS_2, but the average tenure is probably about 3 per cent. Only small commercial shipments have yet been made. It does not appear, from the recent prospecting that has been done, that a continuous vein has been found, and the future of the property is in doubt.

Van Epps Claim

E. E. Van Epps, of Red Cliff, has a molybdenite claim almost at the head of the South Platte River. In a direct line this claim is about 6 miles northwest of Alma, but by the road and trail which follow the river it is 10 or 11 miles. The Hoosier Pass road, which is a very good one, may be followed from either Breckenridge or Alma as far as the almost deserted mining camp Montgomery. From there on the road is almost impassable for a wagon, and it is better to use a saddle horse.

A tunnel on the property is one-eighth of a mile away from, and on the north side of, the creek, at an altitude of 12,400 feet. There is plenty of water in the creek, but there is no wood for timber or fuel within a distance of one or two miles.

The country rocks are pre-Cambrian gneissoid granite and schist. These are crossed by large pegmatite dikes, some of which are considerably mineralized on their borders. Along a vein on the borders of one of these dikes a tunnel has been driven N. 80° W. for 150 feet, then northerly for 50 feet. Considerable pyrite, some chalcopyrite and traces of molybdenite are found in the vein. On the face of the cliff at the mouth of the tunnel near the contact of pegmatite and gneissoid granite, and not far from a 2-foot black basic dike which cuts both the granite and pegmatite, there are considerable quantities of molybdenite which can be traced for 40 or 50 feet. It is not in a well-defined vein, but occurs only as grains and small aggregates impregnating the country rock. The amount of mineral is surprisingly large. Half a dozen chunks 2 or 3 inches across were knocked off from the country rock, crushed and sampled. The molybdenite content was 1.703 per cent. The individual grains are rather large and thick, averaging perhaps one-third of an inch in diameter. There should be more prospecting done on this deposit to prove its extent. It may not amount to anything, but it is quite possible that a vein may be found which will be well worth developing.

White Swan Claims

E. O. Nippert, of Alma, has located a group of seven claims, near the saddle between Democrat and Cameron Mountains, on the divide between the head of Buckskin Gulch and the South Platte River.

The claims can be reached either by following the South Platte River to its very head, or by going up Buckskin Gulch from Alma. The distance the latter way from Alma is about eight miles. There is a wagon road as far as the foot of the hill below the Kentucky Bell Mine, and a rough road on to the mine. A good trail leads from this mine to the claims.

The topography is very rough. The relief is high and the elevation at the claims is about 13,200 feet.

Only location work has been done here, and the ore bodies are not sufficiently developed to warrant positive statements regarding the extent and value of the ore. A large pegmatite dike, 20 feet or more wide, strikes N. 70° E. and cuts country rocks of gray granite and mica schist. In the quartz portions of this pegmatite dike and on the contacts of the dike and the country rock there are some very rich pockets of molybdenite. The mineral occurs in crystals and bunches of varying sizes up to an inch and a half in diameter. Much of the float on the side of the mountain contains molybdenite, and it is probable that there are ore bodies of considerable size in this region.

On account of the high altitude and the distance (2 miles) from timber and (1,500 feet) from water, this property will be an expensive one to work, but the surface showing is favorable and it should be prospected further.

The Humbug Claims

George W. Shelton, of Alma, has located several claims near the head, on the west side, of Buckskin Gulch. These claims are about four miles from Alma, and are situated near the creek which flows from Lake Emma, at an elevation of 12,100 feet.

The country rock is a coarse, white, mica-poor granite. This is cut by massive quartz veins which carry molybdenite and pyrite. Three veins have been opened up by shallow surface cuts, tunnels and shafts. Two veins strike N. 75° E. and one, which is between the other two, strikes due east. All are nearly vertical.

These veins are about 150 feet apart. They vary somewhat in width. The largest one is 5 feet wide, and the smallest is about 12 inches. All the veins are essentially alike in so far as their mineralization is concerned. All carry molybdenite in fine grains and facings irregularly scattered through the deposit. Considerable pyrite accompanies the molybdenite. Copper was seen in one vein, and some lead and zinc occur in the vein farthest south. The grade of the ore when the whole vein is considered is in every case low, although rich streaks can be found. Assays of average samples taken from the vein yielded less than 1 per cent of MoS_2.

It is possible that further prospecting would result in the discovery of larger deposits of molybdenite in this region, and it should be done, for the accessibility of the deposits, their nearness to water and timber and the topographic conditions, with high relief, all favor economical development.

The Crescent Mine

This mine is owned by the F. M. Woods Investment Company, of Colorado Springs, Jesse Robinson, of Cripple Creek, and Alfred B. Dell and his brother, of Guffey. There are three claims in the property, which is situated in the Freshwater Mining District about three miles southwest of Guffey. Guffey is in the southern part of Park County, about 20 miles west of Cripple Creek and 14 miles south of Howbert, a station on the Colorado Midland Railroad. There are good roads to Guffey and to within half a mile of the property, from both Howbert and Cripple Creek.

The relief of the region is rather high. The altitude at the mine is 9,100 feet, but the mine is nearly on top of a hill, so all the work must be below the present site of the shaft. The nearest available water is nearly a mile away and 600 feet below the mine. Timber is rather scarce in this region and there is practically none on the claims.

GEOLOGY

The country rock in this region is chiefly mica and fibrolite schist, into which have come intrusions of coarse, gray, hornblende granite. These rocks are cut by felsite dikes, and at least by one basalt dike which does not appear at the surface.

The shaft was nearly full of water when the property was visited, therefore information regarding the occurrence of the ore, etc., had to be obtained from an examination of the material on the dump, and from questioning men who have worked in the mine. The workings consist of a vertical shaft 300 feet deep, with a 40-foot drift at the bottom, another one about the same length at the 150-foot level and drifts 20 feet to the southwest and 17 feet to the northeast at the 100-foot level. On the dump there is considerable ore rich in sphalerite and galena, which is said to contain values in gold and silver. There is also some zinc ore, without the other minerals, which is said to assay 15 per cent zinc. Molybdenite is said to occur only in the drift at the bottom of the shaft. Apparently the amount present there is very small, for a careful search of the dump failed to show any considerable amount of this ore. What was found occurs as thin coatings in the fractures of quartz veins and in the gneiss and schist country rock. Chalcopyrite is associated with the molybdenite, and also with all the other minerals found on the dump.

Judging by the information given by Mr. Dell and from the character of the ore on the dump, it seems improbable that molybdenum will be found in commercial quantities in this property.

PITKIN COUNTY

The Green Horn Claim

The Green Horn Claim is owned by F. E. Kendrick, Mrs. A. J. O'Leary and H. F. Foley, of Leadville. It is situated about 20 miles southeast of Aspen, on the north side of the creek, near the head of Lincoln Gulch, at an elevation of 11,600 feet. There is a good wagon road from Aspen as far as the mouth of Lincoln Gulch. The rest of the way the road is poor, but it could be improved at a comparatively small cost if there should be sufficient mining activity in the region to make such action desirable.

Only surface work has been done on this claim. There are several shallow cuts and one that is 20 feet long, 10 feet high and 10 feet wide. In this opening two veins, neither of which is more than a foot wide, are exposed. The larger vein dips 45° S. 35° W. The other is vertical and strikes N. 85° W. They join within the limits of the cut. A third small vein, which has been exposed in two or three shallow cuts, strikes S. 10° W. and presumably crosses the other veins, although it is not known to do so.

Molybdenite occurs with considerable pyrite and with small amounts of molybdite in all of these quartz veins. Its main occurrence is as black amorphous facings, but crystalline material is sparingly found scattered through the veins. Specimens which represent the average of the veins assayed 0.947 per cent MoS_2.

The country rock is granite which has been much fractured. Higher up on the mountain side float of mica schist and an intrusive, which is probably trachyte, were found. It is quite possible that there is some connection between the intrusion and the molybdenite veins, but not enough work has been done to demonstrate this point.

There is plenty of timber near, and Lincoln Creek furnishes a large permanent supply of water. The topography is such that there are good tunnel and mill sites. Altogether the conditions are very favorable for mining and milling if future development discloses the necessary amount of ore of high enough grade to be economically handled.

The veins are so small and the ore now exposed is so low grade that the deposit is not regarded as a promising one. It is believed, however, that it would be desirable to sink prospect shafts on the junctions of the veins, where there is the greatest likelihood of striking richer ore.

ROUTT COUNTY

FARWELL MOUNTAIN

A property which contains some molybdenite is owned by the Farwell Mountain Copper Company, whose home office is at 712 St. James Street, Montreal, Quebec. The property is located on the northwest side of Little Farwell Mountain, near the head of Middle Beaver Creek. It is about five miles northeast of the town of Hahn's Peak. The elevation at the tunnel is 9,600 feet. At one time there was a good wagon road all the way from the main Steamboat Springs-Hahn's Peak road to the mine, but it has not been used for several years and has become so badly washed that the last mile to the mine is now impassable to wagons.

DEVELOPMENT

The property has been developed by a 1,000-foot tunnel which has been driven N. 17° E. into the hill, and by several prospect shafts which were sunk higher up on the mountain. All the prospecting done so far has been for copper, veins of chalcopyrite having been found, which outcrop at the surface in a number of places. No important veins were found as the tunnel was driven.

GEOLOGY

The country rocks are pre-Cambrian granite, gneiss and schist, with the latter predominant. Many strong pegmatite dikes cut these rocks. They were formed before the processes which caused the metamorphism of the country rocks were completed, and in consequence the pegmatites show evidence of considerable movement.

One large pegmatite dike was crossed by the tunnel about 200 feet from the portal. Molybdenite occurs on both sides of this dike, and it impregnates the country rock for several inches. The mineral occurs almost entirely in grains which are from one-fourth of an inch up to more than an inch in diameter. Some grains are an inch thick, but most of them are very thin when compared with their surface area. Considerable muscovite occurs with the molybdenite, and it will interfere more or less with the concentration of the ore if it is ever milled. The ore is entirely free from molybdite, pyrite and copper minerals. The molybdenite occurs entirely in pockets which are separated by barren rock.

The value of the whole dike would be very low, but because of the occurrence of the mineral in large grains it can be easily cobbed out and separated from the gangue and the country rock. Assays of roughly sorted material yielded 1.56 per cent MoS_2. It would be possible to sort the ore and get a product which would run from 5 to 10 per cent MoS_2, and whenever the value of 60 per cent MoS_2 concentrates are $2.00 a pound or more, it is believed that this ore might be broken out and handled at a profit.

Absolutely no attempt has been made to develop this deposit, therefore its extent is unknown. A fault cuts through the pegmatite dike, which causes it to appear to pinch out in the roof of the tunnel. The fault could not be traced, on account of the lack of development work, and its effect on the deposit is not known.

The presence of several small surface outcrops which contain molybdenite, coupled with the rather pronounced mineralization along the walls of the dike mentioned above, lead to the opinion that there may be a larger body of ore in this neighborhood, which might be found if strict search were made.

Near the breast of the tunnel there are said to be several small quartz veins which show some molybdenite with chalcopyrite. None of these veins are of commercial size and their mineral content is low.

Both wood and water are fairly accessible. There are comfortable living quarters near the tunnel for a small force of men.

SLAVONIA MINING DISTRICT

Several occurrences of molybdenite have been reported from this district, but no deposits have yet been developed on a commercial scale.

Mr. G. H. Franz, of Clark, reports a promising occurrence of molybdenite on Gilpin Creek. This property is about 15 miles from Clark and is situated on the east side of a spur of the Sawtooth Range at an elevation of about 10,000 feet.

There are said to be several veins in this region. One quartz vein 8 feet wide contains considerable low-grade ore. Another 18-inch vein has rich pockets of molybdenite. No other metallic minerals occur in these veins, according to Mr. Franz. Altogether there are at least 5 claims within a distance of 2 or 3 miles which show molybdenite. The country rock is granite.

Part of these claims are said to be readily accessible to the auto road from Clark. Others are 3 or 4 miles from the road.

Mr. M. A. Hoskinson, of Oak Creek, has a molybdenite claim in the Slavonia District, situated 10 or 12 miles from Clark on a branch of the middle fork of Elk River. It is said that one can drive almost to the property with a team or an automobile.

On this claim there is a quartz vein which has been opened up by a tunnel for a distance of 30 feet. The width of the vein was not given in Mr. Hoskinson's report. The country rocks are granite and mica schist. According to the report from Mr. Hoskinson, average samples of the ore assayed 1.5 per cent MoS_2.

There is said to be a large amount of timber on and near this claim, also plenty of water power and water for mining and milling.

Mr. D. M. Wilt, of Clark, Colorado, also has molybdenite claims in the Slavonia District, but they are wholly undeveloped.

SAGUACHE COUNTY

Merideth's Claim

About seven miles northeast of Alder there is a small molybdenite deposit owned by William Merideth, of Alder, which is under bond and lease to Messrs. W. J. Candlish, J. E. Richardson, and C. W. Savery, of Denver.

The property is reached by a good wagon road which goes from Alder to within about one mile of the claim. A poor wood road and rough trail lead from the end of the wagon road to the property.

The property is located on the west side of the Sangre de Christo Range, at an elevation of 10,200 feet. The relief is high, and the topography rough and mountainous.

The ore occurs very sparingly in a small quartz vein which cuts the quartz mica schist and biotite granite country rocks.

A 10-foot shaft has been sunk on the vein, and a cross-cut tunnel 25 feet long, at the time of the writer's visit to the property, has been started near the creek 200 feet below the shaft.

The vein strikes N. 60° E. It is practically vertical, and can be followed by surface outcrops for 200 or 300 feet.

The ore exposed in the shaft is low grade, and as the vein is small, the deposit is probably not of commercial value.

Other Deposits Near Alder

Several other deposits of molybdenite have been reported from the region, but none has been developed, and all are said to be very low-grade propositions.

SAN JUAN COUNTY

CHATTANOOGA DEPOSITS

About half a mile south of Chattanooga, a station on the Silverton-Red Mountain branch of the Denver & Rio Grande Railroad, there are two groups of claims in which there is considerable molybdenite. These are the Hidden Treasure and the Gold Finch groups owned by Taylor McGrew and Lee Tinsley, of Chattanooga.

The Gold Finch group consists of six 300 by 1,500-foot claims, all of which lie just west of Mineral Creek. There are eight claims of the same size in the Hidden Treasure group and they are situated a short distance east of the wagon road.

DEVELOPMENT

The Gold Finch group has been developed by a cross-cut tunnel driven west 275 feet to the vein; drifts 30 feet north and the same distance south on the vein; an upraise 100 feet to the surface from the intersection of the cross-cut and drifts; and surface cuts which proved the occurrence of the vein for 750 feet west of the creek.

There is a combined shop and an ore-sorting room at the entrance of the tunnel.

On the Hidden Treasure ground there are several tunnels and drifts with a total length of about 1,000 feet. The vein has been opened for 600 feet, and it is said to outcrop for an additional distance of 200 feet.

GEOLOGY

In the Silverton Folio, U. S. G. S. Folio No. 120, the geologic map shows San Juan tuff on the west side of the creek and the Silverton series, of undifferentiated andesite and rhyolite flows and flow breccias on the east side. These rocks are cut by dikes of medium to coarse-grained dark-gray andesite, in which the ore bodies are found.

The veins on the two sides of the creek are very much alike. In the Gold Finch claims the whole vein is four feet wide. It is vertical and strikes nearly due north. The minerals in the vein are chalcedony, quartz, pyrite, molybdenite and some gold and silver. In many places the chalcedony, quartz and molybdenite are beautifully banded. The molybdenite is found chiefly in narrow strips in the quartz and chalcedony bands, 6 or 8 inches wide. In such cases the rest of the vein is barren. These molybdenite strips are very discontinuous, widening to 20 inches and pinching out entirely within a few feet. Most of the molybdenite is in exceedingly fine grains which are very dark gray, or entirely black. These grains are so thoroughly mixed with quartz that where they occur together the bands of the mixture have a bluish-black or black color. Pyrite is widely disseminated through the bands of quartz and molybdenite, but is not commonly found with the chalcedony.

Mr. McGrew reports assays as high as 10 per cent MoS_2 from rich bands in this vein. Average samples of the molybdenite portions of the vein (not the whole vein), taken by the writer, assayed 2.22 per cent of molybdenite.

The Hidden Treasure vein strikes N. 60° W. and is vertical. The whole vein averages about 4 feet between the walls, but the molybdenite streaks are only from 6 to 20 inches wide, including the quartz bands which alternate with the ore. The ore is very pockety. Samples from the molybdenite portions of the vein assayed 3.739 per cent molybdenite.

FUTURE DEVELOPMENT

On the Hidden Treasure vein there are good opportunities for development, for the relief is such that there is more than 1,000 feet of stoping ground.

The Gold Finch Vein does not offer so desirable conditions, because of the lack of stoping ground above the tunnel level.

It is probable that, at first, there will be difficulties encountered in concentrating the ore, but it is not believed that they will prove permanent.

There is an abundant supply of both wood and water close at hand. The transportation facilities are good and if the ore proves to be in large enough bodies, these properties should become producers.

Liberty Bond Claims

About two and one-half miles south of Chattanooga, on the east side of Mineral Creek, nearly opposite the mouth of the middle fork of the Mineral Creek, there are three claims; the Liberty Bond, Liberty Bond No. 1 and No. 2. These claims are owned by E. J. Holman, A. D. Malchus, and R. H. Hoffman, of Silverton.

The topography is rough and mountainous with high relief. The claims are situated at an elevation of 11,150 feet, about 1,100 feet above the road, on a very steep slope.

There is no single well-defined vein exposed here, but there are stringers of quartz in the Silverton series of volcanic rocks which have been uncovered for a distance of 300 feet by four shallow cuts and one 20-foot shaft. An occasional grain of flaky molybdenite with considerable pyrite occurs in these quartz stringers. Not much development work has been done, and only in the 20-foot shaft has solid rock been reached, but from present indications the ore is too much scattered and too low grade to be of commercial value.

Black Diamond Claim

Mr. J. P. Eaker, of Silverton, has located this claim on the north side of South Mineral Creek, about a mile from the mouth of the gulch, at an elevation of 10,500 feet. There is a poorly defined quartz vein here in volcanic breccia. The vein dips 65° S. 27° W. It varies in width from 2 to 12 inches. Thin flakes of molybdenite from a small fraction up to one-eight of an inch in diameter are scattered through the quartz. There is considerable pyrite, but no copper in the vein. Float has been found along the strike of the vein for 150 feet. Elsewhere the ground is so covered with slide rock that no indications of the vein have been found. Only 2 or 3 very shallow openings have been made on the vein, but the exposures of ore in these are not promising. The vein is so small and so variable, and the ore is so low grade, that there is little encouragement for further development work.

HEAD OF SOUTH MINERAL CREEK

There have been several reports of the occurrence of molybdenite near the head of South Mineral Creek. One location is said to be near the trail right on the divide between South Mineral Creek and Routt Lake, where rich float has been found. Another body of ore has been reported from the Rico side of the divide just across from the head of the creek. The Rolling M. and M. Co. has placed samples of molybdenite in the Colorado State Museum which are, presumably, from this region.

The writer has no personal knowledge of these deposits, but from all indications the ground should be thoroughly prospected.

BEAR MOUNTAIN DEPOSITS, NEAR SILVERTON

There is said to be a small deposit of molybdenite on the southwest slope of Bear Mountain about four miles west of Silverton. The deposit is owned by Edward Hollingsworth, of Silverton.

It is wholly undeveloped, and judging from the samples, which were said to have come from this property, it is too low grade to be important at this time. The samples showed thin radiated crystals of molybdenite, in a white quartz vein, but the amount of molybdenite present seems to be very small.

CASCADE BASIN

Molybdenite float that looks very promising is reported from near Molas Lake in Cascade Basin. The mineral is said to occur in lenses in large white quartz veins. Frank Deputy and James Holden, of Rockwood, are said to know of this deposit.

SAN MIGUEL COUNTY

The Molybdenum Queen and the Molybdenum Lode Claims

It is understood that until recently these claims were owned by Guy Knox, of Denver, Newton Sankey, of Ophir, and J. M. Belisle, of Norwood, Colorado.

A short time ago these men organized the Colorado Molybdenum Mining Company, and made Mr. Sankey president, Mr. Belisle vice-president, and Mr. Knox secretary and treasurer. The company is capitalized for $100,000.00, with 1,000,000 shares of a par value of 10 cents each. The company paid to the former owners 400,000 shares of stock which, valued at par, would amount to $40,000.00 for the two claims.

On August 9th, 1917, the writer, accompanied by W. J. Hawkins, of Ophir, examined the Molybdenum Queen Claim and the surrounding country. The claim is situated on the west side of Nevada Gulch, about one mile southeast of Ophir, at an elevation of about 10,350 feet.

Here there is an intrusion of granite porphyry, in which there is a more or less mineralized zone 35 feet wide, exposed on the steep face of the cliff that forms the west side of the gulch. The porphyry is cut by a great many small quartz veins which run in every direction. A majority of the veins, however, seem to trend S. 70° W. There is no sharp line between the mineralized and the non-mineralized areas. The change from one to the other is a very gradual one, and it is not possible to accurately determine the dip and strike of the deposit. As nearly as it can be determined, however, the general dip of the mineralized zone is 50° N. 20° W.

A tunnel has been started near the north side of the mineralized belt, and at the time the property was examined it had been driven for about 40 feet on a course S. 25° W. Several small, strongly pyritized quartz veins are exposed in the tunnel, but there is a striking absence of molybdenite after a point about 10 feet from the mouth of the tunnel is reached.

The molybdenite occurs in this deposit chiefly as grains and crystals which range in size from that of a common pin head up to half an inch in diameter. Most of the ore is near the sides of the mineral belt, where it occurs in quartz veins which vary in width from 1 inch to 2 feet. The veins do not seem to be all continuous and nearly all of them play out within a distance of 2 or 3 feet. There are many barren places in the veins, as well as, of course, some relatively rich ones. Pyrite is associated with molybdenite all through the deposit wherever the latter is found. Near the surface and along many fractures, molybdite is found as an alteration product of the molybdenite. No copper was seen, and no other metallic minerals are known to occur here.

Although it is possible to carefully sort out some of this ore, by hand, and get a product that may assay from 1 to 2 or even 3 per cent MoS_2, there was no considerable amount of such ore available at the time the property was examined, and the geology of the deposit does not warrant the assumption that better ore will occur with depth. It is certainly wrong to think of the whole mineral zone as being one vein, which is the impression conveyed by the prospectus recently published by the company. If the face of the deposit were properly sampled through the whole vertical and horizontal distance, the ore would run only a very small fraction of 1 per cent of molybdenite.

Both wood and water are near the property, and they would be important items if the property is to be developed. The situation of the deposit, well up on the side hill, also is favorable to easy development.

It is, however, the writer's opinion that the solicitation of funds, with which to build a mill and develop the property, is entirely unwarranted in view of the low grade and the unfavorable geological occurrence of the ore. Such solicitation could be justified only by frankly stating that the money was to be used to prospect a deposit of unknown value. And no part of the funds so raised should be used to build a mill, until the extent and value of the deposit have been fully determined and are known to be sufficient to supply a mill with the necessary quantity of ore of a workable grade.

SUMMIT COUNTY

CLIMAX (FREMONT PASS) DEPOSITS

The largest known molybdenum deposit in Colorado, and probably one of the largest in the world, is situated on the continental divide, near Fremont Pass (Climax Station), about 13 miles northeast of Leadville on the South Park branch of the Colorado & Southern Railroad.

This deposit occurs in a large mineralized zone, about one mile east of the pass near the head of Tenmile Creek, on the southwest slope of Bartlett Mountain and on the northwest side of Mount Ceresco. The full extent of the deposit has not yet been determined, but the surface area is known to be more than one-half a square mile, and the vertical range is 500 feet and probably very much more.

The country is mountainous, and the relief is high. The elevation at the top of the pass is 11,300 feet and at the top of the range between 2 and 3 miles to the east it is over 14,000 feet. There is considerable timber near the pass. Tenmile Creek furnishes quite a large amount of water, but probably not enough to supply the requirements of the concentrating mills that are now in operation, or under construction.

GEOLOGY

The geology of this region has not been thoroughly worked out and only general and tentative statements can be made at this time.

The mineral zone is bounded on the west by the Mosquito fault, which occurs about two-thirds of the way from the pass to the top of Bartlett Mountain. The fault strikes approximately N. 15° E.

On the north the boundary has not been determined. Float has been reported from points high up on the side of Bartlett Mountain and the ore is believed by some people to extend to the top of the mountain. The writer has not had the opportunity to study the geology of Bartlett Mountain, but he doubts the existence of large ore bodies far up on the mountain. It seems probable that the northern boundary is made by a strong fault that has been crossed by the main tunnel and the center drift of the Leal tunnel. It also is exposed by the drift on the Molybdenum No. 3 claim, and it appears plainly at the surface about 500 feet east of the Molybdenum No. 2 workings. Where cut by the Leal main tunnel and to center drift, the fault strikes N. 25° W. and dips 60° N. 65° E.

East of the workings of the Molybdenum No. 2 the strike is N. 40° W., and the dip is nearly vertical. So far as surface indications go, in the vicinity of the claims that are now being worked, this fault seems to mark the northern boundary of the ore.

Judging by the topography, it seems probable that a third fault cuts off the ore bodies on the east. This fault probably crosses Tenmile Creek about one-third of a mile east of the Mosquito fault. Its strike is thought to be approximately S. 50° W. If so, it intersects the Mosquito fault near Wortman, and the second fault described above, not far from the head of Tenmile Creek.

If this conception is correct the ore zone is triangular-shaped. The base, represented by the Mosquito fault, is about a mile and a half long, the height represented by the distance east along Tenmile Creek from the Mosquito fault to the junction of the other two is about one-third of a mile, while the other two sides of the triangle are represented by the faults which strike northwest and southwest respectively. It must be understood that this statement is subject to revision, when more work has been done, but it will at least suggest an hypothesis for future work.

Within the fault block there are innumerable small faults and fractures, which on the surface do not seem to have any pronounced uniformity in their arrangement. In the tunnels and drifts of the Climax Molybdenum Company, however, there are two sets of fractures which seem to be arranged, one roughly normal, and one parallel to the big fault at the end of the main tunnel. The amount of fracturing varies greatly, but it is greater near this fault than elsewhere. Typical specimens taken from the Climax Molybdenum Company's tunnel, 200 feet from the fault, show from 6 to 10 distinct fractures per linear inch of surface.

On account of the large amount of fracturing followed by the formation of innumerable quartz veins, the original character of the country rock cannot in all places be determined. It seems to have been chiefly a white, even-grained granite, poor in muscovite and ferro-magnesium minerals. However, some of the country rock seems to be a very much fractured quartzite, which may be the Cambrian ''Sawatch Quartzite,'' faulted into the present position. Before much fracturing of the country rock occurred there were large intrusions of granite porphyry (nevadite). In some cases the porphyry is fractured and highly mineralized, but in general the country rock seems to have been much more fractured than the porphyry, and mineralization has been greatest where there was the most fracturing.

The effect of the intrusion of the porphyry is problematical. Brown and Hayward[1] believe that the molybdenite is of magmatic origin and that it is directly associated with the intrusion of the porphyry. This theory may be correct, but it is the writer's belief that fracturing by the systems of faults described above is of primary importance in producing the situation favorable for the deposition of molybdenite. This inference is based on the geological conditions on Chalk Mountain just west of Climax, where there is a large intrusion of the same granite porphyry that is found on Bartlett Mountain, but no deposits of molybdenite have yet been found there.

It seems possible then that the order of events may have been: First, faulting on a great scale; second, the intrusion of the granite porphyry, accompanied by fracturing, vein filling and ore deposition; third, another period of minor fracturing and silicification.

The ore occurs as molybdenite and molybdite. The latter is found chiefly near the surface and along the larger fractures which extend down from the surface. The molybdenite occurs as exceedingly fine grains in veinlets of quartz. Much of it is so finely disseminated that it can hardly be seen with the unaided eye. It gives a blue tinge to the quartz veins which vary in intensity of color with the amount of molybdenite present. Where the rock is broken, partings are apt to occur along the veins which carry ore, thus leaving exposed their faces of nearly pure molybdenite. Most of such facings are very thin, approximately the thickness of average writing paper, but occasionally much thicker layers are found. There seem to have been three periods of fracturing and vein filling; one preceded, one accompanied, and one followed the deposition of the molybdenite. The whole mass of country rock is more or less mineralized, but certain regions, particularly those only a short distance from the larger faults, seem to be much richer than the others. There are, however, rich and lean streaks scattered all through the mineralized area. Pyrite in varying amounts occurs with the molybdenite. No copper minerals and no other metallic minerals are found.

Many samples taken from various parts of the area indicate that the rock of the whole mineralized zone will run from three-fourths of one per cent to one and one-tenth per cent MoS_2. Some rich streaks will assay as high as 2 per cent and large bodies of ore will run from 1 to 1.2 per cent. All proposed mill operations,

[1]Brown, H. L. and Hayward, M. W., Molybdenum mining at Climax, Colo. Eng. and Min. Journal, vol. 105, No. 20, 1918, pp. 905-907.

however, should be based on an ore with a MoS_2 content of from three-fourths of 1 per cent, to 1 per cent in order to insure a safe margin upon which to work. Mr. Brown, of the Climax Molybdenum Company, states that the ore treated at the company's mill averages almost exactly nine-tenths of 1 per cent MoS_2.

DEVELOPMENT

Three companies are now developing this deposit. They are: The Climax Molybdenum Company, The Molybdenum Products Corporation of Denver, and the Pingrey Mines & Ore Reduction Company of Leadville. These companies own, or control through leases, practically the whole mineralized zone.

When the extent and value of the deposit became well known there was a great rush of people into the district, who desired to locate claims. Unfortunately there have been many charges and counter-charges of: False entry, failure to do assessment work, claim jumping, etc., which it will take the courts years probably to settle.

In addition there has been and still is a dispute over the position of the Lake-Summit County boundary line. It is understood that at first the line was not surveyed, but was located by agreement. In 1917 it was surveyed by the proper officials of the counties concerned, and the line was declared to be correctly located and was not changed. This left all the richer molybdenite deposits in Summit County. The Lake County commissioners, however, have protested the survey, and it will take a court decision and probably a re-survey to settle the matter.

There is also some question regarding the ownership of the water in the upper part of Tenmile Creek.

The Pingrey Mines and Ore Reduction Company

Of the three companies on the ground, the Pingrey M. & O. R. Company of Leadville was the first to concentrate any large amounts of the Climax ore. In 1916 they treated nearly 1,000 tons of ore, about 600 tons of which came from the Molybdenum No. 2 claim owned by C. J. Senter, while the other 400 tons came from the dump of the Leal tunnel, which is now owned by the Climax Molybdenum Company. The ore was treated in a modified zinc concentrating mill at Leadville. The results of the treatment are not available for publication, but it is understood that the ore was crushed to 60 mesh, concentrated by oil flotation, and a marketable product procured. The crude ore is said to have averaged about 0.75 per cent MoS_2.

It is understood that this company will remodel the present mill, or build a new one at Leadville, if the court awards them the property which they claim. At the present time they are carrying on development work on the Rare Metal Claims Nos. 3 and 6, which are located south of Tenmile Creek, and are also developing the Molybdenum Claims Nos. 2 and 3, on Bartlett Mountain. They have done the only important prospecting south of the creek, and have demonstrated beyond any question that the ore continues across from Bartlett Mountain to the west slope of Mount Ceresco. In March, 1918, their tunnel on the Rare Metals No. 6 claim was in 310 feet; 250 feet was in mantle rock and the rest of the distance in granite. For the last 25 feet to the breast, the granite is fractured and shows some low-grade ore. About 500 feet north of No. 6 is the Rare Metal Claim No. 3. Here there was a tunnel 220 feet long, when the property was visited by the writer in March. About 145 feet from the portal the first ore is seen. This continues into the mountain and the value increases with depth. The country rock, fracturing, occurrence, and values of the ore seem to agree closely with those on Bartlett Mountain.

The Climax Molybdenum Company

The Climax Molybdenum Company owns more property in the district than does either of its competitors, and it is the first of the three companies to build and operate a concentrating mill on the ground.

This company has done a large amount of work on a group of five claims: the New Discovery, the New Discovery No. 2, Mountain Maid, Mountain Maid No. 2, and the Mountain Chief. They started work at the mine in August, 1917. At that time there was one small tunnel (the Leal) about 900 feet long. By the end of March, 1918, they had enlarged the original tunnel and had driven an additional length of tunnels and drifts of more than 3,000 feet. They had under way an extensive system of shrinkage stopes and were mining 250 tons of ore a day with little effort. It is estimated that 6,000,000 tons of ore is now blocked out of this level. A new double-track tunnel has been started about 200 feet vertically below the main workings. Through it another large amount of ore will be blocked out.

At the present time the ore is handled as follows: It is broken in the stopes, dropped to the tunnel level and trammed by man power to the mouth of the tunnel where it is dumped into large ore bins. From these bins it is carried by an aerial tram, down the hill about 400 feet to the crusher bin. It is then crushed by a Blake Crusher to pieces four inches or less in size. The crushed ore is carried 100 feet on a belt conveyor to another ore bin. This bin is 5,000 feet distant from, and 500 feet higher than, the mill which is located about 200 yards from the top of Fremont Pass.

A Leschen tram is used to bring the ore to the mill. The buckets have a rated capacity of 1,000 pounds, but actually carry about 850 pounds of ore. The capacity of the tram is said to be 1,000 tons every 24 hours.

The ore is dumped by a tram tender into ore bins, from which it is fed automatically to a belt that carries it to a Chalmers 6 by 6 ball mill where it is ground to eight mesh. After leaving the ball mill it is automatically sampled, elevated, and classified in a Dorr classifier. The fines which pass a 60-mesh screen go directly to the oil flotation system. The middlings and oversizes go back to a 6 by 10 Chalmers ball mill. In this mill the ore is ground to 60 mesh. After leaving the mill it is again elevated and classified. The fines go to the flotation plant direct and the oversizes back to the mill that they just left.

The flotation plant consists of 5 Janney and 5 Callow cells. The Janney machines are banked with about a 3-foot drop between each 2 cells. The whole feed goes into the upper machine. Tails from this form the heads for the second and so on through four machines. Tails from the fourth cell go out of the mill. The concentrates from each of the first four machines flow to the fifth, where they are cleaned. From this cleaner the concentrates are pumped to the first of a three Callow cell series. The concentrates from the first go into a second, and from the second to the third cell. The tails from the fifth Janney machine, the cleaner, and from the three Callow cleaners form the middlings which are pumped back to the first Janney, where the process is repeated.

The concentrates from the third Callow cell go to vanners to separate the pyrite from the molybdenite. The molybdenite concentrates then go to large tanks where they are laundered and settled. From these tanks they are drawn off and dried on steam plates. Considerable water is left in the concentrates. After leaving the steam plates the concentrates are doubled-sacked and are then ready for shipment.

When the mill is finally adjusted it can be handled by 4 or 5 men per shift, including the tram tender.

Each machine in the mill has its own electric motor and the mill is designed for the addition of other units as required.

The present plant can treat 250 tons a day, which is the capacity of the ball mills. Another ball mill is soon to be added, which which will increase the capacity to 400 tons a day. It is said that the flotation system as now installed can probably successfully treat 700 tons a day.

The savings on the ore, which, crude, assays nine-tenths of 1 per cent MoS_2, are said to be more than 60 per cent and they are increasing as the mill is being adjusted. It is believed that at least a 70 per cent saving will eventually be made. The concentrates are said to assay 60 per cent MoS_2. This statement was made before vanners were used to reduce the amount of pyrite which is present in large amounts in the original ore and in considerable quantities in the concentrates that come from the last Callow cell.

This company has a very fine equipment, and is thoroughly prepared to produce molybdenite concentrates on a very large scale. The power is electrical throughout. The mill, offices, boarding house, hospital, etc., at Climax are steam-heated. A spur has been run in by the Colorado & Southern Railroad from the main line to the mill. Arrangements are made so that most of the supplies for the mine and the mine boarding house are carried up on the tram. The plans for developing the mines are extensive and the company is now one of the largest producers of molybdenum in the world.

If the output is estimated on a basis of the daily treatment of 250 tons of ore which carries nine-tenths of 1 per cent MoS_2, and if the saving is 60 per cent., it is evident that 295.65 tons of metallic molybdenum would be produced annually. This amount is 73.05 tons greater than the world's production in 1915, which was 222.6 tons.[1]

The Molybdenum Products Corporation

This company, whose offices are in Denver, owns one 150 by 1,500-foot claim, the Denver No. 2, in the molybdenite belt on Bartlett Mountain. It has also located the Continental placer near the mill, and 14 claims, the Wolf, Nos. 1 to 14, on Chalk Mountain. All the Wolf claims are 300 by 1,500 feet in area. They have not

[1]Hess, F. L., Molybdenum. U. S. Geol. Survey, Mineral Resources for 1915, Pt. 1, 1917, p. 810.

been much developed. The company has leased a right of way for the tram, a distance of 8,400 feet on Bartlett Mountain to the mill at Buffehr's Spur and has a perpetual lease on the Lake placer near the mill.

Considerable development work has been done on the Denver No. 2 claim. A 550-foot tunnel has been driven, with several short drifts out on either side. The ore blocked out by this work is of a very satisfactory grade, and it is believed to be equal to the average of the ore from other parts of the district. It will be mined through shrinkage stopes.

A large building at the mouth of the tunnel serves the combined purpose of a carpenter shop, crusher house, and also covers the ore bins at the head of the tram.

The ore is handled as follows: It is broken in the mine, trammed by hand to ore bins in the crusher house, crushed by a Telsmith machine and classified by screens. All that does not pass a three-quarters mesh is returned to the crusher. The fines are carried by a belt conveyor to the bins at the head of the tram, thence by a Broderich and Bascom tram, which has a rated capacity of 1,000 tons every 8 hours, to the mill. Here it is ground in Marcy ball mills, classified by a Dorr classifier and treated by K. and K. oil flotation machines. The concentrates are dried on special steam tables. The mill is designed for two 150-ton a day units. Each unit has its own crushing and flotation plant. One unit is in place and has been in operation part of the time since the first of May, 1918. The machinery for the second unit is on the ground, but has not been installed. The milling operations have not yet passed the experimental stage and figures of recovery values, operating costs, etc., are not available.

There are boarding houses at the mine and at the mill. The mine office is at the mill.

Early in July the company suspended operations at both the mine and mill, giving as the reason for so doing that it was not possible to market molybdenite concentrates at that time. It intends to resume operations when the demand for the product increases.

KOKOMO DISTRICT

This region is part of the Tenmile Mining District, which is situated in the southwest corner of Summit County. The town of Kokomo, the center of a zinc-mining region of considerable importance, is on Tenmile Creek, and is about 17 miles northeast of Leadville on the South Park division of the Colorado & Southern Railroad.

Joseph Bryant and the Kokomo Milling Company together control most of the molybdenite claims in this district. The original Bryant group consisted of 13 claims, 7 of which were patented. In 1917 these were leased to the Kokomo Milling Company, and more were located by this company.

In July, 1917, considerable development work was being done in two tunnels which are situated about two miles northeast of the town of Kokomo. One tunnel is located right on the wagon road, only a few feet above Tenmile Creek. This tunnel is a cross-cut which has been driven for 540 feet through granite, gneiss, schist and quartzite. About 420 feet from the entrance, a large mineralized zone was encountered, which dips 43° N. 15° W. This zone is in a highly brecciated condition, due to faulting. The mineralization continues through a distance of 60 feet at right angles to the strike.

On the borders of this zone are schist and quartzite. Within the zone the rock is chiefly quartzite and a very impure limestone. There are no large distinct veins, but the whole fractured mass is impregnated heavily with quartz veinlets, which contain considerable pyrite and calcite. An occasional grain of chalcopyrite is found, and scattered through the veinlets there are small thin flakes of molybdenite. The ore is very low grade, and it is doubtful if it can be worked with profit at the present time.

About half a mile southwest of this tunnel and 500 or 600 feet above it, is another claim belonging to the Bryant group. This is reached by a good trail, which winds up the hill from the wagon road. Here a drift has been run for 150-200 feet on a three-foot vein, which dips 45° N. 75° W. The vein is in quartzite and limestone, has distinct walls and is strongly mineralized. Calcite, garnet and quartz are the gangue minerals. Pyrite and small amounts of molybdenite occur in the vein, especially on and near the walls. Average samples from the walls of the vein assayed 1.08 per cent MoS_2.

Mr. George S. Backus, superintendent of the Pingrey mill at Leadville, reports that 500 tons of ore was shipped to this mill from the vein last described. The molybdenite content of the ore averaged considerably less than one per cent. Because of the low grade and small body of the ore the possibilities for development are not believed to be good.

There are both wood and water close to the property, however, and if larger bodies of higher-grade ore should be uncovered, and the price for concentrates increase somewhat, it might be possible to build a mill on Tenmile Creek and handle the concentrating ore at a small profit.

The Salamander and Blue Valley Claims

These claims are owned by R. J. A. Widmar and A. C. Howard, of Breckenridge, Colorado, and are situated about 11 miles southwest of Breckenridge, on the south slope of Quandry Mountain, at an altitude of 12,000 feet. The property is reached from Breckenridge by a good wagon or automobile road for 9 miles up the Blue River Valley, a poor road for a mile and a half up Monte Christo Creek, and a rough, ill-defined trail the rest of the way.

The best showing of molybdenite is in the Salamander vein. The Blue Valley vein is less than one foot wide and does not show much ore.

GEOLOGY

The country rocks are pre-Cambrian gneiss and quartz-mica schist, into which were intruded large, irregular masses of granite, before the metamorphism of the schist was completed. There are also many large pegmatite dikes, which differ from the granite masses just referred to, chiefly in that they do not conform to the gneissoid and schistose structure of the metamorphics. Both the granite and the pegmatite dikes are more or less mineralized, particularly along their borders.

The Salamander vein is in a large pegmatite dike, which dips 80° S. 80° W. Here there is an irregular quartz vein on the hanging wall of the dike, which is rather strongly mineralized. Right on the contact with the country rock there is considerable pyrite, with an occasional grain of chalcopyrite. Just below the pyrite, and in part mingling with it, is a two-foot quartz-muscovite band in which most of the molybdenite of the vein occurs. The molybdenite is closely associated with bunches of very dark-colored muscovite, and the latter will undoubtedly be a drawback to the economical concentration of the ore. Nearly all the molybdenite is in large flakes or thick grains. The largest flake that the writer measured had a surface area about the size of a silver half-dollar. The grains are scattered very irregularly through the vein, giving a succession of rich pockets and barren places. On this account it is impossible to get a fair sample of the ore without breaking and crushing a large amount. The whole vein will probably not assay more than 0.5 per cent MoS_2. But by rought hand-sorting a 1 or 2 per cent product could easily be secured, and a better grade could be made if necessary. This vein has been followed for about 1,000 feet on the surface.

There are several other small veins on the claim, but they do not amount to much.

DEVELOPMENT

There has been little work done on this ground. On the Salamander vein there is a 20-foot drift. About 100 feet west of the main vein another drift has been run 40 feet on a pegmatite dike, which strikes 7° 15′ E. This is believed to cross the main vein. A few other shallow holes have been dug, but they are unimportant.

There are very good opportunities for developing any veins that may be found, for there is a range in elevations of more than 2,000 feet on the slope of Quandry Mountain near these deposits.

There is no serviceable timber within a distance of about a mile, and until a trail or road is completed to the property it would be a very difficult matter to get timber to the claims.

An abundance of water can be had from Monte Christo Creek, a few hundred feet below the claims.

Although the ore shows on the face of vertical cliffs, through which the veins have cut, it is not believed that the present outcrops and the exposed surfaces in the two short drifts allow a fair estimate of the extent and value of the ore bodies, and more work should be done to determine them.

It is unfortunate that there is so much copper with the molybdenite, for its presence undoubtedly will act against the sale and development of the property, although it can be removed chemically, and possibly mechanically, if the ore is ever concentrated and reduced.

MONTEZUMA DISTRICT

Messrs. John Sullivan and Clyde Drolsdraugh, of Montezuma, have a molybdenite property on Glacier Mountain, about two miles from Montezuma.

The claim is reached by a trail from Montezuma. The altitude at the property is 11,700 feet.

One 10-foot shaft, 10 feet wide, has been sunk on the deposit. The country rock is hornblende gneiss. This is cut by quartz veinlets which contain serpentine stringers that run out into the gneiss. Some rich and some lean pockets of molybdenite occur in the quartz and serpentine stringers, but there is no regular occurrence of the ore. The vein walls are not well marked and the deposit is not at all promising.

The ore cannot be traced on the surface of the ground, and it has been found only at one exposure.

Other Localities

Molybdenite in very small amounts has been found on Lenawee Mountain, near Montezuma.

It has been erroneously reported from the Arabella or Star Mine.

UNEVA LAKE

According to newspaper reports, molybdenite has been found near Uneva Lake, in Summit County. The Colorado Geological Survey has not yet been able to substantiate the report.

TELLER COUNTY

Mr. Lafe Fyfe, of Cripple Creek, has located molybdenite near Dome Rock, a few miles north of Cripple Creek.

There are no well-defined veins here, but only occasional stringers of quartz in the coarse-textured, red, ''Pike's Peak'' granite, which contain some well-scattered flakes of molybdenite. The deposit is not believed to be valuable.

Mr. William Smith, of Cripple Creek, has a molybdenite claim 2 or 3 miles due north of Pike's Peak, about 150 feet from the automobile road.

Molybdenite occurs as coarse flakes in a small quartz vein, which cuts the ''Pike's Peak'' granite. Samples of this ore assayed less than 1 per cent of MoS_2, and as the size of the deposit is small, it is not regarded as valuable at this time.

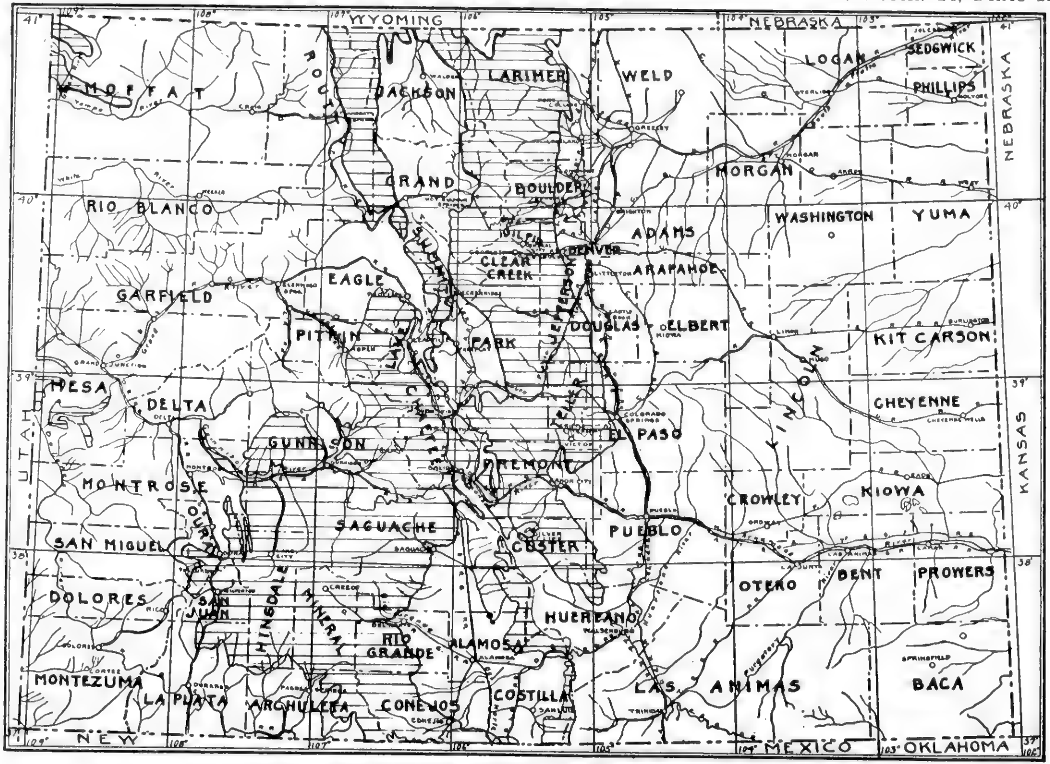
AREAS IN COLORADO WHICH SHOULD BE PROSPECTED

Molybdenite is known to occur in commercial quantities only in igneous and metamorphic rocks, or in contact deposits on the borders of igneous rocks. Therefore it is useless to look for this mineral in Colorado except in the areas indicated on the accompaning map.

Granite intrusions and pegmatite dikes are particularly likely to contain molybdenite, and the borders of all such masses should be prospected. Other intrusions of acidic igneous rocks, such as rhyolites, trachytes, acid porphyries, syenites, etc., may also contain deposits of molybdenite. Basalts and other basic rocks are not likely to contain molybdenite, except as there may be deposits on the contacts of these rocks and younger acidic intrusives. Sandstones and other sedimentary rocks are unlikely to contain molybdenite unless they are cut by acidic igneous rocks.

There seems to be a rather widespread, erroneous impression among prospectors that molybdenite occurs only at high altitudes and that the ore does not extend to any considerable depth. There are no known grounds for such beliefs. It is true that many, although by no means all, molybdenite deposits in Colorado are located at high altitudes, but this is undoubtedly due to the fact that prospecting for molybdenite is a new industry, and it is much easier to find outcrops above timber-line than below. There are no very deep molybdenite mines yet, but, again, the industry is young. In the Winfield District a large quartz vein, which contained considerable molybdenite, was cut in the Banker tunnel at a depth below the surface of more than 1,000 feet. Pegmatite dikes are known to extend to a great depth, and there are good reasons to believe that molybdenite "goes down." There are, of course, some deposits where the geological conditions indicate shallow depths of the ore, but usually they can be readily recognized by the geologist.

The regions of acidic igneous and metamorphic rocks in Colorado should be thoroughly prospected, and particular attention should be given to old dumps and prospect holes, for until recently molybdenite has not been a well-known mineral, and doubtless it has escaped the attention of many prospectors and mine owners.



Scale, 1 inch equals approximately 80 miles.
The shaded areas should be prospected for molybdenite.

CHAPTER VI

CONCENTRATION, REDUCTION, AND ANALYSIS OF MOLYBDENITE ORES

CONCENTRATION

For many years the problem of concentrating molybdenite ores was regarded as a difficult one. That it is not difficult for the modern mill man is well demonstrated by the processes now in operation. There are of course certain details yet to be overcome, such as the complete separation of molybdenite from the other metallic sulphides, pyrite and chalcopyrite, etc.; but the problem is by no means insurmountable and many mills are producing a good grade of concentrates, efficiently and economically.

Horton[1] has discussed this subject fully and the reader is referred to his article or to others on the same subject in the bibliography. Only a brief account of some of the recent developments in the industry will be given here.

Australian Methods

In Australia[2] most of the methods of concentrating the ore are crude and inefficient. The ore is hand picked; or crushed and screened dry; or crushed, rolled and screened, and treated on Wilfley tables. Some of the larger mines now have oil flotation plants of small capacity, the largest reported by Mr. Andrews being that of the Whipstick[3] plant, which has a capacity of 25 tons of ore per day of 3 shifts. [4]The ore at the Whipstick Mine contains bismuth. It is crushed by stamps to 20 mesh. The pulp is passed over Wilfley tables and the bismuth is recovered as a salable concentrate, while the molybdenite goes off as middlings and is carried by launders to a settling pit from which it is elevated

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[1]Horton, F. W., Molybdenum: Its ores and their concentration. U. S. Bureau of Mines Bull. 111, pp. 91-120.

[2]Andrews, E. C., South Wales Department of Mines. Geol. Survey, Min. Res., No. 24, 1916, pp. 4-13.

[3]Andrews, E. C., loc. cit., pp. 10-11.

[4]Extracted freely from Mr. Andrews' report.

to a conical tank. The sand is drawn off from the bottom of the tank, and the molybdenite is carried by water to the mixer of a 12-inch unit of a mineral separation plant. The mixer has horizontal rotating blades which agitate the pulp. About three-quarters of a pound of oil per ton of ore is dropped by a drum into the mixer. The pulp passes from the mixer into Separator No. 1, in which part of the molybdenite rises as a froth and is washed out into settling and dewatering tanks. The sands from No. 1 are drawn by suction into Separator No. 2, where the frothing is continued as in No. 1, and so on through 6 separators. The finished product varies from 82 to 90 per cent molybdenite.

Methods Used in Norway

In Norway the Elmore vacuum flotation process is the one universally used.

This process[1] is said to be very applicable to molybdenite ores and a 90 per cent MoS_2 extraction is made with one operation. Mr. Elmore[2] gives the principles on which the process is based, as follows:

> The process is based primarily upon the fact that, in a flowing pulp of crushed ore and water, oil has a selective action for the metallic mineral particles as distinct from the rocky particles or gangue. This selective action is materially increased in some cases by the presence of an acid; and secondly, upon the fact that the air or gases dissolved in water are liberated, partially or entirely, upon subjecting the same to a pressure less than that of the surrounding atmosphere. These liberated gases may be augmented by the generation of gases in the pulp or by introduction from an external sources. The gases attach themselves to the greased mineral particles, and being largely increased in volume as a result of the partial vacuum applied, cause the greased particles with their attendant bubbles of air or gas to float to the surface of the liquid.

Canadian Methods

In Canada several concentrating methods are in use. The Elmore vacuum flotation process is used by the Renfrew Molybdenum Mines, Limited.[3] They had in 1916 a single unit which treated 30 to 40 tons of 1 per cent ore daily and gave an 80 per cent concentrate.

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[1]Elmore, A. S., Vacuum-flotation process for concentration. Eng. and Min. Journal, vol. 83, No. 19, 1917, pp. 908-909.
[2]Elmore, A. S., loc. cit., p. 908.
[3]Mackenzie, G. C., The mining and metallurgical treatment of molybdenum ores in Canada. Trans. Royal Can. Inst., vol. XI, pt. 2, No. 26, p. 282.

The Dominion Molybdenite Company[1] at Quyon uses the Callow pneumatic flotation cells and is said to be making a very complete recovery from ore which carries between one-tenth of 1 per cent and 20 per cent of MoS_2. There is much pyrite and pyrrhotite in this ore. In 1916, 5,000 tons of this ore averaged 1.7 per cent MoS_2.

The International Molybdenum Company, at Orillia, Ont., mines, concentrates, reduces and refines its own ore, making ammonium molybdate, molybdenum trioxide and ferro-molybdenum. The company has a water flotation[3] plant designed by Mr. G. P. Grant which is said to concentrate ore that carries less than 1 per cent MoS_2, and in one treatment make a 70-80 per cent molybdenite concentrate. The process is described as follows:

> The ore after passing through a gyratory crusher is ground by rolls. The crushed ore is fed dry to a drum revolving in water at the head of a float. A large percentage of the sulphides, including almost all the molybdenite, is thus floated. The stream passes down a gently inclined box 12 feet long. The iron sulphides are carried along with the molybdenite until they strike baffle boards, which help to sink them. The baffles are vertically placed boards over the edge of which the water carries the molybdenite. They interfere very little with this mineral, but cause sinking of the other minerals.
>
> No acids or oils are used in the process. The sulphides float readily on water and the baffles sink the undesirable ores, leaving the molybdenite.
>
> The plant can treat about 50 tons in 12 hours.

The Mines Branch, Department of Mines, at Ottawa[4] has successfully used the Wood film water flotation machines.

Between the time of installing the machines in 1916 and Oct. 2, 1917, the Mines Branch treated "3,612.9 tons of various molybdenite ores containing an average of 2.125% of molybdenite," and made a recovery of "82.8% of the original molybdenite contained in the ore."

This process is regarded by Mr. Mackenzie as particularly satisfactory when mixed sulphides such as pyrrhotite, pyrite, chalcopyrite and molybdenite are to be treated. However, the ore must be very carefully dried, in order to prevent oxidation and the consequent loss of molybdenite.

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[1]Molybdenite from Quebec. Can. Min. Journal, supplement vol. 39, No. 5, March 1, 1918.

[2]Mackenzie, G. C., loc. cit., p. 281.

[3]The concentration of molybdenite by flotation. Can. Min. Journal, vol. 37, No. 19, Oct. 1, 1916, p. 461.

[4]Mackenzie, G. C., The concentration of molybdenite. Can. Min. Journal, vol. 38, No. 20, 1917, pp. 402-403.

The staff of the Department of Mining Engineering of the University of Toronto[1] has perfected a water flotation process for concentrating molybdenite. They crush the ore wet to 10 mesh or less and consider it advisable to split the pulp at 60 mesh, and treat the coarse and fine on separate machines.

The machine consists mainly of a piece of sheet iron bent into a section of a cone. The lower edge dips into still water in a V-shaped tank. The pulp is fed from a small orifice on to the bent sheet iron and flows down and spreads out over it. The result is a gentle wave action.

Between the crests of the waves the pulp layer is very thin and the surface film very much stretched. The result is that the less wetable minerals break through, are picked up by the crest of the next wave and are carried down to the still water, where they float. Here a gentle jet of air keeps them traveling towards the overflow and takes them out of the way of fresh comers.

The thickness of the pulp, the steepness of the plate, the surface tension of the water as affected by modifying agents, are all easily controllable means of affecting the cleanliness of the float, and it is possible to make a very clean separation of different sulphides.

Generally several trips have to be made over the plate, in order to make complete savings. Also it may be necessary to slightly roast the concentrates from the third and fourth trips, to oxidize the iron or copper pyrites, but the selective action of the flotation process is claimed to be so sensitive that this can be done without danger of losing the molybdenite.

Mica, if present in considerable amounts, renders the ore very difficult to treat by this process, although small amounts are said not to be harmful.

The authors state that:

The chief advantages of this system lie in its extreme simplicity and the high grade of concentrates produced. In many cases no re-treatment of concentrates or middlings will be required. When this is necessary the amount to be so treated is very small and the operation simple and effective. The ore can and should be crushed wet, and fine screening is eliminated, so that the mill would be of the simplest type. In dry crushing molybdenite is smeared on other particles, causing them to float by reason of this partial coating. In wet crushing this apparently does not occur.

United States Methods

In the United States as in Canada several methods are in use for concentrating molybdenite ores. Nearly all are now based on some form of oil flotation, although water flotation is used in some cases.

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[1]Haultain, H. E. T., Dyer, F. C., King, J. T., The concentration of molybdenite ores. Can. Min. Journal, vol. 38, No. 13, 1917, pp. 270-271.

The Henry E. Wood Ore Testing Company, of Denver, continues to use the Wood water flotation machine[1] with success.

Mr. Wood stated in a conversation with the writer that he was consistently making better than a 90 per cent concentrate with this machine and that ores containing mica or pyrite were handled without difficulty.

The Primos Chemical Company is using an oil flotation process in its mill at Urad, near Empire, Colorado.

The Climax Molybdenum Company, the largest operator in Colorado at the present time, as stated in another part of this report, uses successfully both the Janney and Callow cells. For details of operations see pages 92 and 93 of this report.

The Phoenix Works, of Denver, use a standard Ruth flotation cell, and a solution the composition of which is kept secret. The ore is crushed wet in a Denver Engineering Works ball mill, to 60 or 70 mesh, and fed directly to the Ruth cell. Mr. Candlish, the manager of the plant, states that practically all the iron and mica, in ores containing these minerals, are separated from the molybdenite, and that a high-grade concentrate is obtained.

The capacity of a single unit of this machine is said to be approximately one ton per hour.

The Molybdenum Products Corporation, whose property is at Climax, has operated a K. & K. oil flotation plant for about two months on the Bartlett Mountain ore. The work so far has been largely of an experimental nature and no figures of the savings, cost of operation, etc., are yet available.

The Pingrey Mines and Ore Reduction Company, of Leadville, treated 1,000 tons of the Bartlett Mountain ore by oil flotation, and this company contemplates the erection of a new oil flotation mill.

Other companies in this state have milled some molybdenite ore, but not, so far as is known, on a commercial scale.

The literature, in which the molybdenite concentrating plants of the United States are described, seems to be very meager. Hess[2] has described the method of treating molybdenite ore at Cooper, Maine, in use 10 years or more ago.

1For a full description of this process see: Wood, Henry E., The Wood flotation process. Trans. A. I. M. E., vol. 44, 1912, p. 684 et seq., or A. I. M. E. Bull. 71, 1912, pp. 1227-1244.

2Hess, F. L., Some molybdenite deposits of Maine, Utah and California. U. S. Geol. Survey Bull. 340, 1907, p. 233.

It is understood[1] that a 50-ton flotation plant is in operation near San Diego, California, to treat the low-grade (1 per cent or less) ores of that region.

Utah, Montana, Arizona and New Mexico are also said to have concentrating plants, but detailed information concerning them has not been available to the writer.

The practices adopted in Norway, Canada and Colorado have been perfected to such an extent that it is safe to say that most molybdenite ores can be concentrated successfully. There are many details, however, still to be worked out. No single process is adapted to all ores, for each deposit has its own peculiar characteristics of gangue, country rock and ore.

Oil flotation seems to be well suited to most finely granular molybdenite ores, although a special treatment of the concentrates to eliminate iron, or iron and copper sulphides, will have to be undertaken in many cases. Probably all the larger low-grade ore bodies in Colorado will be treated in this way.

Where the ore bodies are small and relatively inaccessible, and particularly if such bodies contain coarse flakes of molybdenite, it is probable that some simple form of water film flotation can be used with success. Such methods are particularly desirable in cases where the size, or the state of development of the property, does not warrant the construction of a large, expensive mill, and yet on account of transportation difficulties it is desirable to concentrate the ore.

THE REDUCTION OF MOLYBDENITE CONCENTRATES

Molybdenum is placed on the market, after being reduced from molybdenite concentrates, in four forms, ammonium molybdate, molybdic oxide, metallic molybdenum, powdered or sintered, and ferro-molybdenum.

Ammonium molybdate is produced by roasting the sulphide and leaching the mass with ammonium hydroxide.

The oxide is produced by evaporating an ammonium molybdate solution to dryness, and igniting the crystals to drive off the ammonia.

Powdered molybdenum is produced by roasting the sulphide, and reducing the oxide, with carbon in an electric furnace. The metal takes up carbon, but by adding more molybdic oxide a very pure powder is obtained.

[1] Min. and Sci. Press, vol. 113, Nov. 4 ,1916, p. 667.

Humphries[1] has described a method for making metallic molybdenum rods. The following statements are extracts freely taken from his paper:

Metallic molybdenum is produced in the electric furnace from molybdenite or preferably from ammonium molybdate or molybdenum trioxide. The trioxide or molybdate is heated in an electric furnace in a hydrogen atmosphere and a crystalline product is produced. This is placed in a nickel or nickel-plated boat and heated in a gas furnace to 900 degrees or 1,000 degrees C. Then it is crushed, screened and reduced for several hours. It is examined for oxide, and if any is present it is again reduced, at a temperature of 1,400 degrees C. But there is danger of contamination with iron if a nickel-plated iron boat is used. After the oxide has been removed the metal is powdered, pressed in a steel mold and again heated in the electric furnace at a temperature of 1,200-1,300 degrees C. It is then placed in a furnace, the air is removed and a current of 100 amperes passed through the metal, which shrinks and forms a molybdenum rod. If it is to be used for rods, wire, filament, etc., it is swaged hot from the electric furnace by running the metal through dies of high-speed steel. The pure metal can be made glass-hard by heating to 1,200 degrees C. and quenching several times.

Ferro-molybdenum is made by heating the raw or roasted ore in the electric furnace with some fluxing or desulphurizing agent such as lime. Ferric iron is added and the mixture heated in the furnace. Ordinarily the product contains from 5 to 10 per cent of carbon, which can be removed by adding the proper amount of molybdic oxide. Usually the marketable product contains about 80 per cent molybdenum, although in some cases the percentage is as low as 20. Formerly a 90 per cent MoS_2 concentrate was demanded by the ferro-molybdenum manufacturers, but this is no longer required and a 70 or 80 per cent concentrate is more commonly used. Ferro-molybdenum has a melting point several hundred degrees lower than that of metallic molybdenum, hence its demand for use in the steel industry.

THE QUANTITATIVE ANALYSIS OF MOLYBDENUM ORES

There are several good methods for the determination of molybdenum in ores.

[1]Humphries, C. H., Preparation of Pure Molybdenum. Min. and Sci. Press, vol. 114, 1917, p. 912.

When vanadium, phosphorus and arsenic are absent and the molybdenum content is known to be low the following method has been found practicable:

Fuse 2 grams of the sample with about 10 grams of Na_2O_2 in an iron crucible (bring to quiet fusion). Cool and dissolve in cold water. Transfer the mixture to a 500 c.c. flask, bring up to the mark, shake well and permit residue to settle (about 30 minutes).

Decant 250 c.c. of the solution through a filter into a 250 c.c. flask and after bringing up to the mark transfer it to a 450 c.c. beaker. Add 30 c.c. dilute H_2SO_4 (1-1) and run solution through a Jones zinc reducer attached to a water pump.

Titrate reduced solution with $KMnO_4$. The Fe standard multiplied by .2871 equals Mo.

The Davis[1] method, which was devised for wulfenite ores, gives good results and it is also applicable to molybdenite by simply omitting the first two paragraphs of the process if lead is not present in the ore. A statement of this method follows:

The wulfenite ores found in the southwestern states and Mexico usually contain more or less tungsten and vanadium, and as these elements exert a decided influence on the metallurgical process of extraction, a practical method of analysis of such ores was devised by the writer.

Pb.Mo.V. Treat 1 gram of agate-ground sample with 10 c.c. HCl and 5 c. c. HNO_3, warm on hot plate and after the action has somewhat subsided add 10 c.c. H_2SO_4 and evaporate to strong sulphuric fumes. Cool somewhat, dilute and heat until all is in solution except the lead sulphate and silica. Filter into a pressure bottle (a citrate of magnesia bottle with patent clasp stopper is well adapted for this purpose), washing with H_2O containing a little H_2SO_4. Dissolve the lead sulphate in hot ammonium acetate and acetic acid, filter from SiO_2, washing well with hot ammonium acetate solution, and estimate the lead by titrating with ammonium molybdate. If desired, one may add a large excess of sulphuric acid to the lead acetate solution, boil, add alcohol and determine the lead gravimetrically as $PbSo_4$.

Pass H_2S into the filtrate in the pressure bottle for about 15 minutes, then stop the bottle, place in vessel of warm water and heat to boiling for about 20 minutes.

If the amount of MoS_2 is small, and a preliminary test has shown copper to be absent, collect the precipitate in a Gooch crucible, dry and ignite gently until there is no more SO_2 odor, then heat to faint redness and weigh as MoO_3, containing 66.57 per cent Mo. If this MoO_3 is not entirely soluble in ammonia the residue should be deducted. It is safer, however, especially if there is much Mo., to proceed as follows:

Dissolve the MoS_2 in HNO_3, evaporate in a casserole to dryness, then heat over a wire gauze to remove all H_2SO_4. Add 5 c. c. ammonia and warm until the MoO_3 is all in solution (if copper is present use KOH in-

[1]Davis, R. S., Notes on technical analysis. Metallurgical and Chemical Engineering, vol. 9, No. 9, 1911, pp. 458-459.

stead of NH_4OH_3, dilute, boil, filter off the cupric oxide and estimate the copper by any convenient method). Filter if necessary, acidify with acetic acid, boil and add excess of lead acetate. Filter and wash the precipitate with hot ammonium acetate solution to remove any trace of $PbSO_4$, then with hot water, ignite gently and weigh as $PbMoO_4$ containing 26.15 per cent Mo. The writer has not had much success in estimating Mo. by the Zn. reduction processes excepting when very little Mo. is present.

Boil the filtrate from the MoS_2, which will be green or blue if vanadium is present, to remove the H_2S. Then add $KMnO_4$ to a pink color. The amount of standard permanganate used will give some indication of the amount of V. present plus Fe. Add an excess of $KMnO_4$ and boil at least 5 minutes. Then add ferrous ammonium sulphate until the MnO_2 is dissolved and the liquor is clear and boil 5 minutes longer. Cool to about 70 degrees C., add $KMnO_4$ to a pink color, then run in ferrous ammonium sulphate until a ferri-cyanide spot shows an immediate blue color. Titrate back with standard $KMnO_4$ until the spot shows no color in 30 seconds, read the burette and run in permanganate until pink color is obtained which persists one minute. The iron value of the permanganate times 0.9159 gives the vanadium value. If the quantity of vanadium is so small as to make its presence doubtful it is well to add H_2O_2 to the solution after titrating. This destroys the permanganate color and shows as little as .05 per cent. vanadium by the characteristic red-brown tint.

The amount of iron present is approximately shown by deducting the permanganate used in the vanadium titration from the amount required to oxidize the iron and vanadium above.

WO_3 and SiO_2 are best determined in a separate sample. Treat one gram of ore with 20 c. c. HCl and evaporate to dryness. Add 10 c. c. HCl and about 100 c. c. H_2O and bring to boiling. Filter and wash by decantation with hot dilute HCl until all $PbCl_2$ is removed. Add 10 c. c. dilute ammonia containing a little NH_4Cl to the beaker containing the WO_3 and SiO_2 and allow to stand about five minutes, and pour on to the filter, receiving the filtrate in a platinum dish. Wash 4 or 5 times, using about 2 c. c. ammonia, wash solution each time. Evaporate to dryness, ignite gently until NH_4 salts are volatilized, then at moderate red heat. Do not heat excessively, as WO_3 can be slowly volatilized with a strong Bunsen flame. Add a few drops HF and a drop H_2SO_4, evaporate, ignite and weigh.

Determine SiO_2 in the residue by loss with HF, and add to this any silica found with the WO_3.

The following is the U. S. Bureau of Mines method[1] which is used for ores that carry no tungsten and not more than traces of arsenic or antimony.

Digest the sample of ore—from 0.2 gram to 5 grams, depending upon its seeming richness—with 25 to 35 c. c. of fuming nitric acid in an Erlenmeyer flask for three hours and finally evaporate to dryness. Add

[1]Horton, F. W., Molybdenum: Its ores and their concentration. U. S. Bureau of Mines Bull. 111, 1916, p. 44.

3 c. c. of concentrated sulphuric acid to the residue and heat until dense white fumes are given off in quantity. Cool, dilute to 100 c. c. and filter. Wash the residue with water, allowing the wash water to run into the filtrate. Wash the residue well with diluted ammonia (1-3), and then with water. Make the filtrate alkaline with ammonia to precipitate the aluminum and any iron present in the original mineral. Heat, filter and wash well with hot water. Saturate this alkaline filtrate with hydrogen sulphide to a bright cherry-red color. Filter and wash with hot water. Acidify the filtrate with hydrochloric acid until slightly acid and digest until the precipitated sulphide and sulphur are well coagulated and the excess hydrogen sulphide expelled. Filter on a weighed Gooch crucible. Evaporate the filtrate to dryness in a casserole and drive off the ammonium salts at the lowest possible temperature, being careful not to heat the casserole to redness at any time. Take up the final residue with about 100 c.c. of water to which 5 c.c. of ammonia has been added. Add 10 c.c. of ammonium sulphide, make faintly acid with hydrochloric acid and digest until the sulphide is coagulated. Filter this on the Gooch crucible used for the previous sulphide filtration. Add an amount of sulphur to the combined sulphides equal to about one-half their weight and ignite over a Bunsen burner at a dull-red heat in a stream of arsenic-free hydrogen for ten minutes. The ignition may be accomplished by using a Rose crucible cover and tube over the Gooch crucible. Weigh and repeat the ignition as before, until check weights are obtained. The weight obtained is the weight of molybdenum disulphide.

CHAPTER VII

THE USES, SUPPLY AND DEMAND, MARKET AND PRICES OF MOLYBDENUM

THE USES OF MOLYBDENUM

There is a wide difference of opinion, which finally resolves itself into a question of fact, regarding the uses of molybdenum. It seems evident that suggested uses, or uses that have been advocated after some experimentation, have been confused with actual commercially adopted practices in the use of this metal. In other words, molybdenum may be adopted for many purposes where it is not now used. It is extremely unfortunate that this confusion of statements has arisen, for it has already reacted, and probably will in the future react, to the disadvantage of many prospectors and investors, who have been led to believe that the uses of molybdenum are now so numerous and the demand is so great that the market can absorb all that is supplied, even at a relatively high price.

The following lists indicate the commonly stated uses of molybdenum. The authors of the papers in which these statements appear are given, not with the idea of drawing any individuals into the conflict of diverging opinions, but simply to give the authority and reference for each statement, in case anyone wishes to go into the matter further. Particular attention is called to the statement of Mr. Hess, which should probably be taken as an antidote for some of the ultra-optimistic statements of certain other writers.

Mr. Horton[1] gives the following uses of molybdenum:

The principal use of molybdenum is in the manufacture of alloy steels, to which, particularly in conjunction with chromium, manganese, nickel, cobalt, tungsten, and vanadium, it imparts many desirable properties. These steels are used for a large variety of purposes, such as for crank-shaft and propeller-shaft forgings, high-pressure boiler plate, guns of large bore, rifle barrels, armor plate, armor-piercing projectiles, permanent magnets, wire, and for self-hardening and high-speed machine tools. Metallic molybdenum is used in various electrical contact-making

1Horton, F. W., Molybdenum: Its ores and their concentration. U. S. Bureau of Mines Bull. 111, 1916, p. 20.

and breaking devices in X-ray tubes, and in voltage rectifiers, and in the form of wire for filament supports in incandescent electric lamps, and for winding electric resistance furnaces, and in dentistry. Molybdenum is also employed in the manufacture of chemical reagents, dyes, glazes, disinfectants, etc.

The following is an abstract of the list of "uses of molybdenum" given by Mr. Andrews:[1]

"Blue pigment, used to color porcelain and as a dye for silk and woolen goods, and to color various leathers and rubbers.—To detect phosphorus in the manufacture of steel.—For fire-proofing.—As a disinfectant for cloth used in passenger railway cars.—Molybdenum compounds are used to form stabilizers for high explosives, to prevent deterioration and premature explosion. The great use, however, to which molybdenum is put is in the manufacture of certain steels, as a substitute for tungsten, especially in self-hardening steels, in armors, guns, and other steels needing tenacity and hardness. Molybdenum steel is also much used for rifle barrels, propeller shafts, heavy guns, armor plates, arc-lamp electrodes, and in the production of other materials. European armor plates are said to contain up to 2 per cent. molybdenum. If molybdenum could be procured in large quantities it would be much in demand for steel casting for railroad work."

Mr. Fleck[2] gives about the same list as is found above. The following is an abstract of his statement regarding the uses of molybdenum:

Ammonium molybdate is used as a laboratory reagent in the determination of phosphorus in iron ore, their products, and in fertilizers. Fire-proofing fabric, self-hardening steel, large castings, gun barrels, to prevent corrosive gas action; armor plate; armor-piercing shells (the last two uses contradicted in United States); motor-car steel; magnets; wire for electric furnaces, thermo-couples; coloring agents for leather, rubber and porcelain, preservative for smokeless powders.

Mr. Hess[3] has the following to say about the uses of molybdenum:

The actual uses as now developed for the metal are small. In this country the use of molybdenum in tool steels, according to reports received by the Geological Survey from various sources, has decreased. A small quantity is used in electric work, for supports for tungsten fila-

[1]Andrews E. C., The Molybdenum Industry in New South Wales. N. S. Wales Department of Mines, Geol. Survey, Mineral Resources No. 24, 1916, p. 7.

[2]Fleck, Herman, Molybdenum. Proceedings of the Colorado Scientific Soc., vol. XI, 1516, pp. 134-135.

[3]Hess, F. L., Molybdenum. U. S. Geol. Survey, Mineral Resources for 1915, Pt. 1, Metals, 1917, pp. 808-809.

ments in incandescent lamps, in Roentgen ray apparatus, and in small resistance furnaces; a number of tons of ore is consumed in making ammonium molybdate for use in chemical work; and a little is used in some stellite; but outside of these practically no uses are known. Efforts have been made to use the blue oxide in dyes, but the process is not known to have been adopted on a commercial scale, although stated in certain papers as a prominent use. Statements that molybdenum is used in smokeless powder, gun steels, and armor plate are constantly reiterated and as positively denied.

Abroad molybdenum is apparently used in steel much more than in this country, and it is commonly accepted that the decided rise in prices was caused by German buyers taking available supplies a few months before the beginning of the war. French and English steel makers are apparently now using the metal to some extent.

It is probable that small amounts of molybdenum *are* used in the breech-blocks of large guns, in crank shafts of certain engines, in some stellite[1] and in certain parts of the new Liberty motors. It is said that from 1½ to 3 per cent molybdenum in steel is more beneficial than larger amounts. It is a common statement that from 3 to 5 per cent of molybdenum is used in the heavy German guns. But Howe[2] in a recent paper on the erosion of guns found no molybdenum in the steel taken from two captured German guns, and he shows that the possibilities of reducing the erosion of guns by adding molybdenum are not encouraging.

The substitution of molybdenum for platinum has been suggested, and Fahrenwald,[3] in an extremely interesting paper, concludes the statement of his results respecting the experiments with molybdenum as follows:

> The second part (of the experimental work) develops the fact that, except in two respects, pure ductile tungsten, and, to a lesser degree, molybdenum, meet all of the specifications of a practical substitute for platinum and its alloys. These two defects are its ease of oxidation, and the difficulty with which it can be soldered, and they have been overcome by coating with a precious metal or alloy, the resulting material being in many ways far superior to platinum or its alloys.
>
> This material has met with instant demand, is in many cases replacing the best platinum-iridium alloys, and permits the performance of work which has been impossible with the materials hitherto available.

He concludes his paper with the suggestion that the methods introduced for treating tungsten and molybdenum may be applied

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[1]Haynes, Elwood, Alloys of Cobalt with Chromium and other metals. Trans. A. I. M. E., vol. 44, 1912, pp. 576-577.

[2]Howe, Henry M., The Erosion of Guns. Bull. of the A. I. M. E., No. 134, Feb., 1918, pp. 386-387.

[3]Fahrenwald, Frank Alfred, A development of practical substitutes for platinum and its alloys, with special reference to alloys of tungsten and molybdenum. Bull. A. I. M. E. No. 109, Jan., 1916, p. 148, or Trans. A. I. M. E., vol. 54, 1916, p. 586.

to the "treatment of such metals as iridium, tantalum, rhodium, osmium, etc., in combination with each other, or with tungsten or molybdenum, which may result in the production of alloys possessing properties far superior to those of any material now available."

Haynes[1] states that if molybdenum is added to a cobalt-chromium alloy in which chromium forms 15 per cent of the whole mixture, the hardness of the alloy increases with the increasing amount of molybdenum, until the latter reaches 40 per cent. The resulting mixture scratches glass, takes a fine polish, and resists acids. An alloy composed of 25 per cent molybdenum, 15 per cent chromium, and 60 per cent cobalt has the properties just given; it can be cast but not forged; it takes a strong, keen edge and makes fine cutlery.

Tungsten also is used with chromium and cobalt. The stellite on the market is much used for "high-speed" tools.

The experiments that have been made with molybdenum and its alloys by Fink, Fahrenwald, Haynes, and many others are encouraging.

It is persistently reported that two of the leading automobile manufacturers of this country are now buying large quantities of molybdenite concentrates, and that, if the tests they are now making prove satisfactory, they will require many thousand pounds of molybdenum every year.

In view of all the experiments that have been made, it seems probable that sooner or later a much greater demand for molybdenum may be expected. But at the present time the experimental stage has not been passed and there are no commercial uses for very large amounts of molybdenum.

SUPPLY AND DEMAND

It is evident that no large tonnage of molybdenum can be absorbed by the world's market, except as it is used in the manufacture of molybdenum steel.

Much has been written about the necessity of developing adequate supplies of molybdenum before the steel manufacturer would give serious attention to its use on a large scale, and it has often been definitely stated that if the molybdenum resources were developed and reserve supplies assured, the increased use of the metal would also be assured. It now remains to be seen whether or not

[1]Haynes, Elwood, Alloys of cobalt with chromium and other metals. Trans. A. I. M. E., vol. 44, 1912, pp. 573-577.

this prophecy is correct, for the resources have been developed and already a very large tonnage of concentrates is being placed on the market. It is estimated that with the present equipment Colorado alone can produce annually not less than 800 short tons of metallic molybdenum from the mines at Climax and Empire. Other small properties in the state would add a considerable amount to this tonnage. The data for Arizona's production are not available to the writer, but it is probably safe to estimate the annual possible production from that state as not less than 400 tons. The other states of the United States, Australia, Canada, and Norway can certainly furnish at least 800 tons a year if it is required, thus making an estimated minimum immediate total production of 2,000 tons a year of metallic molybdenum. This is equivalent to 3,000 tons of molybdenum trioxide (MoO_3), which is nearly equal to one-fourth the amount of tungsten trioxide (WO_3) produced in the world in 1915,[1] and it is nearly ten times the amount of molybdenum produced during that year,[2] which was 222.6 short tons.

It should be borne in mind that these figures are intended to give estimates of what may be produced, not what will be produced in any year in the near future. It seems to the writer very doubtful if the demand will meet the available supply for some time to come. At the same time the potential uses of molybdenum are so varied that it is entirely possible that new demands may be made for the metal at any time.

Certainly it is the wise and patriotic thing to do, at this time, to prospect for, and develop, all the sources of supply. But the organization of companies for the production of molybdenum ores and concentrates should be done most conservatively with the facts clearly in mind that, even with entirely favorable conditions of mining and milling, and low total cost of production, there may be no immediate market for the product, and the venture, therefore, may not be a financial success.

MARKET

Molybdenite concentrates are sold with the metal values based on the MoS_2 content. Wulfenite concentrates are sold either on the basis of the molybdenum trioxide (MoO_3) or the metallic molybdenum (Mo) content. One part of molybdenum sulphide (MoS_2) by weight is equivalent to 0.9 part of MoO_3, and 0.6 part of Mo.

[1]Hess, F. L., Tungsten. U. S. Geol. Survey, Mineral Resources of the U. S. for 1915, Part 1, Metals, p. 827.

[2]Hess, F. L., loc. cit., Molybdenum, p. 810.

Or one part by weight of Mo is equivalent to 1.5 parts of MoO_3, and 1.67 parts of MoS_2.

While 90 per cent. MoS_2 concentrates are desired, they are no longer demanded. It is reported that 20 per cent MoS_2 concentrates are salable when the market is short, and it is probable that for ferro-molybdenum a 70-85 per cent MoS_2 concentrate will eventually become the standard.

The presence of pyrite, arsenic, bismuth, antimony, tungsten or copper is objectionable, and if any of these except pyrite occur in amounts of more than 1 per cent the difficulty of marketing the concentrates is very greatly increased. As the percentage of undesirable minerals increases, penalties also increase until they may become so high that the product is entirely unsalable.

The market for crude ores is uncertain. So far as is known, S. W. Shattuck and the Henry E. Wood Company, of Denver, are the only molybdenum ore buyers in Colorado.

Wilson[1] gives the following list of consumers of molybdenum in the United States and Canada:

Baker & Adamson Chemical Co., Easton, Pa.
J. T. Baker Chemical Co., Phillipsburg, N. J.
Electro Metallurgical Co., Niagara Falls, N. Y.
Foote Mineral Co., Philadelphia, Pa.
General Electric Co., Schenectady, N. Y.
Goldschmidt Thermit Co., 90 West St., New York City, N. Y.
Grasselli Chemical Co., Cleveland, Ohio.
Imperial Munitions Board, Ottawa, Ont.
International Molybdenum Co., Orillia and Renfrew, Ont.
Pfanstiehl Co., N. Chicago, Ill.
Primos Chemical Co., Primos, Pa.
S. Schaaf-Regelman, New York City, N. Y.
David Taylor, Boston Bldg., Salt Lake City, Utah.
Tivani Steel Co., Belleville, Ont.
Henry E. Wood & Co., Denver, Colo.
York Metal & Alloys Co., York, Pa.

There are new brokers and users constantly coming into the market, whose addresses can be learned from the Mining Journals.

PRICES

It is obvious that the price of molybdenum will continue to be controlled by the supply and demand. Unless the metal is more

[1]Wilson, A. W. G., Molybdenum. The Mineral Industry for 1916, vol. 25, 1917, p. 517.

largely used in the steel industry than at present, the price will probably settle down to what it costs the largest producers, plus a small profit. If new uses are found so that there is a strong demand for the metal, the price will be higher, and will probably be somewhere nearly the same as that of tungsten.

The writer does not wish to appear pessimistic, but it is his opinion that the price of concentrates containing 70-85 per cent MoS_2 will probably soon be not more than \$10.00 or \$12.00 a unit, and that those companies which cannot produce the ore and concentrates on this basis will be forced out of business, until such a time as a largely increased demand causes an increase in price. If this opinion is correct, only two classes of properties will be successfully operated. These are, first, very large low-grade properties, where a large tonnage can be handled with relatively low overhead expenses and where a small profit on a large tonnage will pay the interest on the original investment; second, high-grade properties, most of which will be small, that can produce rich concentrates at a low cost. Those deposits which contain injurious minerals, and those which are disadvantageously situated, will be unable to stand competition at the present time.

Ball[1] says: "No molybdenite mine should be opened unless a 90 per cent. concentrate can be produced for from \$800 to \$1,000 per ton. If the world's production should suddenly increase, the price might temporarily fall even below the former figure, but probably would eventually exceed it. Ore occurring in fair amounts and carrying 2 per cent or even 0.5 per cent MoS_2, if all factors are favorable, can be profitably treated."

The writer is entirely in accord with this view and believes it highly desirable that a conservative view of the molybdenum industry be held by investors and companies organized to develop molybdenite properties.

This does not mean that prospecting should not be continued or that good prospects should not be developed. But certainly there should be long-time contracts or other reliable assurance of a market for the product, before new companies should be organized and highly capitalized, for the production of molybdenum in Colorado.

Before 1915, European nations furnished the largest market for molybdenum and Horton[2] gives the following table to show the scale of prices for an eight-year period:

[1]Ball, S. H., Molybdenite and its occurrences. Eng. and Min. Journal, vol. 104, No. 8, Aug. 25, 1917, p. 334.
[2]Horton, F. W., Molybdenum: Its ores and their concentration. U. S. Bureau of Mines Bull. 111, 1916., p. 38.

PRICES OF HIGH-GRADE MOLYBDENITE CONCENTRATES (90 TO 95 PER CENT MoS_2) IN EUROPEAN MARKETS, 1908 TO 1915

Year	Prices per Unit of 20 Pounds	Prices per Unit of 22.4 Pounds Shillings
1908..........	$6.50 to $7.60	30 to 35
1909..........	5.65 to 7.15	26 to 33
1910..........	6.30 to 6.75	29 to 31
1911..........	6.95 to 9.10	32 to 42
1912..........	7.15 to 11.95	33 to 55
1913..........	10.90 to 18.50	50 to 85
1914..........	19.50 to 31.50	90 to 145
1915..........	23.90 to 36.90	110 to 170

The New York prices for 1917 are given by the Engineering and Mining Journal.[1] The price per pound multiplied by 20 gives the price per unit for comparison with Horton's table.

PRICES OF 90 PER CENT MOLYBDENITE CONCENTRATES 1917

Month	Price per Pound	Month	Price per Pound
January	$1.81	July	2.16
February	1.80	August	2.14
March	1.90	September	2.18
April	2.10	October	2.20
May	2.95	November	2.20
June	2.15	December	2.27

Prices for the first 6 months of 1918 were quoted by the Engineering and Mining Journal as follows:

PRICES OF 90 PER CENT MOLYBDENITE CONCENTRATES 1918

January 19	$2.25 per pound.
February 16	$2.15 per pound.
March 16	Market demoralized, no buyers.
April 13	Very dull, Great Britain, France and Italy out of the market.
May 18	After a long period of stagnation. Some business done on $1.25 pound basis.
June 8	$1.25 nominal quotation only.

For concentrates containing less than 90 per cent. MoS_2, the price decreases on a sliding scale, and the whole molybdenum content is not paid for, but a margin is left to allow the buyer to raise the grade of the material by retreatment.

[1]Eng. and Min. Journal, vol. 105, No. 2, 1918, p. 92.

THE FUTURE OF THE INDUSTRY

From what has been said in the preceding pages it is evident that, at the present time, the outlook for a rapidly expanding industry is none too bright. What the future has in store no one can say. It is the writer's belief that the demand will increase slowly as successful metallurgical experiments develop new uses or improved uses for the metal. The price for some time to come will probably be considerably less than that of tungsten, and only those properties from which molybdenite can be produced at a low cost will be worked.

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INDEX

PUBLICATIONS OF THE COLORADO GEOLOGICAL SURVEY

R. D. George, State Geologist
Boulder, Colo.

FIRST REPORT, 1908. Out of print except A.

- A. The Main Tungsten Area of Boulder County, by R. D. George.
- B. The Foothills Formation of Northern Colorado, by Junius Henderson.
- C. The Montezuma Mining District, Summit County, by H. B. Patton.
- D. The Hahns Peak Region, Routt County, by R. D. George and R. D. Crawford.

BULLETINS 1 AND 2, IN ONE VOLUME, 1910:

Bulletin 1: Geology of Monarch Mining District, Chaffee County, R. D. Crawford.

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Bulletin 5, Part I: Geology of the Rabbit Ears Region, Routt, Grand and Jackson Counties, P. G. Worcester, F. F. Grout and Junius Henderson. Part II: Permian or Permo-Carboniferous of the Eastern Foothills of the Rocky Mountains in Colorado, R. M. Butters.

BULLETIN 6, 1912: Common Minerals and Rocks, Their Occurrence and Uses, by R. D. George. Out of print.

BULLETIN 7, 1914: Bibliography of Colorado Geology and Mining, Olive M. Jones.

BULLETIN 8, 1914: Clays of Colorado, G. M. Butler.

BULLETIN 9, 1916: Bonanza District, Saguache County, H. B. Patton.

BULLETIN 10, 1916: The Gold Brick District, Gunnison County, R. D. Crawford and P. G. Worcester.

BULLETIN 12, 1917: Common Minerals and Rocks, Their Occurrence and Uses, R. D. George.

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BULLETINS IN PRESS

BULLETIN 14: Molybdenum Deposits of Colorado, P. G. Worcester.

BULLETIN 15: Manganese Deposits of Colorado, G. A. Muilenburg.

BULLETIN 17: The Twin Lakes Mining District, Lake and Pitkin Counties, J. V. Howell.

TOPOGRAPHIC MAP OF COLORADO, 1913: 40x56: Scale 8 miles to the inch; R. D. George. Supply approaching exhaustion.

GEOLOGIC MAP OF COLORADO, 1913: 40x56: Scale 8 miles to the inch; R. D. George. Supply almost exhausted. If requested, the State Geologist will mark on this map the areas structurally favorable for the occurrence of oil.

BULLETINS READY FOR PUBLICATION

BULLETIN 11: The Mineral Waters of Colorado, O. C. Lester and Harry A. Curtis.

BULLETIN 16: The Uranium-Vanadium-Radium Ore Deposits of Western Colorado, R. C. Coffin.

BULLETIN 18: The Fluorspar Deposits of Colorado, H. A. Aurand.

BULLETIN 19: The Cretaceous of Northeastern Colorado, Junius Henderson.

BULLETIN 20: Reports on the oil possibilities of two areas in Eastern Colorado, Norman E. Hinds and James Terry Duce.

BULLETIN 20: Report on the oil possibilities of an area in Western Colorado, R. C. Coffin.

BULLETIN 21: Ward Mining District, Boulder County, P. G. Worcester.

BULLETIN 22: A sketch of the Mineral Resources of the country adjacent to the Moffat Road. (Includes Grand, Routt, Moffat and Rio Blanco Counties.) H. A. Aurand and R. D. George.

COLORADO GEOLOGICAL SURVEY
BOULDER
R. D. GEORGE, State Geologist

BULLETIN 15

MANGANESE DEPOSITS OF COLORADO

BY
G. A. MUILENBURG

DENVER, COLORADO
EAMES BROTHERS, STATE PRINTERS
1919

GEOLOGICAL BOARD

LETTER OF TRANSMITTAL

State Geological Survey,
University of Colorado, November 27, 1918.

Governor Julius C. Gunter, Chairman, and Members of the Advisory Board of the State Geological Survey.

Gentlemen: I have the honor to transmit herewith Bulletin 15 of the Colorado Geological Survey.

Very respectfully,

R. D. George,
State Geologist.

CONTENTS

PREFATORY

Early in the present biennial period the entrance of the United States into the war created urgent demands for a number of mineral substances such as: ores of manganese, molybdenum, nickel and tungsten; pyrite for the manufacture of sulphuric acid, fluorspar for fluxing and for optical purposes. In compliance with requests from the Federal Government, the Advisory Board instructed the State Geologist to undertake an investigation of the deposits of these substances in Colorado.

During these investigations the Colorado Geological Survey was in frequent communication with various Federal boards and committees to whom the results of findings were promptly reported. In this way the Federal authorities were kept fully posted as to the progress of the work and the possibilities of obtaining a supply of these materials from this state. As a consequence of this mode of procedure the important results of the investigation as embodied in these reports have been in the hands of the proper Federal boards for several months.

This report covers the investigation of the manganese deposits of the state in so far as the time and funds available would permit.

The report is incomplete. Deposits are known which could not be examined, but it appears desirable to publish the results of work already done, and finish the investigation at another time.

R. D. George,
State Geologist.

PREFATORY

The following letter from the Director of the United States Geological Survey was received after the present bulletin had gone to press:

> It is understood that the Colorado Geological Survey made some investigations of manganese ores in Colorado during the last field season. As you may remember, Mr. E. L. Jones, Jr., of the United States Geological Survey, examined a few deposits in Colorado.. in the summer of 1917. The Federal Survey plans to publish in its bulletin, Contributions to Economic Geology, 1919, by States, accounts of the principal manganese-ore reserves in the United States. There is not sufficient material at hand to make a separate chapter on Colorado, and I am wondering what your plans may be for publishing the results of the State Survey work. If you expect to publish anything the United States Geological Survey would be glad to co-operate with you to the extent of furnishing descriptions by Mr. Jones of the deposits he examined in Colorado. Should your Survey have considerable additional material that it would be willing to place at the disposal of the United States Geological Survey this Survey would be glad to publish it also in the bulletin, Contributions to Economic Geology.
>
> Yours very truly,
>
> GEORGE OTIS SMITH.

As a consequence of this suggestion and request an exchange of manuscripts was agreed upon. A comparison of the reports of the two geologists showed that while Mr. Muilenburg's work covered the state more completely than did that of Mr. Jones, the latter had reported on three occurrences which Mr. Muilenburg had not visited. The report of Mr. Jones on these three is therefore included in this bulletin, and permission has been given to the Director of the United States Geological Survey to publish in part or in full the report prepared by Mr. Muilenburg.

R. D. GEORGE.

The Manganese Deposits of Colorado

Scope of the Work

In this report are presented the results of work, during the summer of 1917, on the manganese deposits of Colorado. The field season was short and the ground to be covered considerable, hence the report must of necessity be brief. Practically every known manganese property, or prospect, in the state was visited and studied, with a view to determining the relations of the deposit to the surrounding rocks, estimating the available tonnage, and ascertaining the commercial value of the ore. To this end, samples were taken in nearly all cases, representing as nearly as possible average material. These were analyzed in the Survey laboratory at Boulder.

The work was carried on under the direction of Prof. R. D. George, State Geologist, and was undertaken in the hope that it might stimulate the mining of manganese ore, thereby increasing the output of a metal much needed by the steel industry, especially at this time when the United States Government's demands for quantities of steel for prosecuting the war developed a material shortage of the supply.

Acknowledgments

In carrying on the field work, the writer was courteously received by owners and operators of the various prospects and properties, and in many instances was furnished considerable assistance in going over the ground by men who were familiar with the deposits.

To Professor George the writer is grateful, in that he furnished the facilities and means for carrying on the work and, furthermore, for assistance by timely suggestions.

The United States Geological Survey must be mentioned here as having placed at the disposal of the writer a good deal of information, obtained through the work of Mr. Jones. The director, Mr. George Otis Smith, kindly furnished this information, to be used as the Colorado Survey saw fit.

Mr. H. A. Aurand, of this Survey, assisted in furnishing information on one or two deposits, which the writer did not visit personally, and through the kindness of Mr. Barnevald, a report on a Cripple Creek property, by Mr. Frank G. Willis, was turned over to the Survey.

In the preparation of the report the writer is greatly indebted to published literature on the subject of manganese deposits. Free use was made of these publications and, except in a few cases, no further acknowledgment will be made.

General Statement

One of the metals that have come into prominence, on account of the European war, is manganese. Prior to 1914 a large part of the ores and alloys of manganese used in this country was imported. No particular effort had been made to stimulate domestic production, and a condition similar to that prevailing in the potash and dye-stuff industries prevailed. The reason for this condition was the fact that it was not considered possible to compete with the foreign product. With the outbreak of the war, however, steel manufacturers suddenly found themselves short of an almost indispensable metal. The natural result was a rapid rise in price of all manganese material, and the reopening and energetic development of mines that had been idle for years, together with a widespread search for manganese ore, attended in some cases with considerable success.

Many persons will be surprised to learn that, in point of tonnage, the amount of manganese reduced from its ores is exceeded only by that of iron, copper, lead, and zinc. For over fifty years manganese has been used in the manufacture of steel and is now regarded as almost indispensable in the production of steel of every grade.

As a metal, unalloyed with other metals, manganese is practically unknown. It is exceedingly difficult to reduce, and so unstable when reduced that it decomposes water as do sodium and potassium, combining with the oxygen and liberating the hydrogen.

The only way it can be preserved in metallic state is to immerse it in oil, as in air it oxidizes very rapidly. The metal is hard and brittle, melts at a high temperature, and volatilizes quite readily. In combination with some other metal, such as iron, for instance, it is easily reduced, and that is about the only way it is used. Manganese as an unalloyed metal is so rare that very few people have even seen a sample of it.

In the Engineering and Mining Journal[1] it is stated that ferromanganese and spiegeleisen consumed in steel making in the United States in 1916 contained a total of 253,643 long tons of manganese. This was at the rate of thirteen and one-fourth pounds of manganese for every ton of steel produced. Since other countries produce, in the aggregate, nearly as much steel as United States, it is not too much to say that the world's consumption of manganese, alloyed with iron, in that year (1916) was not far from half a million long tons. From this it is manifest that manganese is far from the "minor" metal it is so often considered to be.

1Engineering and Mining Journal, Jan. 12, 1918.

CHAPTER I

SOURCES OF MANGANESE

Distribution of Manganese Ores in the United States

Manganese ores are found in a great many places in the United States, but the localities where they have been profitably mined are comparatively few. In the East mining has been carried on in New England; in various parts of the Appalachian Mountains, and in the Piedmont region. In central United States mining has been confined to Arkansas. In western United States California is about the only state where much mining has been done, although some ore has been mined in Colorado, Utah, and New Mexico. When we consider manganiferous iron ores and manganiferous silver ores we must add the Lake Superior district for the former and Leadville for the latter. Many of the manganiferous ore deposits are so low in manganese, however, that they are used more for the other metals they contain.

Origin of Manganese Ores

Practically all deposits of manganese and manganiferous ore in this country are secondary concentrations. A few exceptions to this statement are deposits of the carbonate, rhodochrosite, and the silicate, rhodonite. Examples of such concentration are seen in the ores of eastern United States, Lake Superior, Arkansas, Leadville, and California. In a few places deposits of bog manganese occur, and while these are regarded primary by some, they are, as a matter of fact, also secondary, since they were derived by leaching from other manganese-bearing minerals. The only primary concentrations of manganese are deposits of rhodochrosite, rhodonite, and other primary minerals found in a few localities. Rhodochrosite veins are common in the Rocky Mountain region, as, for instance, at Rico, Alma, Monarch, and other places in Colorado, and Butte, Montana. Rhodonite veins are found in several places, while the sulphide, alabandite, is found in only a few localities in Arizona and Colorado.

The secondary concentration deposits have all been formed directly or indirectly by weathering, which caused the decomposition of the parent rock containing manganese-bearing silicates. Frequently the material has been reconcentrated from sediments where it was first deposited in disseminated form. Such is the case, for example, in northern Arkansas. Iron is often present with manganese, and they may have been deposited together, but more often they have become separated, due perhaps to the fact that conditions favorable for deposition are not the same for both. Another reason may be found in the fact that soluble compounds of manganese, formed by weathering, are more stable than corresponding iron compounds, and therefore may be carried farther. The manganiferous ores of the West are largely concentrations produced by oxidation of primary deposits produced by, or derived from, igneous activity.

Circulating ground water, when it reaches the surface, frequently deposits small amounts of manganese, and where such deposits attain considerable size they are known as "bog manganese." The manganese in these waters may have been obtained directly from manganese-bearing minerals in crystalline rock, as, for instance, in some Lake Superior deposits, or, as in the northern Arkansas deposit, it may have come from disseminations in sediments.

Manganese oxides are known to be precipitated from sea-water, since nodules and concretions were found by dredging during the Challenger expedition. They were found in many places in the Pacific Ocean at depths over 2,200 fathoms. It has been suggested that the manganese came from the decomposition of rocks thrown out by submarine volcanic eruptions, and was then deposited in concretionary form around fragments of shells and other material.

Manganese, like iron, is dissolved out of crystalline rocks, in which it is almost invariably present in small quantities, by agencies which are everywhere working on the rocks, namely, the processes of weathering. It may go into solution as a sulphate, or a carbonate, to be redeposited later as carbonate, oxide, or hydroxide, under various conditions and in a variety of forms. Deposition as the dioxide, either hydrous or anhydrous, is very common, and is frequently seen in the dendritic infiltrations which occur in many rocks and in the black coatings which sometimes cover river pebbles or surround manganiferous mineral springs.

Manganese differs from iron, however, in its degree of oxidation. Ferrous oxide and hydroxide, as such, are unknown in nature, but manganosite (MnO) and pyrochroite $(Mn(OH))_2$ are well-known minerals. Manganite $(Mn_2O_3.H_2O)$ corresponds in type with goethite, the iron compound, and hausmanite (Mn_3O_4) is the equivalent of magnetite, although the two species are crystallographically unlike. The most common of manganese minerals, pyrolusite (MnO_2), is not matched by any iron compound. Besides this, there are several other manganese minerals which are not represented in type by iron compounds.[1]

The sedimentary ores produced by the alteration of manganiferous minerals have diverse origins. Certain laterite deposits in India contain pyrolusite and psilomelane as integral constituents. In Brazil manganese ores of residual character are known to occur. These have been derived from crystalline rocks whose most characteristic minerals were manganese garnets. Bog or swamp deposits of manganese are common, so that the iron ores are again paralleled to a certain extent. Only the gossan ores have no true manganese equivalent.[2] The sulphides of manganese are relatively rare and their oxidation products are only occasionally observed.

Iron and manganese, then, are dissolved out of the rocks by the same reagents, at the same time, and under essentially the same conditions. They may be redeposited in a similar manner, but not always together, for a separation is more or less perfectly effected. It is true that nearly all limonite contains some manganese, and nearly all psilomelane contains some iron, but in many cases the various minerals are precipitated separately. This separation is explained in a number of ways, some of which have considerable merit.

According to Fresenius, who has analyzed the deposit formed by the warm springs of Wiesbaden,[3] iron is precipitated, first, as ferric hydroxide. The manganese in the water remains in solution much longer as a bicarbonate, and is finally precipitated in the form of carbonate as an impurity in calcareous sinter. That is, solutions of manganese carbonate are more stable than solutions of ferrous carbonate, and manganese is therefore carried farther. A partial separation of the two metals from the same solution is thus effected.

1Clarke, F. W., Date of geochemistry: Bull. U. S. Geol. Survey No. 616, pp. 533-536.
2Clarke, F. W., loc. cit.
3Clarke, F. W., loc. cit.

Quite in harmony with the facts mentioned above are the arguments based upon well-known principles of thermochemistry. These arguments, in the main, are based on the principle that, when several reactions are possible, the one which is accompanied by the greatest evolution of heat will take place. From Clarke's "Data of Geochemistry" we get the following equations:

$$2FeO + O = Fe_2O_3 + 26.6 \text{ Calories of heat.}$$
$$2MnO + 2O = 2MnO_3 + 21.4 \text{ Calories of heat.}$$

Hence, if oxygen acts on a mixture of FeO and MnO, or upon substances equivalent to them, ferric oxide will form first and be more stable.

$$FeO + CO_2 = FeCO_3 + 5.0 \text{ Calories of heat.}$$
$$MnO + CO_2 = MnCO_3 + 6.8 \text{ Calories of heat.}$$

When carbon dioxide acts on these oxides, then the manganese compound will form first and be more stable. If oxygen and carbon dioxide act together in considerable excess ferric oxide and manganese dioxide will both be formed, but if they act slowly, and in small quantities, the oxygen will go to make ferric oxide, and manganese carbonate will be formed at the same time with the carbon dioxide. The manganese carbonate, being somewhat soluble, may then be separated from the ferric oxide by subsequent leaching processes.

The heats of formation of other manganese compounds as given by Clarke are:

$Mn + S$,	22.6 Calories,
$Mn + O$,	47.4 Calories,
$Mn + O + CO_2$,	54.2 Calories,
$Mn + O_2$,	58.1 Calories.

From these figures it will be seen that the dioxide appears to to be the most stable of the compounds in the series. It is, therefore, the most easily formed and the principal ore, which fact is proven by abundant field evidence.

According to F. P. Dunnington[1] it is more than likely that manganese sulphate plays an important part in the separation of the two metals. He has proven experimentally that acid solutions of ferrous sulphate, such as are formed by the oxidation of pyrite, will dissolve manganese oxides to a certain extent. As this solution is exposed to air or meets with calcium carbonate it will lose iron, the calcium carbonate removing all free acid, and an excess of limestone would remove all iron from the solution as ferrous car-

[1]Am. Jour. Sci., 3d ser., vol. 36, 1888, p. 175.

bonate, while the manganese sulphate would remain in solution until exposed to both air and calcium carbonate at the same time. Furthermore, in contact with any manganese carbonate in the presence of air, ferrous sulphate is rapidly oxidized, producing manganese sulphate, ferric hydroxide, and carbon dioxide. Both sulphates of iron react with limestone, while the manganese sulphate reacts but little unless plenty of air is accessible.

From these reactions it is easy to see that limestone may be an important factor in the separation of iron and manganese. Where sulphates of the two metals percolate through limestone, iron will be by far the more easily precipitated, while manganese will remain in solution until it is exposed to air in the presence of limestone.

Classification of Sources of Manganese

For convenience in discussing manganese we may classify the commercial sources into four groups as follows:[1]

1. Manganese ores.
2. Manganiferous silver ores.
3. Manganiferous iron ores.
4. Manganiferous zinc residuum.

Only the first three of the above are classed as ores, the fourth being a residual product obtained from zinc oxide furnaces using New Jersey zinc ores. These ores contain, in addition to zinc, iron and manganese. The zinc is removed as oxide, while iron and manganese, being non-volatile at the prevailing temperature, remain. This residuum is used in making spiegeleisen.

[1]Bull. U. S. Geol. Survey, No. 427, p. 17.

CHAPTER II

MANGANESE ORES

The ores of manganese are those minerals from which the metal can be profitably extracted. Dana's "System of Mineralogy" describes over a hundred species of minerals containing manganese. Of these, however, only about half a dozen are of commercial importance as sources of the metal. As in the case of iron, the most common minerals are oxides. The carbonate, rhodochrosite, is found only occasionally in quantities sufficient to be considered an ore. The silicate, rhodonite, contains too large a percentage of silica to be of any use as a source of manganese. Below is given a list of the more important ores of manganese:

Pyrolusite MnO_2.
Psilomelane $MnO_2.H_2O$ $\left(\begin{matrix} K_2O \\ BaO \end{matrix}\right)$
Wad; impure mixture of the oxides of Mn, Fe, Pb, etc.
Manganite, $Mn_2O_3.H_2O$.
Braunite, $3Mn_2O_3.MnSiO_3$.
Franklinite, $(Fe, Mn, Zn)O.(Fe, Mn)_2O_3$.
Rhodochrosite, $MnCO_3$.

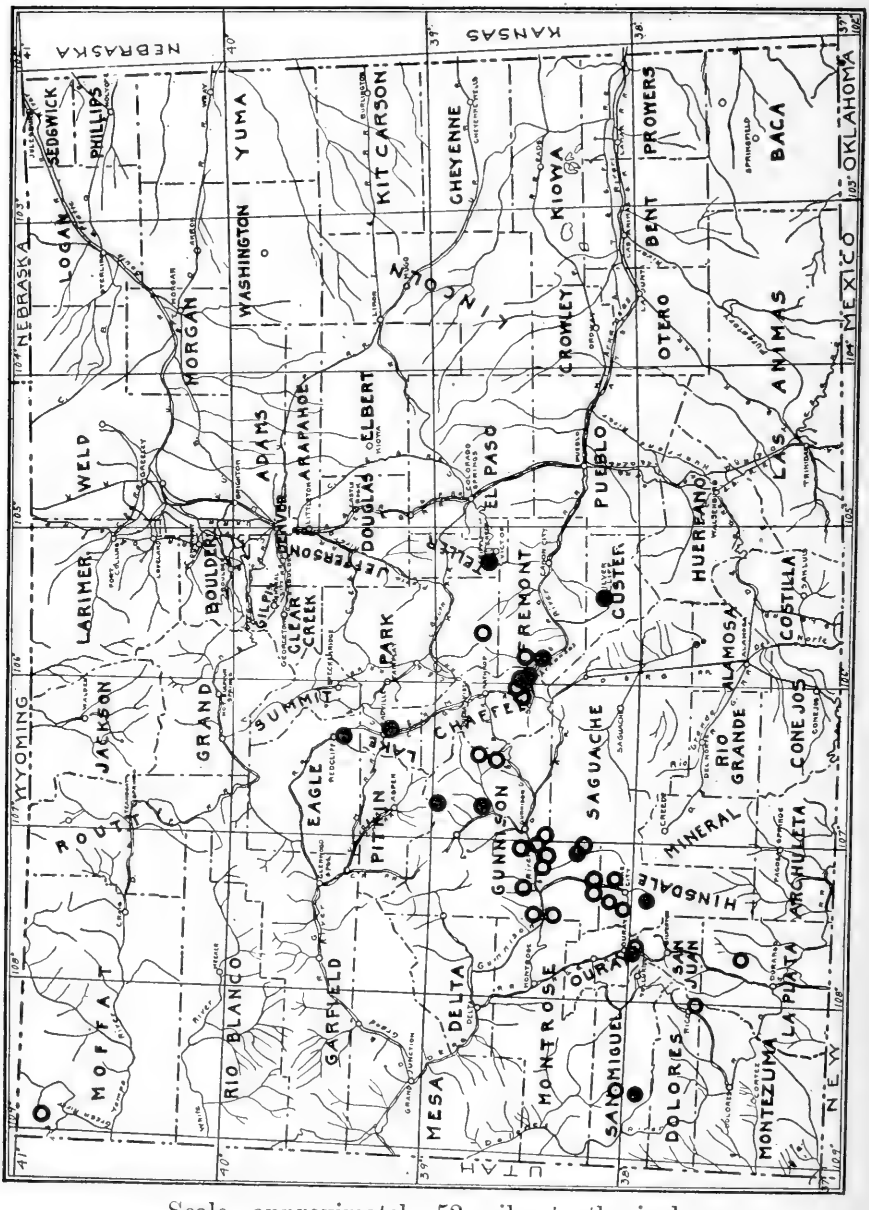
In addition there are other minerals sometimes used when associated with the above, or when they occur in sufficient quantity to be mined.

There are many compounds of manganese other than those mentioned above, some of them valuable on account of other elements they contain, while others are interesting because of the fact that they are the original, primary sources of manganese ores. Compounds belonging to this class are silicates, such as the amphiboles, pyroxenes, micas, chlorites, garnets, olivines, epidotes, etc., many of which carry manganese. The rarer compounds used for other elements chiefly are: tungstates, niobates, and tantalates, while still others, such as sulphides, sulphates, arsenides, arsenates, borates, etc., are interesting mainly from a mineralogic standpoint.

For a complete list of manganese minerals the reader is referred to Bull. No. 427, U. S. Geol. Survey, p. 20.

MANGANESE DEPOSITS OF COLORADO

Colorado Geological Survey. Bulletin 15 Plate I



Scale: approximately 52 miles to the inch.

The black circles indicate important locations of manganese.

The clear circles indicate less important locations.

A brief description of the more common manganese minerals, compiled from various sources, follows:

PYROLUSITE, MnO_2

(Commonly contains a little water)

Pyrolusite is a grayish-black or black mineral occurring in fibrous and columnar forms, in acicular crystals, which are probably pseudomorphs after manganite, in crusts and masses, and in dendritic forms along seams, also granular massive, and sometimes reniform and botryoidal. Its hardness ranges from 2 to 2.5; its specific gravity is 4.8. It has a very black streak and metallic luster. On account of its softness it very readily soils the fingers. Before the blowpipe it is infusible, and with soda or borax gives the characteristic manganese bead. When pure it contains 63.2% metallic manganese. (It should be mentioned here that on account of impurities, such as clay and fragments of rock present in mineral deposits, and on account of impurities in the minerals themselves, the manganese content of a deposit never runs as high as the theoretical percentage in the individual minerals.)

Pyrolusite is a secondary mineral resulting from the alteration of other manganese minerals. Manganese is dissolved out of the crystalline rocks, in which it is almost always present in small amounts, and redeposited under various conditions, chiefly as pyrolusite. Rocks and pebbles are frequently found covered with a coating of manganese. In arid and semi-arid regions this is especially common and is known as "desert varnish." At other times the coatings are in forms resembling minute plants or the veins of a leaf. These are known as dendrites. Beds and pockets of manganese ores are often found in residual clays, especially those resulting from the decay of limestones. As the limestone weathers and its soluble constituents are dissolved out, the insoluble manganese becomes concentrated in nodules and remains as such in the clay. Small quantities of manganese nodules have at times been brought up by deep sea dredges, showing that there also concentration of manganese takes place. In the oxidized portions of veins pyrolusite is common, associated with quartz and various metallic minerals.

Pyrolusite generally occurs associated with psilomelane, filling or lining cavities in it, or occurring in alternating layers with it in botryoidal masses. Under these conditions, it is very commonly fibrous in structure, with the fibers perpendicular to the surface of the layers. Scattered through such masses one often finds crystals of pyrolusite in such relations with the psilomelane that it seems evident that the former is an alteration product of the latter. Polianite (MnO_2) has characteristics similar to pyrolusite, but is tetragonal in crystal form. It occurs but rarely.

PSILOMELANE

Psilomelane, a black or bluish-black mineral, is of uncertain composition, being composed chiefly of manganese oxides, MnO_2 and MnO, together with water and small amounts of barium, potassium, and sometimes cobalt, oxides. It does not occur in crystalline forms, but is usually massive, botryoidal, or stalactitic. It has a hardness of 5-6 and specific gravity of 3.7-4.7. Streak, brownish-black to black; luster, submetallic to dull. Before the blowpipe it acts like pyrolusite. It is distinguished from other manganese oxides by its superior hardness. The percentage of metallic manganese varies from 45 to 60.

It occurs as a secondary mineral associated with pyrolusite.

MANGANITE, $Mn_2O_3.H_2O$

Manganite is a heavy, steel-gray to black-colored mineral, occurring massive, in prismatic, orthorombic crystals, or in columnar and fibrous masses. The crystals are usually deeply striated parallel to the long direction. Its hardness is 4, and specific gravity 4.3. The luster is metallic and the streak brownish black. Blowpipe tests are similar to those for pyrolusite. When pure it contains 62.4% metallic manganese.

It is usually associated with other manganese minerals and iron oxides as a secondary mineral, but has also been found as a vein mineral.

BRAUNITE, $3Mn_2O_3.MnSiO_3$

Braunite is a heavy, shiny, brownish-black to steel-gray mineral, occurring usually in tetragonal pyramids resembling isometric octahedrons. It is also found massive. It has a hardness of 6, and specific gravity of 4.8. The luster is submetallic and the streak is grayish black. When pure is contains 69% metallic manganese.

It occurs secondary in veins and other deposits associated with pyrolusite and psilomelane. It is not a very common ore of manganese.

WAD

This mineral is a mixture of oxides of Mn, Fe, Pb, etc., occurring in soft, black, or brownish, more or less porous masses, with a hardness of 1-3, and specific gravity from 3-4.5. It is found as an alteration product, due to the weathering of other manganese minerals. It is also found in bog deposits associated with limonite.

FRANKLINITE, $(Fe, Mn, Zn)O.(Fe, Mn)_2O_3$

Franklinite is a heavy, black-colored mineral, occurring massive, coarse or fine granular, or in distinct octahedral crystals. Its hardness is 6, and specific gravity 5.15. It has a metallic luster and black color with dark-brown streak. At times it is slightly magnetic.

Before the blowpipe it becomes strongly magnetic, and with borax gives the manganese bead.

The percentage of metals present varies widely, since any one is capable of replacing any of the others.

It is found practically only in the Franklin Furnace district of New Jersey, and is an ore of both manganese and zinc.

RHODOCHROSITE, $MnCO_3$

Rhodochrosite is a pink or rose-colored mineral occurring in cleavable and granular to compact masses. It is also found in distinct rhombohedral-hexagonal crystals. It has a perfect cleavage in three directions, i.e., parallel to the faces of the rhombohedron. The hardness varies from 3.5-4.5; the specific gravity is 3.5; the luster vitreous, and the color various shades of rose, red, or pink. It becomes black on exposure to air, due to the formation of manganese dioxide.

Before the blowpipe it gives the characteristic manganese tests.

Rhodochrosite is usually a primary mineral occurring in veins with ores of silver, lead, and copper, and other manganese minerals. It is used as an ore of manganese in limited quantities. When pure it contains 47.8% metallic manganese.

RHODONITE, $MnSiO_3$

Rhodonite is found in cleavable and compact masses and occasionally in triclinic crystals. It has a fairly well-developed cleavage in two directions, approximately at right angles to each other. Its hardness is 6.0, specific gravity 3.6, and color pink to red, often stained with manganese oxide.

Before the blowpipe it fuses to a dark-colored glass, and with borax gives the characteristic manganese bead.

Rhodonite is a primary mineral occurring in veins and metamorphic limestones. It is not used as an ore of manganese, but is a source of many of the secondary oxides of manganese.

MANGANIFEROUS IRON ORES

Manganiferous iron ores are simply mixtures of manganese oxides with iron ore in various proportions. The manganese oxides are chiefly psilomelane, but pyrolusite and manganite and other oxides have been observed in quantity. The iron ores are largely limonite, or the so-called "brown ores," although in the Lake Superior region much ore is in the form of hematite. Manganese and iron ores may occur together as a mixture in which the different minerals can readily be distinguished in hand specimens, or they may occur in such intimate and minute mixtures that it is difficult, if not altogether impossible, to tell whether it is a mechanical mixture or a chemical combination. Where individual minerals are recognizable, limonite has at times been observed lining cavities in manganese ores, and at other times nuclei of psilomelane are found in the interior of limonite nodules. It seems more common for manganese to have penetrated deeper into the mass and iron to have remained nearer the surface, but, as a rule, there is no evidence of any definite relation between them.

The amount of manganese in manganiferous iron ores varies from a fraction of a per cent up to as much as 40% or more. The higher grades are used in the manufacture of ferromanganese and spiegeleisen, while the lower grades are used only in making manganese pig iron.

MANGANIFEROUS SILVER ORES

Manganiferous silver ores occur widely distributed in the oxidized portion of metalliferous deposits of the Rocky Mountains and western regions. The ores are composed of manganese and iron oxides, carrying small quantities of silver chloride and lead carbonate, and at times a little free gold, and other metals. The iron and manganese minerals are very intimately mixed and appear to be absolutely non-crystalline. In much of the material of high manganese content manganese is present probably as wad. Iron occurs as limonite and other hydrous oxides. Occasionally manganese is more abundant in the ore than iron, as at Butte, but more commonly the ore runs higher in iron. At Leadville, for instance, the average manganese content varies from 15 to 25% in the oxidized ore, while at the same time the iron varies from 25 to 50%.

The manganese content of the ores is in part the result of oxidation of vein minerals, but in part, also, is derived from other sources. At Leadville the unoxidized portions of the veins are remarkable for the absence of the manganese minerals, rhodonite and rhodochrosite, although analyses show manganese in quantities slightly over 1%. The oxidized ore, on the other hand, shows in places from 10 to 40% manganese, averaging, as before stated, 15-25%. Emmons and Irving suggest that this universal increase in the amount of manganese may be due to leaching from surrounding rocks.[1]

The manganiferous silver ores are classed under three heads with regard to use:

1. Ores high in silver and lead; used primarily as a source of these metals; manganese and iron content, valuable only in so far as it serves as a flux in smelting; premiums are often paid for these by the smelters.
2. Ores low in silver and lead, but high in manganese and iron; used for ferromanganese and spiegeleisen.
3. Ores low in silver and lead, and also low in iron and manganese; used principally as flux on account of the iron and manganese; the silver and lead are usually recovered, since the flux is used in smelting other silver ores.

MANGANIFEROUS ZINC RESIDUUM

This source of manganese is important only in New Jersey and neighboring places where New Jersey zinc ores are treated. As before mentioned, it is the residue left after the zinc has been oxidized, and contains both iron and manganese. Most of this comes from the mineral franklinite (Fe, Mn, Zn)O.(Fe, Mn)$_2$O$_3$. A little manganese comes perhaps from tephroite and rhodonite, which are both present as gangue. The material is used chiefly for spiegeleisen.

[1] Emmons, S. F., and Irving, J. D., The downtown district of Leadville, Colo.; Bull. U. S. Geol. Survey No. 320, 1907, pp. 34-35.

USES OF MANGANESE

While it is not within the scope of this work to give a detailed account of the various uses of manganese, it is deemed advisable, nevertheless, to include a brief summary of the more important uses of the metal.

In the steel industry manganese has come to play a very important role, on account of certain properties which it imparts to steel. Before it can be used it must be alloyed with iron and carbon to form either ferromanganese or spiegeleisen. The former may contain as much as 80% manganese, but the domestic product averages about 70%. In spiegeleisen the percentage of manganese is much lower, the standard figure on which the price is based being 20%. The average manganese content is even lower than this, frequently not exceeding 18%. Both alloys are high in combined carbon, the amount running up to as much as 7%.

The manganese alloys are added to molten steel in the converter, or open hearth furnace, for the purpose of introducing both manganese and carbon. Manganese cleanses the steel by combining with the contained oxygen and, to some extent, with sulphur and phosphorus, and then carries these impurities into the slag. The carbon serves the purpose of giving the steel hardness and strength. By adding larger amounts of these alloys, manganese steel, which is noted for its hardness, tenacity, and durability, is produced. This is much used in the wearing parts of heavy machinery.

In recent years the tendency has been to use more ferromanganese and less spiegeleisen, on account of the smaller amount of ferromanganese necessary to add to the steel. Spiegeleisen usually has to be melted in a cupola furnace before using, whereas ferromanganese can be added direct. The latter also introduces less carbon, which sometimes is an advantage.

Ferromanganese and spiegeleisen are produced by smelting a mixture of manganese ore and iron ore in an ordinary blast furnace. A high temperature is required and more fuel is used than in iron smelting. During the process large quantities of manganese go into the slag. Slag from a ferromanganese furnace often contains as much as 10% manganese. A considerable amount of iron-manganese alloys is now being made in electric furnaces.[1] This method effects considerable saving, not only in fuel, but in the production of a higher-grade product, and consequently less loss

[1]Met. and Chem. Engineer, Dec. 15, 1917, pp. 701-704. Eng. and Min. Journal, Dec. 15, 1917, pp. 1027-1030.

through rejection. In this connection experiments have also been made with a ferro-silicon manganese with good results.

Phosphomanganese, iron and manganese alloyed with considerable phosphorus, has been used slightly in the manufacture of phosphorus steel. It is prepared in a blast furnace from a mixture of manganese ore and apatite.

Cupromanganese is the most important of manganese alloys, with the exception of ferromanganese and spiegeleisen. It is prepared by heating a mixture of powdered manganese ore, coal dust, and granulated copper, with a cover of fluorspar, salt, and powdered charcoal, in a graphite crucible. It is used in making manganese bronze, manganese brass, German silver, etc.

Other alloys with manganese are: manganese amalgam, a manganese-mercury alloy; manganese-aluminum alloy; Heusler's alloys, which are magnetic alloys of copper, manganese, and aluminum, and several others with zinc, tin, magnesium, antimony, arsenic, bismuth, and boron.

In the chemical industry manganese ore of high grade is used in considerable quantity in the manufacture of dry and wet batteries. Manganese ore is also used in glass-making, brick and pottery, paints and dyes, and as a disinfectant. Formerly large quantities of high-grade manganese ore were used in making chlorine and bromine. However, at present, electrolytic methods have largely replaced the manganese-peroxide method. In the manufacture of oxygen it is still used in quantity, since it carries such a relatively large amount of available oxygen. One of the atoms of oxygen in the peroxide (MnO_2) is very loosely combined and is quickly liberated by heat or acids. MnO_2 carries theoretically 36.8% of oxygen, and as half of it may be liberated, 18.4% would indicate the available oxygen. Practically, 13 to 17% only is available, on account of the impurities in the natural peroxide.

Both the manufactured peroxide and the native minerals, especially pyrolusite, are used for oxidizing purposes, but the pyrolusite must be very pure. The manganese itself is not used for any of these purposes, but acts only as a carrier of oxygen, and is valuable because it so easily gives up its available supply and also readily unites with more under certain treatment.[1]

[1]Penrose, R. A. F., Manganese: Its uses, ores and deposits, Ann. Rept., Ark. Geol. Survey, 1890, vol. 1, pp. 44-46.

TESTS FOR MANGANESE

Bead test:—Powder a small piece of the mineral to be tested, and fuse a very small quantity of the powder on a borax bead, made by heating the end of a piece of platinum wire in a blowpipe flame, then dipping it while hot into powdered borax and fusing the borax that adheres to the wire. While still hot dip the bead lightly in the powdered mineral and fuse again. If manganese is present the bead will become amethyst colored, unless too much of the mineral was used, when it will be dark and opaque. If this is the case the operation should be repeated until an amethyst bead is obtained, showing the presence of manganese, or a clear bead, showing no manganese.

Chlorine test:—The higher oxides of manganese when powdered and treated with dilute hydrochloric acid react, causing the evolution of chlorine, a greenish-yellow gas of stifling odor.

Physical tests:—A simple way to distinguish manganese oxide minerals from iron minerals in the field is by making a mark on a piece of white chert or quartz, with the mineral to be determined, and noting the color. Manganese minerals will make a black mark, whereas iron minerals will make a red to yellowish-brown mark, depending on whether hematite or limonite predominates; manganiferous iron minerals will make a brownish-black streak as a rule. (Magnetite makes a black streak.)

Since a number of manganese oxide minerals are so nearly alike that they cannot be positively distinguished without analysis, the following field tests may be applied and the minerals in question provisionally classed: If the mineral is hard and non-crystalline, or amorphous, it may be classed as psilomelane. One that is crystalline and fairly hard may be called manganite, but if it is soft it is more probably pyrolusite. Minerals that are soft and non-crystalline and do not show the compact, closed-grained structure of psilomelane are to be classed as wad.

HISTORY OF PRODUCTION

For many years prior to 1914 Russia was by far the greatest producer of high-grade manganese ores. Most of this output came from one district, Sharopan, near Chiaturi, south of the Caucasus Mountains. Some engineers have estimated the total reserves of high-grade manganese ore in this one district to be upwards of

100,000,000 tons, although this has been disputed. For some time before the war Russia's output averaged over half a million tons yearly.

Next in importance to Russia as sources of manganese ore are Brazil and India. In Brazil there has been a very rapid development of the industry, and the production of manganese ore in 1917 is estimated to have been about 500,000 tons. As the war has practically stopped the exportation of manganese from Russia and India, the deposits in Brazil have assumed very great importance.

The United States has never been a large producer of manganese ore. A writer in Mineral Industry some years ago stated that the manganese output of this country was insignificant, because of the trifling character of the deposits. In 1914 the total production in the United States of ore containing more than 40% of manganese was 2,635 long tons. In the production of ferromanganese and spiegeleisen, and in the other arts using manganese compounds, it was desirable to have an ore containing at least 40% of the metal. Before the war it was almost impossible to find a steel maker willing to buy a lower grade. At the present time some steel manufacturers buy ore containing only 28% of manganese, and are glad to get it. Most of the manganese-bearing ores mined in the United States were classified as manganiferous iron ores, which may or may not contain silver and lead. In these ores the manganese is valuable mainly as a flux in smelting operations, although it can sometimes be used for making spiegeleisen. The recent high prices have resulted in a material increase in the domestic production of high-grade ore, and the output for 1917 was more than 125,000 tons, but even this amount is still much below the requirements.

Purchasers of Manganese and Manganiferous Ores to October 1, 1917[1]

a Purchase manganese ore with 40% or more manganese and less than 2% iron.

b Purchase manganese ore with 40% or more manganese and 2% or more iron.

c Purchase manganiferous ore with 15 to 40% manganese.

d Purchase manganiferous ore with 5 to 15% manganese.

1Prepared by U. S. Geol. Survey.

c Allan Wood Iron & Steel Co., Philadelphia, Pa.
c Algoma Steel Corp., Sault Ste. Marie, Ontario, Canada.
cd Alleghany Ore & Iron Co., Buena Vista and Iron Gate, Va.
a American Carbon & Battery Co., East St. Louis, Ill.
a American Ever Ready Battery Co., Long Island City, N. Y.
bcd American Manganese Mfg. Co., Bullitt Bldg., Philadelphia, Pa. (or Dunbar, Pa.).
bc American Steel Foundries, McCormick Bldg., Chicago, Ill.
a Anglo-American Flash Light Co., Pittsburgh, Pa.
c James B. Bailey, Pine Forge, Pa.
b Beckman & Linden Engineering Corp., Bay Point, Cal.
ab Bennett-Brooks, 120 Liberty St., New York, N. Y.
ab Berkshire Iron Works, Bullitt Bldg., Philadelphia, Pa.
bc Bethlehem Steel Corp., South Bethlehem, Pa.
ab Bilrowe Alloys Co., 201 Bernice Bldg., Tacoma, Wash.
ab Binney & Smith, 81 Fulton St., New York, N. Y.
ab Chas. A. Burdick, E. M., 15 Broad St., New York, N. Y.
abc C. F. Burgess Laboratories, Madison, Wis.
a L. H. Butcher & Co., Marine Bldg., San Francisco, Cal.
abcd Cambria Steel Co., Pittsburgh, Pa.
ab Carnegie Steel Co., Pittsburgh, Pa.
bcd Central Iron & Coal Co., Holt, Ala.
bc Charcoal Iron Co., Detroit, Mich.
a Charles B. Chrystal, New York, N. Y.
a Cleveland-Cliffs Iron Co., Cleveland, Ohio.
c Colorado Fuel & Iron Co., Pueblo, Colo.
d Corrigan, McKinney & Co., Cleveland, Ohio.
ab W. R. Cuthbert (National Paint & Manganese Corp.), Lynchburg, Va.
bc Delaware River Steel Co., Chester, Pa.
abc W. H. Denison, Cushman, Ark.
b Electric Reduction Co., Washington, Pa.
b Empire Steel & Iron Co., Catasauqua, Pa.
b Fuller & Warren Co., Troy, N. Y.
ab Robert Gilchrist, 82 Beaver St., New York City.
b Goldschmidt Thermit Co., New York, N. Y.
d M. A. Hanna & Co., 1300 Leader-News Bldg., Cleveland, Ohio.
a Charles Hardy, 50 Church St., New York, N. Y.
a Harshaw, Fuller & Goodwin Co., Electric Bldg., Cleveland, Ohio.
a Hazel-Atlas Glass Co., Clarksburg, W. Va.
c W. P. Heath & Co., 509 Olive St., St. Louis, Mo.

bc Hickman, Williams & Co., St. Louis, Mo.
ab C. W. Hill Chemical Co., Los Angeles, Cal.
ab E. C. Humphrey & Co., Detroit, Mich.
ab Illinois Steel Co., 208 South La Salle St., Chicago, Ill.
a Import Chemical Co., New York, N. Y.
d International Smelting Co., Salt Lake City, Utah.
bc Jones & Laughlin Steel Co., Pittsburgh, Pa.
b Juniata Furnace & Foundry Co., 30 West Girard Ave., Philadelphia, Pa.
c La Belle Iron Works, Steubenville, Ohio.
c La Follette Coal & Iron Co., La Follette, Tenn.
bc Lackawanna Steel Co., Buffalo, N. Y.
a J. S. Lamson & Bros., Inc., 80 Maiden Lane, New York, N. Y.
ab E. J. Lavino & Co., Bullitt Bldg., Philadelphia, Pa.
a C. W. Leavitt & Co., 30 Church St., New York, N. Y.
b Lebanon Blast Furnace Co., Lebanon, Pa.
a Levensaler-Speir Corp., Monadnock Bldg., San Francisco. Cal.
ab David Loeser, 1400 Broadway, New York, N. Y.
ab Los Angeles Pressed Brick Co., Los Angeles, Cal.
bc Low Moor Iron Co. of Va., Lowmoor, Va.
b T. L. McCarty, Box 217, Eureka, Utah.
c McKeefrey Iron Co., Leetonia, Ohio.
d Mangan Iron & Steel Co., 321 Manhattan Bldg., Duluth, Minn.
a Manhattan Electrical Supply Co., 41-47 Morris St., Jersey City, N. J.
abc E. E. Marshall, Bullitt Bldg., Philadelphia, Pa.
ab The Metalores Corp., 56 Pine St., New York, N. Y.
abc Miami Metals Co., Tower Bldg., Chicago, Ill.
ab Mines & Metals Corp., 77 Broad St., New York, N. Y.
cd Mississippi Valley Iron Co., 6500 South Broadway, St. Louis, Mo.
bc National Alloy Co., Philadelphia, Pa.
a National Carbon Co., Cleveland, Ohio.
abc Noble Electric Steel Co., 995 Market St., San Francisco, Cal.
c Northwestern Iron Co., Milwaukee, Wis.
a Nungesser Carbon & Battery Co., Cleveland, Ohio.
ab Oakley Paint Mfg. Co., Los Angeles, Cal.
c Old Dominion Pig Iron Corp., Roanoke, Va.
b Pacific Coast Steel Co., San Francisco, Cal.
abc Pacific Electro Metals Co., Balboa Bldg., San Francisco, Cal.

ab Pacific Sewer Pipe Co., Los Angeles, Cal.
c Perry Iron Co., Erie, Pa.
a Pittsburgh Lamp Brass & Glass Co., Pittsburgh, Pa.
cd Pittsburgh Steel Co., Pittsburgh, Pa.
c Pulaski Iron Co., Pulaski, Va.
c Republic Iron & Steel Co., Birmingham, Ala.
ab A. P. Rice, Spencer, Ohio.
b Ricketson Mineral Paint Wks., Milwaukee, Wis.
ab Rogers, Brown & Co., New York, N. Y.
bc Frank Samuel, Philadelphia, Pa.
c John A. Savage & Co., Duluth, Minn.
c Scullin Steel Co., St. Louis, Mo.
abc Seaboard Steel & Manganese Corp., 50 East 42nd St., New York, N. Y.
c Seattle Smelting Co., Van Asselt Station, Seattle, Wash.
ab Arthur Seligman, 165 Broadway, New York, N. Y.
bc Shaffer Engineering Co., Nazareth, Pa.
bc Sligo Furnace Co., 915 Olive St., St. Louis, Mo.
cd Sloss-Sheffield Steel & Iron Co., Birmingham, Ala.
b C. Soloman, Jr., South San Francisco, Cal.
abc Southern Manganese Corp., Anniston, Ala.
bc Standard Steel Works Co., 11th floor, Morris Bldg., Philadelphia, Pa.
ab Oscar Stromberg, Tribune Bldg., New York, N. Y.
abc The Suffern Co., Inc., 96 Wall St., New York, N. Y.
ab Superior Portland Cement Co., Concrete, Wash.
c Tacoma Metals Co., Tacoma, Wash.
abc Tennessee Coal, Iron & Railroad Co., Birmingham, Ala.
c Thomas Iron Co., Hokendauqua, Pa.
c Toledo Furnace Co., Toledo, Ohio.
a U. S. Glass Co., Pittsburgh, Pa.
d United States Smelting, Refining & Mining Co., Salt Lake City, Utah.
bc United States Steel Corp., Empire Bldg., New York, N. Y.
b Utah Iron & Steel Co., Salt Lake City, Utah.
b Vanadium Steel Alloys Co., Latrobe, Pa.
ab Western Reduction Co., Portland, Ore.
b Wharton Steel Co., Morris Bldg., Philadelphia, Pa.
c Wickwire Steel Co., Buffalo, N. Y.
c Wisconsin Steel Co., Harvester Bldg., Chicago, Ill.
c Worth Bros. Co., Widener Bldg., Philadelphia, Pa.
d Zenith Furnace Co., Duluth, Minn.

PRICES

There has been considerable complaint because of the great difference in price of manganese in high-grade and low-grade ores. Technical difficulties prevent the use of low-grade ores in the manufacture of manganese alloys. Silica and phosphorus in large amounts render an ore almost worthless for this purpose. For this reason many shippers of manganiferous iron ores receive no more for their ore than they would if it contained only iron. Manganese can replace iron to almost any extent in a lead blast furnace slag, and in addition increases the fluidity of the slag. Therefore, for ores running from 5 to 30% manganese, there is a considerable demand from the smelting companies. However, the great need in the United States now is the opening of more high-grade deposits and the development of methods by which low-grade ores can be concentrated. Considerable progress has been made in milling processes, and one operator has announced that he has been able to remove the silica from a 16% ore and make a high-grade concentrate. The principle of the process has not yet been divulged.

The average price at Pittsburgh for 80% ferromanganese during 1917 was about $307 per ton. For three months during the year the average price was $400. Before the war the price was about $50, and went as low as $27.50 during 1914.

In February, 1918, the quotations were $250, with spiegeleisen selling for about $60 a ton. The price for high-grade ore is $1.20 per unit, or about $60 a ton for 50% ore.

SCHEDULE OF PRICES

Prices of manganese ores are governed by the following schedules, established by the Carnegie Steel Company, the price being for delivery at Pittsburgh or South Chicago:

Prices are based on ores containing not more than 8% silica, or 0.20% phosphorus, and are subject to deductions as follows: For each 1% in excess of 8% silica, 15 cents per ton; fractions in proportion. For each 0.02%, or fraction thereof, in excess of 0.20% phosphorus, 2 cents per unit of manganese per ton.

Ores containing less than 40% manganese, or more than 12% silica, or 0.225% phosphorus, are subject to acceptance or refusal, at the buyer's option.

Settlements are based on analysis of sample dried at 212° F., the percentage of moisture in the sample as taken being deducted from the weight.

Manganese ores for chemical purposes, and for use as oxidizers and coloring agents, are valued according to the quantity of manganese dioxide present. As a rule, 80% manganese dioxide and not more than 1% iron are the specifications.

On account of war conditions the above schedule has not been very rigidly enforced, because of the fact that in some cases the need has been so urgent that steel makers were glad to get even lower-grade ores.

CHAPTER III

MANGANESE ORES OF COLORADO

Location and General Features

Manganese and manganiferous ores occur in a great many localities in the Rocky Mountain region, from Canada to Mexico, but ores suitable for commercial purposes are confined to a few places. The manganiferous silver ores are more valuable for their silver content than for the manganese they contain, consequently they are used as a source of that metal. Moreover, such ores are rarely sufficiently high grade to make them suitable as a source of manganese. Colorado, however, seems to be an exception to this rule, especially at Leadville, where some of the argentiferous deposits contain a considerable quantity of manganese and manganiferous iron ore. In other places, although the ores are not used as a source of these metals, manganese and iron present in the ore are valuable for fluxing and are paid for as such by the various smelters. Deposits of manganiferous ores are known at Leadville, Rico, Monarch, Alma, Gilman, Red Cliff and other places.

In addition to the manganiferous silver ores mentioned above, considerable quantities of manganese and manganiferous iron ore occur in places in Colorado, and with increased prices and transportation facilities they will probably be developed and the ores placed on the market to help supply the steel industry.

Nature and Mode of Occurrence of Colorado Manganese Ores

Most manganese ores occur in the form of oxides and are frequently associated with iron. The most important ones occur as bedded deposits in limestone or sandstone, often showing considerable replacement.

Besides the bedded deposits, manganese is found in the form of oxides in lava flows and in veins in igneous, metamorphic, and sedimentary rocks. The former occur as little veinlets in massive lava, as a cement in a flow breccia, in cavities and vugs, and as irregular mammillary masses imbedded in a sandy matrix associated with the lava flows. The ore is hard and compact, but usually runs high in silica. It seems likely that the ore has originated by alteration of manganiferous silicates in the lava and subsequent segregation of manganese in the form of oxides. It was evidently deposited from waters percolating downward from the surface, through the weathered material to the solid rock below. In places this contained numbers of small fissures and cracks, and in these manganese oxides were deposited. Where the rock was composed of a sandy lava matrix the manganiferous solutions penetrated farther and deposited their load around sand grains, forming irregular nodules. In still other places it forms the cementing material in volcanic breccias. The fact that little iron occurs with the manganese can be accounted for by the explanation given in a previous chapter, and the high silica content is explained by the associations and the manner of formation. These last-named types occur over an exceedingly large area, but since the quantity is always small and the quality poor, they are of no commercial importance.

THE IRON MOUNTAIN OR WELLSVILLE DEPOSIT

The ground on which this body of ore occurs is owned by Mr. W. H. Boyer, of Salida, and Mr. E. Frankenberry, of Canon City, and is being developed and operated by Mr. Boyer.

The property is located two miles northeast of Wellsville, a station on the Denver & Rio Grande Railroad, six miles east of Salida. From the railroad to the mine the wagon road runs up a steep narrow gulch, but the roadbed is good.

The ore occurs in massive limestones, probably of Carboniferous age. As no further differentiation has been made of the rocks, nothing can here be said as to the exact correlation with beds in other places. The region has undergone considerable folding and, as a result, the beds dip in an easterly direction at angles ranging from 20 to 40°. Farther away from the mine the strata flatten out and become more nearly horizontal. On either side of this area, a short distance away, are found the old pre-Cambrian formations, consisting of slate, schist, gneiss, and quartzite, and overlying the sediments are extensive rocks of more recent age.

The ore occurs as an irregular bed between two beds of limestone. It follows quite closely along the bedding, although the contact with the lower bed is irregular. As a result it is inclined to be pockety and irregular, varying in thickness from twelve inches to four feet. This pinching and swelling gives rise to the formation of pockets, which may contain forty or more tons of good ore.

The extent of the ore body is not known, as only a little work has been done on it, but it appears to be 150 feet long and about 100 feet wide. However, the croppings can be traced along the surface for a distance of about 250 yards, when they pass over the crest of a hill and are covered up.

The ore itself consists largely of pyrolusite and psilomelane with mixtures of wad. It is possible that more or less manganite is mixed in with the pyrolusite. In places the ore is crystalline and fibrous, and here and there one finds little cavities lined with botryoidal psilomelane. The greater part of it, however, is granular and soft. In the cavities are seen alternating bands of compact psilomelane and fibrous, crystalline pyrolusite. In places there are little nests or cavities filled with a granular white calcite. Around the cavities there is usually a zone of rather porous material, as if solution had removed some of the constituents.

The enclosing limestone is massive, fine grained, and but slightly crystalline. Apparently it is quite pure, as its color is white, even after exposure on the surface.

The ore was probably derived from manganese-bearing minerals in the metamorphic rocks of the region. Upon weathering it was carried out and deposited, either in disseminated form or directly concentrated into its present form. Its position in the limestone rather favors the latter alternative, and furthermore suggests the possibility of a slight local unconformity. If this is the case it would seem that the concentration took place in a relatively small shallow basin, which was gradually sinking. The irregular contact with the limestone below seems to suggest unconformity. There is no evidence at hand that the ore is of a residual character, while the small amount of replacement in evidence probably occurred subsequent to the deposition of the ore in its present form.

The ore body has been opened by a forty-foot inclined winze and a seventy-foot tunnel about thirty feet below the bottom of the winze. Several carloads of ore were taken from these openings and shipped to the Colorado Fuel & Iron Company, to be used in the manufacture of steel. There was in sight at the time of examination from 3,000 to 5,000 tons of ore, that would run from 20 to 40% manganese. It is entirely possible that by working farther along the outcrop of the deposit and down along the dip considerably more good ore will be discovered.

The analysis of an average sample of ore taken from material in the stock pile ready for shipping gave the following results:

Mn	40.0%
Fe	3.6%
SiO_2	4.0%
P	0.03%
S	0.7%

From this analysis it will be seen that the ore comes well within the limits of silica, phosphorus and sulphur as set by the smelter. By selective mining and sorting a better grade of ore could be produced.

A second bed of ore is found about fifty feet higher stratigraphically than the one described. It is much thinner and is more irregular than the first one. Very little work has been done on it, but it can be traced for a considerable distance along the hillside. Possibly if it were opened up some good ore might be obtained.

WALTER HIGHAM'S MINE, SALIDA

The manganese property operated by Walter Higham & Sons, of Salida, is known as the Liberty Hill Mine, and is located about ten miles northwest of Salida. The road to the mine is in good shape and can be used by auto trucks. The elevation above sea-level is approximately 9,000 feet.

The ore is found in massive gray limestone, probably of Carboniferous age, and as in the case of the Wellsville deposit, is associated with folded rocks. The folding here, however, is not as pronounced and sharp as at Wellsville. The ore is probably in the same formation as that just described. The strike of the rocks is the same and the dips are also in about the same directions. The only difference is that the Wellsville deposit is on the west limb of a syncline, and this one is on the east limb. Here also the ore occurs in an irregular bed, showing pinching and swelling and other irregularities. In general it seems to follow the bedding planes with a little evidence of replacement of the limestone.

The extent of the ore body is not known, as little development work has been done on it. It is exposed in an inclined tunnel for about fifty feet, and small diggings along the surface show that it persists laterally at least 200 feet. It is probable that the bed will continue along down the dip for a considerable distance, and more prospecting may show it to extend farther laterally.

The ore itself is composed chiefly of wad, bog manganese, and a little impure pyrolusite. Overlying it is a bed of low-grade siderite, mixed with calcite, from a foot to two feet thick.

The ore is soft and brownish black in color, much of it resembling soot.

The contact with the enclosing rocks is more or less irregular, especially the lower one, and this fact, together with the nature of the minerals, indicates a bog deposit. The deposit is very similar to the one at Wellsville, except that the latter contains a higher grade of ore.

The property was worked for a short time in 1916 and a small amount of ore taken out. The only development consists of the tunnel above mentioned and two or three small open pits. There is probably in the neighborhood of 1,000 tons of ore in sight. Undoubtedly a good deal more could be developed.

An average sample of the shipping ore assayed in the laboratory gave the following results:

Mn	33.83%
SiO_2	7.61%
Fe	6.57%
S	0.65%
P	0.037%

Selective mining and careful sorting will improve the grade, and ore running materially higher in manganese can be produced.

Walter Higham & Sons have also another property where a deposit of manganese occurs. This is located four and one-half miles northwest of Salida.

The ore here is found in a vein cutting through the metamorphic rocks. It stands nearly vertical, with here and there a slight eastward dip. In width it varies from about three inches to five feet and exhibits, to a remarkable extent, pinching and swelling. The widest portions of the vein are pockets formed by these swellings. The walls on either side are composed of pre-Cambrian schists, slates, and quartzites.

Where the vein is narrow, the ore is low grade and carries a large percentage of silica. It consists of a mixture of pyrolusite, wad, and a little psilomelane, the two first named predominating. Generally the ore is soft and soils the fingers, but where the vein narrows it becomes harder on account of the siliceous character. Here also more psilomelane is present.

Ore of good quality has been mined from pockets, but none has been shipped. When the mine was visited, about six or eight tons of ore, fairly homogeneous and uniform in character, had been shot out of one of these pockets and was piled on the dump.

The extent of the ore body here is rather limited. Good ore is confined to pockets, some of which contain only a few thousand pounds, while other deposits may contain ten to fifteen tons. When one is mined out, little ore can be obtained until another is found. However, by careful sorting and picking considerable good ore can be produced. Hardly enough work has been done to give grounds for any estimates as to the quantity of ore available. The vein has been traced for a distance of ten or twelve miles, striking N. 65° W., but wherever it crops out at the surface it shows the same pockety character. Where it has been worked by Mr. Higham it gives the best promise along its length, although, according to statements made by non-interested parties, the surface showing was no better than in other places.

The ore in this case is very likely the oxidized portion of a deep vein, although there is a possibility of its being a fissure filled with material concentrated from surrounding rocks. Here and there small fragments of unaltered carbonate are found with very uneven surfaces and covered with a coating of oxides, showing that alteration is still in progress. The depth of the oxidized zone is not known, as in no place has the vein been opened to a depth greater than ten feet. However, it is evident that it extends below the bottom of the gulch, which in places is more than twenty-five or thirty-five feet lower than the croppings.

A sample of ore from these workings, while not representing average material for the whole vein, gives a good idea of the grade of ore that can be produced. Analysis showed it to contain:

Mn	42.91%
SiO_2	21.40%
Fe	1.40%
S	0.503%
P	0.067%

Another sample, which the owner had assayed, is said to have contained:

Mn	27.0%
SiO_2	7.67%

Fe	3.98%
S	0.31%
P	0.04%

This vein is said to pass right near the Sedalia copper mine, according to old miners, and some say that it crosses that property. The writer followed it a distance of about three miles to the northwest from the Higham claim, and later from a point on Arkansas River, near Brown's Canyon, he followed a vein striking in the same direction, for several miles. It seems quite probable that in both cases he was on the same fissure. Other prospects, worked by Mr. D. C. Austin, on the right-hand side of Arkansas River, and by Mr. A. Pledger and Messrs. Glascock and Brickey, on the left-hand side, are probably on the same vein. These prospects did not show much ore, and the vein was too narrow here to give much promise. However, on account of its irregular character, it is impossible to tell when a good-sized pocket may be found.

COTOPAXI

Reports of manganese ore occurring nine miles west of Cotopaxi, a station on the Denver & Rio Grande, west of Canon City, were received a number of times from different parties, but the information was so vague and indefinite that no clue could be obtained as to the location. According to reports, the deposit is in a vein from eight inches to ten feet wide. No further information could be obtained.

BLACK MOUNTAIN

According to information received by the writer after he had left the field, a deposit of manganese occurs on Black Mountain, fifty miles southeast of Leadville, owned by A. S. Pierce, of Lake George. According to another report, referring probably to the same deposit, it is located thirty-five miles from Canon City, up Cottonwood Creek, and was claimed by Kent Eldred, of Canon City. It is said to be only twelve miles from the railroad, with a good auto road leading up to the mine. About twelve inches of ore was found in several small shafts sunk on the vein. No samples were seen and nothing is known as to the occurrence.

GALPIN AND VREELAND

Mr. C. R. Galpin, of Salida, has done a little work on a claim owned by him and Mr. Vreeland. Float rock, showing a good deal of psilomelane, was found in a number of places, and the outcrop of a small vein has been located about three and one-half miles north of Wellsville.

The vein is a fissure in fine-grained granite or aplite. The extent of the ore is not known, as the only working there has caved. It is quite likely, however, that the manganese ore, which is in the form of psilomelane, represents the oxidized portion of a carbonate vein. It was impossible to obtain a fair sample of the ore, so no assays have been made. The owners claim that it runs about 40% manganese and is low in silica and iron. However, the maximum width is not over six inches of solid ore, consequently no commercial deposit is in sight.

BONANZA[1]

In the Eagle mine, four miles east of Bonanza, a considerable body of manganiferous ore is found in the oxidized part of the vein. In sinking the shaft, it is said that about eighty feet of oxides was encountered, which assayed from 15 to 35% manganese, and 25 to 50% silica, with only a little iron. The vein is seven to eight feet wide at the surface and outcrops for at least 1,500 feet.

Practically all the mines and prospects of the so-called Manganese Belt show considerable quantities of manganese oxides, mixed with limonite and clay, carrying also values in gold and silver. The manganiferous ore is valuable only as a flux in smelting. No deposits of pure manganese ore are known to occur in this district.

CRIPPLE CREEK

The following information is taken from a report on the Homestake or Ironclad Mine, at Cripple Creek, furnished by Mr. Barnevald:

The property is located on Ironclad Hill and has long been mined for gold, which occurs in the large deposits of oxidized material.

The present value of the property seems to lie in a large deposit of manganiferous iron ore that has been lately opened. The ore occurs in the form of a large deposit in compact form in the surrounding country of oxidized breccia. There are but few workings which show this deposit and, with two exceptions, these

[1]For discussion of the geology and ore deposits of the Bonanza District see Bull. No. 9, Colo. State Geol. Survey, Horace B. Patton.

are shallow holes just through the wash. From the workings it seems that this body of ore extends over an area 150 by 300 feet, but owing to the overburden it, is impossible to tell how much of it is manganese ore.

It is very difficult to estimate with any degree of accuracy the amount of ore in sight, when the only available openings are small surface holes. From indications the ore body is of considerable size, and it seems reasonable that there should be at least 10,000 tons of ore, and maybe several times that amount.

The character of the ore is shown by the following analysis, which is the average of six samples:

MnO_2	32.25%	(Equivalent to Mn 17.22%)
Fe_2O_3	30.26%	
SiO_2	8.57%	
CaO	7.11%	
P	0.069%	

WESTCLIFFE

In the vicinity of Westcliffe, in Custer County, several deposits of manganese are found, and while not of high grade have furnished some marketable ore.

The Westcliffe Mining & Milling Company is working a property a short distance east of the town of Silver Cliff.

The ore occurs near the surface in a highly altered formation, probably of igneous origin. Manganese oxides have to a large extent replaced the original rock, and the remainder has been weathered to clay or replaced by jasper. Manganese and jasper occur together in large masses. As a result, the ore has to be hand picked to free it from siliceous material.

The valley walls all around Westcliffe are composed of pre-Cambrian metamorphic rocks, or of later eruptive formations. It seems likely, therefore, that the origin of the manganese oxides is in these igneous rocks from which it was dissolved and carried down to its present position.

The ore is exposed in a pit, thirty feet wide by one hundred and fifty feet long, and occurs in a bed nine feet thick. The ore body is known to extend considerably farther back into the hill, and contains perhaps 25,000 tons of ore, and maybe more. Whether it is all of the same grade cannot be determined for lack of development. Several carloads have been shipped to the Colorado Fuel &

Iron Company, at Pueblo, where it is used in making spiegeleisen. The production is at the rate of ten to fifteen tons a day, but the mine is not worked continuously.

Samples taken from various parts of the pit and analyzed show an average composition as follows:

Mn	24.74%
SiO_2	34.50%
Fe	8.42%
S	0.068%
P	0.039%

Mr. E. Nutter is working a small vein, four miles north of Westcliffe. The oxidized portion shows considerable manganese, and has been opened to a depth of thirty feet for about one hundred feet, along the strike.

The vein occurs in igneous and metamorphic rock, and contains a good deal of clay and brecciated material. Manganese oxides act as a cement, holding the fragments of rock loosely together. The ore must be carefully sorted and freed from these fragments before it is ready for shipment. About one carload has been taken out, but none has been shipped. The character of the ore can be seen from the following analysis:

Mn	23.24%
SiO_2	44.36%
Fe	6.37%
S	0.026%
P	0.066%

The vein is not large enough and the ore is not of sufficiently high quality to make this a commercial proposition.

Mr. John Edman and several other parties own a property about twenty miles up the valley, south from Westcliffe. Manganese occurs here in a number of small seams and numerous irregular lumps or nodules in a loose, heavily cross-bedded sandstone of Quaternary age. The sand is coarse grained, the grains are well rounded, and but loosely cemented. Manganese oxides have been carried in by surface waters, probably from surrounding igneous rocks. They occur in small veins and large, irregular masses.

A tunnel has been cut in the hillside through this sandstone for a distance of about 100 feet. In the roof and walls abundant manganese nodules and stringers can be seen, but no large body has been found. The character of the material and the small amount, distributed so widely, make it impossible to mine the ore at a profit. Samples analyzed show the following composition:

Mn	31.74%
SiO_2	35.40%
Fe	0.187%
S	0.010%
P	0.100%

LEADVILLE

The Leadville district, long famous for rich deposits of gold, silver, lead, and zinc, is again coming into prominence by the production of large quantities of manganiferous iron ore. For nearly half a century this material has been mined for fluxing, but within the last few years, on account of the far-reaching effects of the war, it has been used to a considerable extent in the steel industry. In fact, nearly 500 tons of ore are shipped daily to the various steel plants, which are dependent, to a large extent, upon this district for their supply of manganese. The ore, which runs from 20 to 25% manganese, 25 to 30% iron, and 10 to 15% silica, is used in making spiegeleisen, with excellent results.

The manganiferous ores occur along the eastern edge of Poverty Flat, on Carbonate Hill and in Iowa Gulch. One deposit has recently been opened on the west slope of Iron Hill, and not far away is still another, which has produced a considerable quantity of ore.

Very few deposits are seen outcropping on the surface, consequently the prospector is guided mainly by records of earlier mining and by the occurrence of manganese waste on the dumps of mines.

In general the ore occurs in the Blue limestone below old lead workings, but many cases exist where abundant manganese ore is found in workings which have produced practically no other metal.

In August, 1917, when the writer visited Leadville, eight or ten mines were shipping ore daily, and several others were about ready to begin. These have no doubt been added to the list of producers before now. The largest shipper was Cramer & Company, operating the Star Group, producing daily over 200 tons. The other mines produced from twenty to fifty or sixty tons daily.

A large percentage of the ore is hand sorted, to remove siliceous nodules and clay material coming from the numerous seams that traverse the ore. Mining is, on the whole, a rather expensive operation, not only because of the necessity of sorting, but also because much of the ground has been reworked a number of times, and much trouble is encountered in old workings from waste and old timbers in abandoned stopes. On account of the abandoning of many workings much caving has taken place.

Any estimate of available tonnage is accompanied by considerable chance of error, since little development work is done in advance of the actual mining. The ore bodies are opened up in so many places by old tunnels and drifts that the question of accessibility is of very little importance, and the ore is extracted as fast as old stopes are cleaned out. Consequently it is impossible to tell the amount of ore ahead. Another source of error in estimates is the amount of unmapped ground. Large areas may have been worked out, but no record is available of much of it. However, estimates made by various operators indicate that the present production could be doubled, and even quadrupled, and maintained for a period of several years. At that rate, several million tons of good manganiferous iron ore are available. However, the accuracy of this estimate has not been proved, and it is probably safer to say that in the neighborhood of a million or a million and a half tons can be obtained.

As to the origin of the ore little need be said here. Much has been written concerning the Leadville deposits, and it is sufficient to give the conclusions. According to the United States Geological Survey, the manganese oxides represent infiltrations from surrounding porphyries and other volcanic rocks. Phillip Argall,[1] however, has shown that manganiferous siderite is present in quantity as a replacement of limestone and was probably the source of manganese upon oxidation.

RED CLIFF

Immense bodies of low-grade manganiferous iron ore have been discovered in the property of the Empire Zinc Company, in the old Iron Mask Mine, now known as the Eagle No. 1 and Eagle No 2. The ore is not shipped at present, but abundant opportunity exists for rapid development on a large scale.

The manganese deposits can be seen outcropping about 400 or 500 feet up, on the canyon wall, two and one-half miles below Red Cliff. Two deposits, occurring at nearly the same horizon, stratigraphically, are found about half a mile apart. The ore occurs in great lenses along the bedding of Carboniferous lime-

[1]Argall, Phillip, Mining and Scientific Press, vol. CIX. 50, 128, 1918.

stones, dipping about 15° northeast. The main bodies of the ore have been extensively developed for zinc and pyrite, one for a distance of about 2,000 feet down the dip, and the other for nearly 3,000 feet. They lie in small synclines, transverse to the regional strike, marked on the surface by considerable widening of the valley. Sulphides of iron and zinc occur in a manganiferous siderite gangue. The manganese ore deposits form only a part of the ore body, but as they have not been fully explored it is impossible to say what the extent is. From work done, it is evident that in the western body manganese oxides form a considerable portion of the ore throughout a zone about 3,000 feet long by 1,000 feet wide. The thickness is variable and not known, but in places is in the neighborhood of fifty feet. Allowing for irregularities, which are known to exist, and waste accompanying extraction, it is probably conservative to estimate from 500,000 to 750,000 tons of manganiferous iron ore in this deposit.

The eastern deposit is very similar to the western, but is probably not as large. Several years ago it is said over 200,000 tons of ore were removed from this ore body to be used for fluxing. According to the indications there must be from 250,000 to 500,000 tons of ore remaining. This would give a total tonnage for the Red Cliff district which may conservatively be placed at somewhat over a million tons.

The character of the ore is indicated by the following analysis:

Mn	18.60%
SiO_2	3.04%
Fe	37.60%
S	0.961%
P	0.023%

GUNNISON REGION

Large bodies of manganiferous iron ore are known to occur along Taylor River, northeast of Gunnison, in the Elk Mountains, near the boundary between Gunnison and Pitkin counties, and also in the vicinity of White Pine and Tincup.

The ore in these places is mainly hematite and magnetite, with unaltered sulphides and silicate minerals. It is found associated with Paleozoic sediments, which have been altered by metamorphism, resulting from igneous activity. According to Leith[1] these ores represent original concentrations under the influence of igneous

[1]Bull. No. 285, U. S. Geol. Survey, pp. 196, 197.

rocks. The average of several analyses given by Leith shows that the main body of the ore is iron. As will be seen from the analyses, silica and phosphorus are rather low, while sulphur in cases runs high.

Fe	30-64%
SiO_2	7.7%
S	0.077-5.88%
P	0.007-0.069%

At the surface the ores are oxidized to limonite and clay with the introduction of manganese oxides. These were probably derived from the various lava flows covering the adjacent ridges. A sample of ore from near the surface of the deposit on Taylor Peak shows that iron greatly predominates.

Mn	14.13%
SiO_2	1.69%
Fe	33.75%
S	0.023%
P	0.037%

A sample of ore taken from the property of C. M. Carter, of Houston, Texas, located along Spring Branch of Taylor River, about ten miles northeast of Almont, on the Crested Butte branch of the Denver & Rio Grande, assayed as follows:

Mn	32.07%
SiO_2	16.00%
Fe	1.31%
S	0.068%
P	0.063%

CEBOLLA VALLEY

Cebolla Valley is in the southwestern part of Gunnison County, on the western slope of the Rocky Mountains. Manganese and iron ores have been found here two miles above Powderhorn Postoffice, about eight miles east of the Lake City branch of the Denver & Rio Grande narrow-gauge railroad. Powderhorn is about fifteen miles south of Iola, a station on the Denver & Rio Grande Railroad, west of Gunnison, and is reached by a good auto road.

The manganese occurs in limestone, in the form of pockets or lenticular beds, from one to four feet thick. It is massive and but slightly crystalline, and of a bluish-black color. Most of it is psilomelane, but a little pyrolusite is found. In some places the manganese ore is associated with hematite, limonite, and siderite, and in other places it is separate from the iron. Frequently one finds small cavities, or vugs, which are filled with white, crystalline calcite. Wherever the ore occupies exposed positions it is more or less porous and honey-combed, due to leaching out of calcite and other soluble constituents. The iron ore, like the manganese, often contains pockets of calcite.

The enclosing limestones are brownish colored and rather coarsely crystalline and granular, and everywhere contain masses of crystallized calcite. In places the limestone contains beds of micaceous schist, which is very much decomposed, and underlying it is a bed of quartzite. The whole formation gives evidence of having been metamorphosed to a considerable extent. Overlying these formations is a series of trachyte and andesite flows. On weathering, abundant clay is formed, and this is to a large extent mixed with the ore.

The rocks strike in a general north and south direction and dip at angles varying from 60 to 80° to the west. The ore appears in a series of hills north of the creek.

It occurs in the limestone chiefly as a replacement along the bedding and joint planes. Wherever observed it has a tendency to follow along the bedding, and in some places large lenticular beds are found. It is very irregular in distribution, being entirely absent in places and at other places composing a considerable proportion of the rocks. At still other places the pockets or lenses run together to form a solid layer of ore.

Near the surface the ore is much weathered, with an abundance of limonite and clay. The manganese oxides have been introduced probably from the overlying trachyte and andesite flows. Manganese was dissolved out of the minerals carrying it and brought downward by surface waters, to be deposited when coming in contact with the limestone. Weathering and alteration have changed much of the iron carbonate in the limestone to limonite.

The property has been but slightly developed, and this was done so long ago that nearly all the workings have caved and are filled with debris. Owing to this, a very thorough examination and estimation of the amount of ore available was out of the question. Although the ore is very irregular in occurrence it is quite probable that other pockets will be found lower down.

No ore has been shipped, as the distance from the railroad at Iola is considerable and the wagon road to the Lake City branch is very poor.

The following analysis represents ore from one of the workings only. It is probably not an average sample of the whole, as there is considerable iron present in some of the ore.

Mn	43.27%
SiO_2	21.13%
Fe	7.63%
S	0.67%
P	0.291%

Mr. J. A. Proffitt, of Boulder, has a property in Cebolla Valley, about four miles southeast of Powderhorn Postoffice.

The ore here is associated with a good deal of limonite, and occurs irregularly distributed through metamorphic rocks and intrusive granites. It is very likely an eastward extension of the deposit just described. The outcrop varies from a few inches to several feet in width, and can be followed along the surface for a distance of several hundred yards. The limonite probably represents alteration from carbonate, although no carbonate was observed. Manganese oxides were probably introduced from overlying lava flows, as a result of solution and redeposition.

The ore is mostly wad mixed with limonite and jasper. By very careful sorting the jasper could be discarded, but much silica would still remain. Not enough work has been done on the property to give any idea as to the extent of the ore. As far as it is opened up the ore is low grade and of no commercial value.

An average sample that was assayed gave the following results:

Mn	21.66%
SiO_2	21.20%
Fe	19.65%
S	0.034%
P	0.147%

STEUBEN VALLEY

This is a small tributary of the Gunnison River, cutting through a series of lava flows and breccias. Manganese ore is found in a great many places in this locality. Most of the ore is in a breccia composed of angular and partly rounded fragments, from a fraction of an inch to several feet in diameter, imbedded in a sandy matrix.

The ore occurs as a black, highly siliceous psilomelane in cavities in the breccias, and frequently replaces the matrix in which the lava fragments are imbedded. In this manner it impregnates large masses of the rock, consequently its distribution is extremely irregular.

Besides this ore in the breccia, manganese oxides are found in the massive overlying lavas as hard, glossy, black veins and stringers, from one to four inches wide. The rock in which it occurs is hard and brittle and has a distinct conchoidal fracture resembling obsidian. Sometimes cavities are found which are lined with the same hard siliceous psilomelane in botryoidal forms. These cavities vary in size from a few inches to several feet and are usually closely associated with a network of little veins and stringers.

The ore was probably deposited by waters heated by the lava, which dissolved out the manganese content and later deposited it in cracks and fissures. The cavities may be the result of solution by these heated waters, and later a layer of manganese oxide was deposited on the walls.

The following is an analysis of ore such as is found in small quantities scattered over a large area:

Mn	34.30%
SiO_2	36.97%
Fe	6.71%
S	0.132%
P	0.061%

Various difficulties are in the way of making a commercial proposition of this area. The widely scattered nature of the deposits, the small quantity of ore, and the high silica content are among the most important impediments in the way of development. As long as quantities of high-grade ore can be obtained development would not be justified.

SAPINERO

About four miles south of Sapinero are found deposits of manganese very similar to those just described as occurring in Steuben Valley. The ore is a black, highly siliceous oxide, consisting mainly of psilomelane, in places hard and compact and again finely granular. It occurs in pockets varying from a few inches to several feet in diameter, in the shape of large kidneys and botryoidal masses, mixed with a good deal of sandy material. Frequently it occurs in a network of small veins from a half to three or four inches wide, in a breccia similar to that described above, and also in the massive lavas. Usually where it is found in the massive lava, the rock is a partly or entirely opalized rhyolite. Below the breccia there is what appears to be a bed of sedimentary sandstone, consisting of rather loosely cemented sand in places and of a hard, flinty, quartzite bed in other places. On the maps of the old Hayden Survey this is represented as Cretaceous. This sandstone rests almost horizontally on underlying crystalline and metamorphic rocks, and in places carries infiltrations of manganese oxides.

Manganese ores of similar nature are found in a great many places in this part of the region. In fact, they occur wherever the lava flows are present. At some places they occur more abundantly than in others, but the entire volcanic series which overlies this part of Colorado contains some of these little manganese deposits.

Mr. D. H. Goss, of Montrose, has a claim south of Sapinero in which several of these little veins have been followed down in a small shaft to a depth of about twelve feet. Invariably they pinch out and end in irregular siliceous nodules, in which the manganese oxides act as a binder for a sandy material. A sample taken from his shaft gave the following results:

Mn	26.91%
SiO_2	47.25%
Fe	1.40%
S	0.057%
P	0.122%

Samples taken from the claim of Mr. Tobe Barnes, of Montrose, which is in this same area, gave the following:

Mn	27.63%
SiO_2	43.19%
Fe	3.16%
S	0.49%
P	0.36%

CIMARRON

Mr. T. W. Monell, of Montrose, has located a claim in the western edge of Gunnison County, on the ridge between Little Cimarron and Big Blue creeks. It is about twelve miles from Cimarron, just off the road to Sapinero.

The surface rocks here are the same as in other parts of Gunnison County, just described, consisting of a series of Tertiary lava flows and volcanic breccias. A dike of latite porphyry cuts diagonally across the claim, but is in no way connected with the ore.

Manganese occurs in small surface fractures in the lava and extends downward for only a short distance. With increasing depth there is a decided increase in the amount of silica in the ore. In places manganese oxide forms the cementing material which holds fragments of lava together in the breccia. On the surface one can see large numbers of little fissures filled with manganese oxide, but none of them are continuous for more than ten or twelve feet.

The ore mineral is a hard, black, shiny psilomelane, running high in silica. Specimens of nearly pure psilomelane can be picked out, but the average material is very siliceous.

The ore was deposited in these crevices probably as the result of the action of heated waters in the lavas. These waters dissolved manganese out of the rocks and redeposited it in cracks and crevices. The manganese oxide now found in the numerous small fissures was therefore the result of deposition by the surface waters percolating down through the rocks.

Mr. Monell has a second claim on a small terrace in the valley of Big Blue Creek. The terrace is composed largely of siliceous clay, derived from the weathering of the lava, and buried in this are quantities of manganese nodules and lumps that have weathered out of the eroded rocks. In every case these nodules are composed of material similar to that found in place in the lava.

The average of several samples of ore from Mr. Monell's claims gave results as follows:

Mn	29.80%
SiO_2	42.22%
Fe	2.40%
S	0.074%
P	0.091%

In addition to the localities described, mention should be made of the claims of C. W. Carr, of Sapinero; Jack Bell, at Madera Siding; Benson Brothers, at Youman; E. W. Ashby, of Montrose; A. G. Underwood, of Ridgeway, and Louise Maurell, of Ouray. These parties have staked claims in the southwestern part of Gunnison County and adjoining parts of Hinsdale County.

Nearly all of these locations were visited, and a number of others which were unclaimed or on patented ground which the owners cared not to develop. The manganese minerals were all found associated with volcanic rocks, consisting of a great series of flows and flow breccias of andesites, rhyolites, latites, etc. The ore mineral is chiefly psilomelane, hard, glossy, and black with conchoidal fracture. Nearly every specimen tested was high in silica. It occurs, as above mentioned, in a network of small veins, or as a botryoidal lining in cavities, but more often still it has permeated the sandy matrix of the breccias. Wherever work has been done on the deposits it invariably shows that the small veins and stringers decrease in size and purity as depth increases. Most of them end in irregular, sandy masses, held together by the manganese oxide. The source in every case seems to be in the lava flows, and its present form and position is the result of secondary concentration.

A sample of ore from Mr. Underwood's claim up Henson Creek, about ten miles from Lake City, in Hinsdale County, assayed:

Mn	49.81%
SiO_2	12.20%
Fe	0.93%
S	0.043%
P	0.091%

This is higher in manganese than most of the material from this region, and considerably lower in silica. The iron content is also less. However, on account of the small quantity of ore available, and its inaccessibility, the value is doubtful.

Perhaps special mention should be made of the claim of Louise Maurell. This is located on what is known as Alpine Plateau, near the foot of Uncompahgre Peak, at an elevation of over 12,000 feet. It is interesting chiefly because of the unusual size of the cavity in which the ore is contained. The cavity is about twelve feet in diameter and roughly circular in form. Its depth could not be ascertained because of snow and ice in the bottom. The ore occurs on the walls in globular and botryoidal crusts, from a fraction of an inch to three inches thick. No samples were obtained, as no means of getting in and out of the shaft were available. A single small specimen found on the surface consisted of the usual psilomelane, but apparently contained less silica than most of the ore in this district. On account of the difficulties of transportation, and the small quantity of ore available, this cannot be considered a commercial proposition.

HINSDALE COUNTY

Reference has already been made to several locations in Hinsdale County, and mention was made of the fact that in nature, mode of occurrence, and origin, as well as in distribution and quantity, the ore is exactly similar to that described in southwest Gunnison County. Therefore it is unnecessary to repeat here descriptions of the many localities in this county where prospecting has been done. It is sufficient to say that no commercial ore has been discovered.

One property, however, deserves special mention on account of the fact that the ore is of an entirely different nature. The writer himself did not visit the property, because the owner, Mr. C. E. Slocum, of Denver, was unable at the time to accompany him, and no one else could be found to show the way. The claim is located about twelve or fourteen miles from Lake City, up the Lake Fork of the Gunnison River, towards Burrows Park. According to information obtained from Mr. Slocum, the ore is found in a large fissure vein, cutting nearly vertically through the lava formations. In width it varies from two to ten feet, and the outcrop on the surface has been traced for more than 600 feet.

The vein material is practically all rhodochrosite, which has altered to pyrolusite in the oxidized zone. The rhodochrosite is apparently very pure and free from sulphides of iron and copper. Most of it is well crystallized and has a deep pink color. Large masses of pyrolusite, when broken open, showed irregular centers of crystalline rhodochrosite. The depth to which the oxidation extends has not been determined, as the vein has not been explored. Out of about 500 pounds of ore that had been brought down from the prospect, an average sample was taken, which gave the following analysis:

Mn	41.40%
SiO_2	17.30%
Fe	0.47%
S	0.241%
P	0.61%

So far as information could be obtained no other manganese occurrences are known in Hinsdale County, and unless others should be discovered no great amount of commercial ore can be produced. The last-mentioned property might possibly be developed, but transportation is the difficult problem.

SILVERTON DISTRICT

Manganese deposits in the Silverton District are very limited. No extensive deposits of oxides are known to occur anywhere in San Juan County. Rhodonite and rhodochrosite both occur in the gangue of a number of veins, and in the oxidized zone they have altered to oxides. However, the amount is very small, and only occasionally does one encounter pockets of manganese oxides of any size.

OURAY DISTRICT

In the vicinity of Ouray there are a number of small manganese deposits that have attracted local prospectors from time to time. Most of them consist merely of the oxidation product of rhodochrosite in small veins and are hardly worth mentioning. A few occur in the eruptive rocks, and are similar to those in Gunnison and Hinsdale counties.

George Keller owns several claims, which have showings of manganese in the oxidized zone. The veins carry values in gold and silver. Manganese oxides form only a very small per cent of the ore, and in addition they run high in silica. The largest of his veins is on Bear Creek, about three miles above Ouray. This vein is in the pre-Cambrian slates and quartzites. It is six or seven inches wide and consists chiefly of pyrolusite. The sample assayed shows the ore to contain:

Mn	35.74%
SiO_2	28.88%
Fe	2.34%
S	0.107%
P	0.047%

Another property nearby, which is apparently unclaimed, showed outcroppings of a vein similar to the one just described. This gave the following results:

Mn	29.11%
SiO_2	23.35%
Fe	7.95%
S	0.032%
P	0.050%

None of the small veins can produce marketable ore under present conditions.

Dr. B. B. Slick, who is operating the Sutton property on Hayden Mountain, has opened a number of veins where considerable manganese oxide is present throughout the gangue. This has been derived from carbonate in the veins. The property is located in the eruptive rock forming the cap of Hayden Mountain. The veins are greatly oxidized and are well defined. The width is from twelve to twenty inches. Small amounts of gold and silver are present. On account of the small quantity of manganese ore and the high silica content they are of no importance as manganese producers.

Dr. E. C. Weatherly, of Ouray, who owns adjoining claims, has the same proposition. The veins on his property are perhaps a little wider, but as he has reached a greater depth, the oxidation is less and as a result his gangue is mainly a siliceous rhodochrosite.

THE ACKERSON PROPERTY

This property is located on the lower part of Hayden Mountain, just back of the "Mineral Farm," and is owned by Rollo Ackerson and his father, of Ouray.

The rocks in which this deposit occurs are limestones of Carboniferous age. The prevailing dip is to the northward at low angles. Very few exposures are seen on the property, since it is covered over with surface debris. The workings have long since been abandoned, consequently a thorough examination was impossible. In an old open cut ore is exposed in a number of places, and has the appearance of a bedded vein, but a short distance away it seems more like a very wide fissure. The caving and washing that have taken place made it impossible to determine what it really is. The ore is a mixture of manganese and iron oxides, with the latter predominating, but so intimately mixed that individual minerals could not be distinguished. Limonite and wad are the chief mineral constituents.

As to available tonnage, nothing can be said, as no development work has been done that would give any idea of the extent of the ore body.

Just before the smelter at Ouray closed the ore body was opened and a quantity of ore mined, to be used as flux. In a short time, however, the smelter closed and the property was abandoned.

The sample taken represents a fair average of the ore exposed in the open cut, and yielded:

Mn	23.07%
SiO_2	11.74%
Fe	27.33%
S	0.123%
P	0.042%

As the property is only three miles from Ouray, and a good road runs up to it, there is apparently no reason why it could not be developed if a market can be found for the ore. It is excellent for fluxing, as it contains in addition some lime. It is also suitable for ferromanganese and spiegeleisen under present conditions.

The old development work on the property consists of an open cut, about eighty or one hundred feet long and from five to ten feet deep, and a number of shallow pits or shafts. Ore of practically the same character was found in all of these workings, and was said to outcrop in a number of places, but could not be seen on account of recent washing in of surface debris.

RICO DISTRICT

In several of the mines at Rico, especially those on Newman Hill and Nigger Baby Hill, manganese carbonate, rhodochrosite, forms a considerable part of the gangue mineral. The mineral is delicate pink in color and but faintly crystalline, and is frequently mixed with quartz and fluorite. In the oxidized portions of the veins considerable quantities of manganiferous limonite were found, as a result of oxidation of minerals containing these elements. The manganese minerals are chiefly hydrous oxides, probably in the form of wad, containing a large per cent of silica. In places oxidation extends to a depth of over 200 feet. The resulting material is soft and earthy, and often carries values in gold and silver. None has ever been used as a source of manganese, but it possesses value as a flux.

A sample taken from the dumps of the Rico Consolidated Mines yielded:

Mn	25.25%
SiO_2	44.40%
Fe	3.27%
S	0.602%
P	0.050%

This was probably a fair sample of the material found in the oxidized zone. The workings were abandoned, so no material could be obtained from the vein.

Another sample from the Rico Argentine Mine gave the following result:

Mn	31.18%
SiO_2	23.60%
Fe	2.34%
S	0.082%
P	0.027%

These results show that the ore is too low in manganese and too high in silica to have any value as a source of manganese. As a flux it would have some value. A considerable quantity of the material was left in the veins because it carried no values, but on account of the abandoning of the workings this could not be recovered. The present workings are below the zone of oxidation, hence contain only unaltered carbonate.

NEEDLE MOUNTAIN[1]

In the east part of the Needle Mountain a manganese deposit has been located by Mr. Dan Cason and several other parties, of Durango.

The property is located eight and one-half miles east of Needleton, on the Denver & Rio Grande narrow gauge railroad, north of Durango, on the east slope of Hope Mountain. From the railroad station, a wagon road runs for a distance of about six miles and a trail for the remainder of the way to Hope Mountain, over Columbine Pass.

The vein is in granite, standing nearly vertical and striking N. 35° W. It outcrops for a distance of 2,200 feet and is about two feet wide. The vein is well defined, but little work has been done on it, consequently nothing can be said as to its depth. The ore consists of pyrolusite and wad. A large amount of the vein material is composed of fragments of granite, coated with manganese oxide. By careful picking and sorting fair quality ore can be obtained, but as taken from the mine much silica would be present from the granite fragments. An average of samples taken across the vein, from which all granite fragments had been removed, yielded the following results:

Mn	33.43%
SiO_2	18.14%
Fe	6.03%
S	0.310%
P	0.052%

This cannot be considered as a commercial proposition, on account of the poor quality of the ore, distance from the railroad, and high cost of production.

1Notes on this property were furnished by Mr. H. A. Aurand of this Survey.

SOUTHWESTERN COLORADO DEPOSITS

COLORADO MANGANESE MINING & SMELTING CO.

This company is incorporated under the laws of Colorado, and owns five mining claims at the head of Gypsum Valley, in San Miguel County. The location is near the top of the divide separating Gypsum Valley from Dry Creek Basin, forty-five miles southwest of Placerville, a station on the Denver & Rio Grande narrow gauge railroad. Placerville is the nearest shipping point. The mines are reached by a wagon road, which in places is rather poor, with a couple of steep grades, but is passable for motor trucks and autos a large part of the year.

Only four of the claims show manganese. They are called the Black Diamond, Black Prince, Blackbird, and Black Baby.

The rocks in this region vary in age from Carboniferous to Cretaceous. A generalized section for Gypsum Valley is as follows:

Cretaceous	Mesaverde
	Mancos—1,000 feet
	Dakota—80 to 100
Jurassic	McElmo—750
	LaPlata—150
	unconformity
Triassic	Dolores—50
	unconformity
Carboniferous	

The region has been subjected to considerable folding and some faulting. The valley walls of Gypsum Creek are the eroded limbs of an anticline, and it is in this anticlinal rim that manganese ore is exposed. The beds strike N. 60° W. and dip to the north at an angle of about 10°. The sandstone which underlies the ore forms a sort of terrace around the valley wall.

While manganese ore can be seen outcropping on all four claims, development work has been done only on the Black Diamond. The ore occurs as a blanket vein between a bed of sandstone at the base and a sandy red shale at the top. This probably marks the line between the La Plata and McElmo formations, although it has been described as occurring in the Dolores. It varies in thickness from twelve inches to a little over three feet, averaging close to twenty inches. The outcrop can be traced around a spur in the rim of the valley for a distance of about 1,200 to 1,500 feet, and is probably continuous with that of the Black Prince. The floor on which the ore rests is somewhat undulating, and this gives rise to pinchings and swellings, as the roof is fairly even. Occasionally the ore body is split in two by thin clay seams or streaks of sandy shale. The stratification of these is parallel to that of the floor and roof.

The ore is composed almost wholly of soft crystalline to granular pyrolusite, with associated manganite and psilomelane. Associated with the ore in small cavities are found barite and calcite. Only small amounts of iron oxides are present in the ore body, and siliceous material is nearly absent from the ore. The pyrolusite frequently shows a beautiful fibrous structure, and at times it is found interbanded with psilomelane.

Average samples of ore assayed in the laboratory at Boulder gave the following results:

Mn	43.38%
SiO_2	8.20%
Fe	Trace
S	0.469%
P	0.039%

An average of analyses of cobbed ore, furnished by the company, is as follows:

Mn	54.75%
SiO_2	2.79%
Fe	0.46%
P	0.029%
H_2SO_4	2.69%
Al_2O_3	0.20%
CaO	0.53%
MgO	0.20%
BaO	5.35%
Cu	0.68%

In ore that has been shipped iron has run less than 0.25% in carload lots, and never more than 1%, according to a statement by the operators. Silica has always been less than 8%.

Very few impurities which would be detrimental to the chemical trade are present. It has been tested by battery manufacturers and glass works, and both have reported favorably on it.

The development on the Black Diamond consists of two tunnels, with various drifts running off from them. No. 1 tunnel has been driven into the hill about 150 feet, with good ore showing along its entire length. No. 2 tunnel, 800 feet north of No. 1, is about 235 feet long, with about 300 feet of drifts in both directions, all in ore running from twelve inches to three feet in thickness and averaging about twenty inches. The ore body seems to be fairly homogeneous in all of the workings, and at the breast of No. 2 tunnel is about three feet thick.

The development, consisting of 700 feet of tunnelling, has proven the ore body to be at least 1,200 feet wide and 235 feet deep, with an average thickness of about twenty inches. This would indicate upwards of 50,000 tons of ore in sight.

As no development work has been done on any of the other claims, little can be said of the nature and amount of ore available. As before mentioned, the Black Prince is probably continuous with the Black Diamond. The other two, which are situated south and east of the two mentioned, across a steep gulch, are not as promising. Here the ore is found in small vertical seams and fissures and as impregnations of the walls. It consists mainly of highly siliceous nodules and lumps or masses of sandstone, in which the cementing material has evidently been replaced by manganese dioxide. It extends but a short distance in any direction and the crevices are narrow.

The origin of the ore is evidently contemporaneous with the formation of the rocks. Interbedded clay and sandy shale are found with bedding parallel to that of the floor and roof. Evidently the manganese concentraction took place in an isolated basin, and deposition of sediments was practically nil at the time. The ore filling the small fissures and cracks on two of the claims is evidently the result of the leaching of manganiferous material higher up.

Development work on the property was done in 1915 and 1916. Up to the time of examination about ten carloads of ore had been taken out of the workings, four of which had been shipped to eastern markets, and the remainder was either piled up at the mine or at the station at Placerville. Drilling was done with a coal auger, as the rock is soft. A four-foot hole could be drilled in this manner in about forty-five minutes. The cost per ton was estimated to have been about $2.50. Hauling to Placerville cost about $12 per ton, but could probably be lowered by using trucks.

This deposit seems to be one of the most promising in the state, and is well worth looking into and developing. The ore is high grade and suitable for all purposes for which manganese ore is used. There seems to be no reason why the property could not be energetically worked. It is true, of course, that high freight rates and hauling costs offer some obstacle, but with the present demands for good ore this property ought to make good.

M'NUTT BROTHERS' PROPERTY, NATURITA

McNutt Brothers, of Naturita, own a claim about five miles southeast of the town, near the top of the divide between San Miguel River and Dry Creek Basin, in San Miguel County.

The rocks here are of Cretaceous age and occur in a series of low folds. Where the folds have been eroded by streams, the more resistant beds form a rim around the valleys.

It is in this rim rock, which is probably of Dakota age, that a small seam of manganese is found between two beds of sandstone. Apparently it is a sort of parting in the sandstone, and is only from a fraction of an inch to four inches thick. A few other little parting seams are seen above and below, separating thin beds of sandstone.

The ore is chiefly wad, with a little pyrolusite, and contains considerable iron. Only a very small quantity is available and the cost of mining would be prohibitive. The composition of the ore is as follows:

Mn	37.95%
SiO_2	4.24%
Fe	23.40%
S	1.61%
P	0.033%

BLUE MOUNTAINS DEPOSIT

According to information received from Mr. Frederic Porter, of Vernal, Utah, a rather extensive body of manganese and iron ore occurs on the north face of Blue Mountains, in the extreme northwest portion of Colorado. The place is about eighty miles from Craig, the present terminus of the Denver & Salt Lake Railroad (Moffat Road), and about fifty miles from Vernal, Utah.

The manganese ore was discovered in connection with exploratory work on some zinc properties, and is said to lie in the Mississippian limestone. Not enough work had been done at the time this information was received to give any accurate statement of the extent, but the ore body is believed to cover a large area. In places considerable limonite is said to be mixed with the manganese. Samples of the ore for analysis were not available, consequently little is known as to the character and value.

CHAPTER IV

BIBLIOGRAPHY

on the

Occurrence, Geology, and Mining of Manganese,
with some References on its Metallurgy and Uses,
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COLORADO

GUNNISON COUNTY

Potter Claims.—Several claims located for manganese by J. G. Potter are situated 4½ miles north of Iola in a small canyon which is drained by a stream that flows to Gunnison River. A newly made road extends to Iola, a station on the Denver & Rio Grande Railroad. Several shallow open cuts and a tunnel 70 feet long comprise the workings on these claims. No ore has been shipped from the property and the quantity disclosed by the workings is so small that further work is not advisable.

The claims lie in a canyon several hundred feet below the summit of a hill at an average altitude of 8,500 feet. From the Gunnison Valley, a gravel capped mesa extends northward for about two miles along the canyon in which the manganese deposits are situated, and merges into the outlying ridges of the higher mountains. This mesa is underlain by sandstone, tuffs and agglomerate, which are capped by lava flows, and all are probably Tertiary in age.

The manganese minerals are contained in small seams and fissures which cut the sandstone and tuff and in small nodules in the sandstone.

A vertical fissure vein which strikes N. 15° E. is exposed in an open cut. The vein material is composed of a clay gouge six inches thick in which some chert or chalcedonic material contains narrow veinlets of manganese oxides. The veinlets are not persistent and it is not possible to separate a marketable grade of manganese oxides from the siliceous matrix. In another open cut horizontal sandstone is cut by veinlets of manganese oxides a fraction of an inch wide, but there is no indication that they occur in commercial quantities. In places small sandstone nodules partly replaced by manganese oxides show on the weathered surface. A tunnel 70 feet long driven on the fissure explored by the open cut, disclosed no ore.

SAGUACHE COUNTY

Iron King.—The Iron King prospect, owned by the Miller Mining & Milling Company, is situated in Saguache County, about 15 miles east of Moffat on Cedar Creek, a small stream that flows west to San Luis Valley. From the prospect to the valley, three miles distant, the road is steep and in poor repair, but the remaining 12 miles to Moffat over the level valley floor is good. In August, 1916, ten tons of ore were shipped that contained 41 per cent of manganese, 4.75 per cent of iron, 0.0402 per cent of phosphorus, and 15.28 per cent of silica. Since 1916 no work has been done, and the development discloses little ore. The property is developed by several short tunnels driven in the mountainside at elevations ranging from 9,200 to 9,700 feet above sea level, and by open cuts and trenches.

Quartzites, conglomerates and slate intruded by small masses of granite and rhyolite dikes are the rocks in the vicinity of the prospect. These rocks have been greatly faulted and the sequence of the sedimentary formations is not apparent here. Manganese minerals occur in several places as replacements in shear zones in the granite and as small veins in the sedimentary rocks. The small shipment came from a lenticular body in the granite. In the sedimentary rocks manganese oxide occurs in narrow veins associated with fluorite and quartz. Some specimens show manganese oxides encrusted with fluorite several inches thick and the fluorite is coated with small quartz crystals. A specimen from a body in the granite is composed of a complex intergrowth of psilomelane and a crystalline aggregate of hausmannite.

Ben Boyer Claims.—Two claims owned by Ben Boyer lie a short distance south of the Iron Mountain group. A tunnel 15 feet long which cuts thick-bedded limestone is the only opening on the claims. The limestone is broken by a north-south fissure and above the floor of the tunnel small masses of manganese oxides occur in crevices. The manganese oxides form crusted botryoidal masses and short rod-like growths. Pyrolusite or wad forms the center of each rod or concretion, and the outer shell is hard psilomelane. Secondary calcite is abundant in the ore and it assumes the same concretionary forms as the manganese oxides. Only a small quantity of ore is disclosed by the tunnel and it is not known to what depth the oxides extend in the fractured limestone.

Other small manganese deposits have been found in massive limestones on the ridge above the Iron Mountain and Boyer claims. but little development work has been done on them, and in order to market the ore it would be necessary to build a road 2 miles long.

Galpin and Vreeland Claims.—Two claims owned by C. R. Galpin and Vreeland are located on a ridge at the head of Potkill

Gulch about 3½ miles east of Wellsville. They are at an altitude of 9,300 feet and 1½ miles distant from the nearest road in Wells Canyon. There has been no recent development work and the location is based on the presence of manganese oxides in material on the dump of an old shaft which is now caved. The country rock is a sheared fine-grained aplite and manganese oxides form veinlets in it as much as 4 inches thick. The oxides are psilomelane and pyrolusite and they not only have been deposited in open fissures but also replace the sheared aplite. The width and trend of the deposit could not be ascertained as the deposit does not outcrop.

INDEX

A

L

M

N

O

P

R

S

T

U

W

PUBLICATIONS OF THE COLORADO GEOLOGICAL SURVEY

R. D. George, State Geologist
Boulder, Colo.

FIRST REPORT, 1908. Out of print except A.

A. The Main Tungsten Area of Boulder County, by R. D. George.

B. The Foothills Formation of Northern Colorado, by Junius Henderson.

C. The Montezuma Mining District, Summit County, by H. B. Patton.

D. The Hahns Peak Region, Routt County, by R. D. George and R. D. Crawford.

BULLETINS 1 AND 2, IN ONE VOLUME, 1910:

Bulletin 1: Geology of Monarch Mining District, Chaffee County, R. D. Crawford.

Bulletin 2: Geology of Grayback Mining District, Costilla County, H. B. Patton.

BULLETIN 3, 1912: Geology and Ore Deposits of Alma District, Park County, H. B. Patton.

BULLETINS 4 AND 5, IN ONE VOLUME, 1912:

Bulletin 4: Geology and Ore Deposits of the Monarch and Tomichi Districts, Chaffee and Gunnison Counties, R. D. Crawford.

Bulletin 5, Part I: Geology of the Rabbit Ears Region, Routt, Grand and Jackson Counties, P. G. Worcester, F. F. Grout and Junius Henderson. Part II: Permian or Permo-Carboniferous of the Eastern Foothills of the Rocky Mountains in Colorado, R. M. Butters.

BULLETIN 6, 1912: Common Minerals and Rocks, Their Occurrence and Uses, by R. D. George. Out of print.

BULLETIN 7, 1914: Bibliography of Colorado Geology and Mining, Olive M. Jones.

BULLETIN 8, 1914: Clays of Colorado, G. M. Butler.

BULLETIN 9, 1916: Bonanza District, Saguache County, H. B. Patton.

BULLETIN 10, 1916: The Gold Brick District, Gunnison County, R. D. Crawford and P. G. Worcester.

BULLETIN 12, 1917: Common Minerals and Rocks, Their Occurrence and Uses, R. D. George.

BULLETIN 13, 1918: Geology and Ore Deposits of the Platoro-Summitville Mining District, Rio Grande and Conejos Counties, H. B. Patton.

BULLETINS IN PRESS

BULLETIN 14: Molybdenum Deposits of Colorado, P. G. Worcester.

BULLETIN 15: Manganese Deposits of Colorado, G. A. Muilenburg.

BULLETIN 17: The Twin Lakes Mining District, Lake and Pitkin Counties, J. V. Howell.

TOPOGRAPHIC MAP OF COLORADO, 1913: 40x56: Scale 8 miles to the inch; R. D. George. Supply approaching exhaustion.

GEOLOGIC MAP OF COLORADO, 1913: 40x56: Scale 8 miles to the inch; R. D. George. Supply almost exhausted. If requested, the State Geologist will mark on this map the areas structurally favorable for the occurrence of oil.

BULLETINS READY FOR PUBLICATION

BULLETIN 11: The Mineral Waters of Colorado, O. C. Lester and Harry A. Curtis.

BULLETIN 16: The Uranium-Vanadium-Radium Ore Deposits of Western Colorado, R. C. Coffin.

BULLETIN 18: The Fluorspar Deposits of Colorado, H. A. Aurand.

BULLETIN 19: The Cretaceous of Northeastern Colorado, Junius Henderson.

BULLETIN 20: Reports on the oil possibilities of two areas in Eastern Colorado, Norman E. Hinds and James Terry Duce.

BULLETIN 20: Report on the oil possibilities of an area in Western Colorado, R. C. Coffin.

BULLETIN 21: Ward Mining District, Boulder County, P. G. Worcester.

BULLETIN 22: A sketch of the Mineral Resources of the country adjacent to the Moffat Road. (Includes Grand, Routt, Moffat and Rio Blanco Counties.) H. A. Aurand and R. D. George.