COLORADO GEOLOGICAL SURVEY
BOULDER
R. D. GEORGE, State Geologist

BULLETIN 15

MANGANESE DEPOSITS
OF COLORADO

BY
G. A. MUILENBURG

DOI: https://doi.org/10.58783/cgs.b15.elyq8268

DENVER, COLORADO
EAMES BROTHERS, STATE PRINTERS
1919

GEOLOGICAL BOARD

His Excellency, Julius C. Gunter	Governor of Colorado
George Norlin	President University of Colorado
Victor C. Alderson	President State School of Mines
Charles A. Lory	President State Agricultural College

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.

---

[1] Engineering 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.

---

[1] Clarke, F. W., Date of geochemistry: Bull. U. S. Geol. Survey No. 616, pp. 533-536.

[2] Clarke, F. W., loc. cit.

[3] Clarke, 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 $MnO_2.H_2O \begin{pmatrix} K_2O \\ BaO \end{pmatrix}$
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, $MnCO_3$.

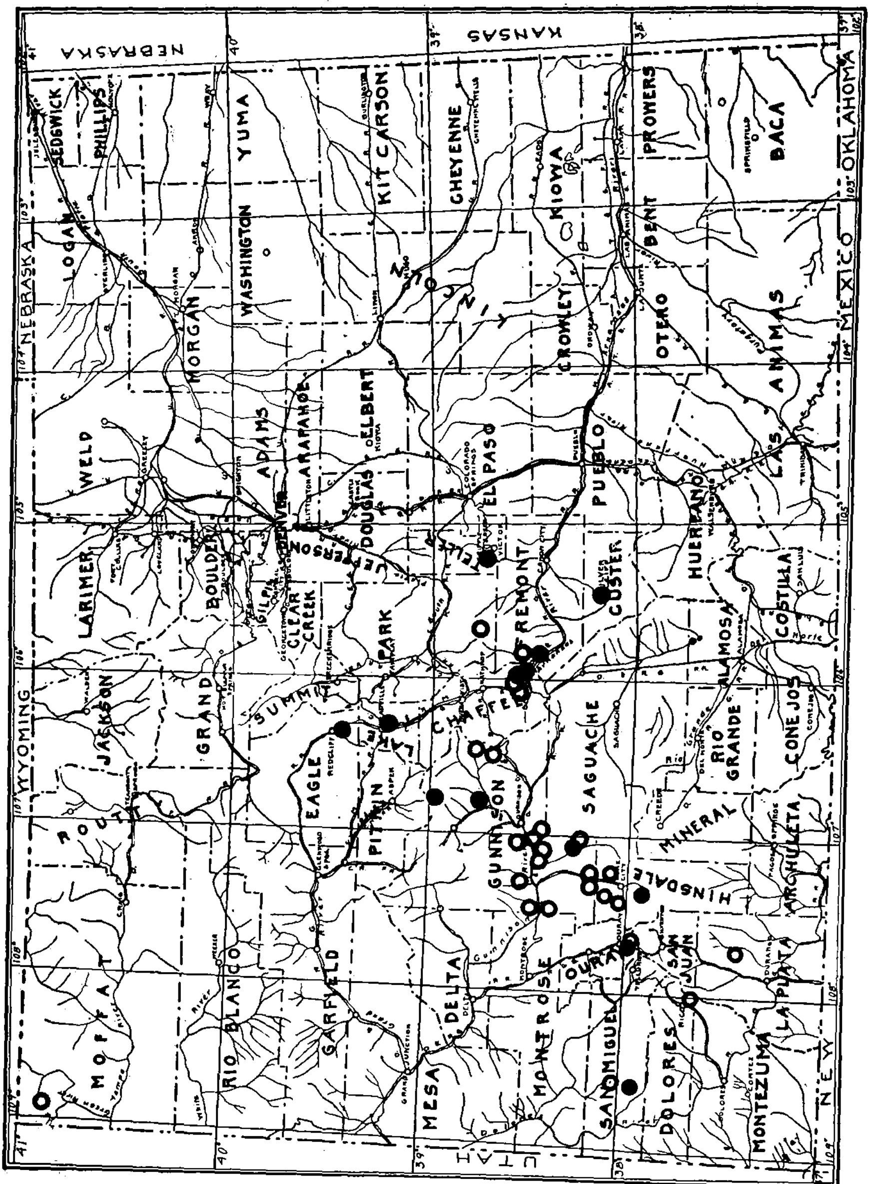
In addition there are other minerals sometimes used when associated with the above, or when they occur in sufficient quantity to be mined.

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 $(Fe, Mn, Zn)O.(Fe, Mn)_2O_3$. 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.

---

[1] Prepared 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. CIIX. 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 Post-office, 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.

---

[1] Notes 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,
Compiled by
HAROLD L. WHEELER,
Librarian, Missouri School of Mines.

BIBLIOGRAPHIES

Short bibliographies are usually included in the chapter on "Manganese," in the annual volumes of "The Mineral Industry."

Bibliography of manganese.—Edmund C. Harder. *In* Manganese deposits of the United States. U. S. Geol. Surv., Bull. 427, pp. 284-288. 1910.

Bibliography.—H. I. Coe. *In* Manganese and its effects on iron and steel. Staffordshire Iron and Steel Inst., Proc., vol. 25, pp. 16-47.

Bibliography of the analytical chemistry of manganese, 1785-1900. —Henry P. Talbot and John W. Brown. Washington, Smithsonian Inst., 1902. 124 pp.

Bibliography of the manufacture of ferro-manganese.—E. C. Buck. Met. & Chem. Eng., vol. 17, pp. 638-642. Dec. 1, 1917.

Bibliography. *In* Research with regard to the non-magnetic and magnetic conditions of manganese steel.—B. Hopkinson and Sir Robert Hadfield. Amer. Inst. Min. Eng., Trans., vol. 50, pp. 494-496. 1914.

Bibliography on manganese steel. *In* Manufacture and uses of alloy steels.—H. D. Hubbard. U. S. Bur. Mines, Bull. 100, pp. 34-36. 1916.

Bibliography of the manganese sulphides and silicates in iron and steel.—Donald M. Levy. Iron and Steel Inst., Carnegie Scholarship Mem., vol. 3, pp. 279-281. 1911.

A complete bibliography of the colorimetric determination of manganese.—H. H. Willard and L. H. Greathouse. Jour. Amer. Chem. Soc., vol. 39, pp. 2376-2377. Nov., 1917.

A list of papers treating of the manganese deposits of west-central Arkansas and the adjoining part of Oklahoma. *In* Manganese deposits of the Caddo Gap and the DeQueen quadrangles, Arkansas.—Hugh D. Miser. U. S. Geol. Surv., Bull. 660-C, pp. 60-61. 1917.

Manganese and its compounds. (Numerous bibliographic footnotes.) *In* The halogens and their allies.—G. Martin and E. A. Dancaster. London, 1915. pp. 256-321.

References. *In* Arizona Bur. Mines, Bull. 91, p. 32. Aug., 1918.

References on manganese.—Heinrich Ries. *In his* Economic Geology, 4th ed. N. Y., 1916. p. 771.

PRODUCTION

An annual review of manganese production and of the industry may be found in the annual volumes of "The Mineral Industry" and of the U. S. Geological Survey's compilation, "Mineral Resources of the United States."

Greater use of domestic manganese supply.—F. L. Garrison. Iron Age, vol. 101, pp. 680-682. Mar. 14, 1918.

Manganese, its uses, production, imports, exports, and the war. Engineering, Jan. 1, 1915.

Producers and consumers of manganese and manganiferous ores. Eng. & Min. Jour., vol. 105, pp. 195-197. Jan. 26, 1918.

CHEMISTRY

Analoid method for the determination of manganese in steel, iron ore, and slag. Met. & Chem. Eng., vol. 12, pp. 793-794. Dec., 1914.

Analyzed iron and manganese ores; methods of analysis. U. S. Bur. of Standards, Circular 26, 1911. 19 pp.

The chemistry of manganese.—M. L. Hartmann. Pahasapa Quarterly, Dec., 1916. Abstract of same, Min. & Sci. Press, vol. 114, pp. 91-92. Jan. 20, 1917.

Colorimetric determination of manganese by oxidation with periodate.—H. H. Willard and L. H. Greathouse. Jour. Amer. Chem. Soc., vol. 39, pp. 2366-2377. Nov., 1917.

A colorimetric determination of manganese in the presence of iron. —M. R. Schmidt. Jour. Amer. Chem. Soc., vol. 32, pp. 965-967. Aug., 1910.

Determination of manganese and chromium. Eng. & Min. Jour., vol. 105, pp. 248-249. Feb. 2, 1918.

Determination of manganese as sulphate and by the sodium bismuthate method.—William Blum. U. S. Bureau of Standards, Bull., vol. 8, pp. 715-740. Mar. 1, 1913.

Differential iodimetry: the analysis of pyrolusite and other oxidized manganese ores.—O. L. Barneby and George M. Bishop. Jour. Amer. Chem. Soc., vol. 39, pp. 1235-1238. June, 1917.

Differential iodimetry: determination of the available oxygen in soluble and precipitated oxidized forms of manganese.—O. L. Barneby and W. C. Hawes. Jour. Amer. Chem. Soc., vol. 39, pp. 607-610. April, 1917.

Electrolytic determination of manganese and its separation from iron and zinc.—George P. Scholl. Jour. Amer. Chem. Soc., vol. 25, pp. 1045-1056. Oct., 1903.

Estimation of manganese in aluminum alloys and dust.—J. E. Clennell. Eng. & Min. Jour., vol. 105, pp. 407-410. Mar. 2, 1918.

Manganese and its compounds. *In* The halogens and their allies. —Geoffrey Martin and E. A. Dancaster. illus. London, 1915. pp. 256-321.

New method of preparation and some interesting transformations of colloidal manganese dioxide.—E. J. Witzemann. Jour. Amer. Chem. Soc., vol. 37, pp. 1079-91. May, 1915.

Oxidation of manganese solutions in the presence of air.—V. Lenher. Econ. Geol., vol. 11, pp. 115-117. March, 1916. Same, Jour. Amer. Chem. Soc., vol. 38, pp. 638-640. March, 1916.

The place of manganese in the periodic system.—F. Russell von Bichowsky. Jour. Amer. Chem. Soc., vol. 40, pp. 1040-1046. July, 1918.

Separation of iron and manganese.—F. H. Campbell. Jour. Soc. Chem. Ind., vol. 32, pp. 3-4. Jan. 15, 1913. Abstract of same, Eng. & Min. Jour., vol. 95, pp. 377-378. Feb. 15, 1913.

The use of the platinized anode of glass in the electrolytic determination of manganese.—F. A. Gooch and M. Kobayashi. Amer. Jour. Sci., ser. 4, vol. 44, pp. 53-56. July, 1917.

The volumetric determination of manganese in rock, slags, ores, spiegels.—F. J. Metzger and L. E. Marrs. Jour. Ind. Eng. Chem. 5:125-126. Feb. 1913.

OCCURRENCE AND GEOLOGY

(See also under "Mining and Ore Dressing," as many of the articles on mining include brief discussions on geological occurrence.)

The agency of manganese in the superficial alteration and secondary enrichment of gold deposits in the United States.—William H. Emmons. Amer. Inst. Min. Eng., Trans., vol. 42, pp. 3-73. Discussion, pp. 917-920. 1911.

Geological occurrence of manganese.—J. J. Runner. Pahasapa Quarterly, vol. 6, pp. 9-17. Dec., 1916. Abstract of same, Min. & Sci. Press, vol. 114, pp. 128-129. Jan. 27, 1917.

Manganese.—Irving A. Palmer. Colo. Sch. Mines Mag., vol. 8, pp. 55-57. April, 1918.

Manganese.—Heinrich Ries. *In his* Economic Geology; 4th ed. N. Y. 1916. pp. 758-771.

Manganese deposits of the United States, with sections on foreign deposits, chemistry, and uses.—Edmund C. Harder. U. S. Geol. Surv., Bull. 427. 1910. 298 pp., maps, illus.

Manganese in superficial alteration.—F. T. Eddingfield. Econ. Geol., vol. 8, pp. 499-501. Aug., 1913.

Manganese ore in the United States.—D. F. Hewett. Amer. Inst. Min. Eng., Bull. 129, pp. v-xiii. Sept., 1917. (Not printed in the Transactions.)

Manganese ores of Russia, India, Brazil and Chile.—E. C. Harder. maps. Amer. Inst. Min. Eng., Trans., vol. 56, pp. 31-76. 1916.

Manganiferous iron ores.—E. C. Harder. U. S. Geol. Surv., Bull. 666-EE. 1917. 12 pp.

Occurrence of tungsten in manganese ore.—W. S. Palmer. Eng. & Min. Jour., vol. 105, p. 780. Apr. 27, 1918.

On the formation of deposits of oxides of manganese.—F. P. Dunnington. Amer. Jour. Sci., ser. 3, vol. 36, pp. 175-178. 1888.

Our manganese and chromium supplies.—J. E. Johnson, Jr. Iron Age, vol. 100, pp. 1328-1331. Nov. 29, 1917.

Our steel industry's manganese supplies. Iron Age, vol. 100, pp. 224-226. July 26, 1917.

Prospecting for manganese.—Henry V. Maxwell. Eng. & Min. Jour., vol. 105, p. 286. Feb. 9, 1918.

Sources and principal uses of manganese.—Ernest F. Burchard. Min. & Eng. Wld., vol. 38, p. 68. Jan. 11, 1913.

Utilizing domestic manganese supplies.—E. Newton. Iron Age, vol. 100, pp. 1290-1292. Nov. 29, 1917.

Valuation of manganese ores.—George T. Holloway. Eng. & Min. Jour., vol. 105, pp. 1163-1165. June 29, 1918.

Arizona

Manganese.—M. A. Allen and G. M. Butler. Arizona Bur. Mines, Bull. 91. Aug., 1918. 32 pp.

Manganese ore in unusual form.—William P. Blake. Amer. Inst. Min. Eng., Trans., vol. 41, pp. 647-649. 1910.

The Reymert manganiferous lode, Arizona, and its formation.—Harrington Blauvelt. Eng. & Min. Jour., vol. 47, pp. 139-140. Feb. 9, 1889.

Arkansas

Manganese: its uses, ores, and deposits.—R. A. F. Penrose. illus. Arkansas Geol. Surv., Annual report, 1890. vol. 1. 642 pp.

Manganese deposits of the Caddo Gap and De Queen quadrangles, Arkansas.—Hugh D. Miser. maps, diagr. U. S. Geol. Surv., Bull. 660-C, pp. 59-122. 1917.

Manganese in Arkansas. Eng. & Min. Jour., vol. 104, p. 247. Aug. 11, 1917.

Manganese in west-central Arkansas.—G. A. Joslin. Min. & Sci. Press, vol. 113, pp. 947-948. Dec. 30, 1916.

On the age of the manganese beds of the Batesville region of Arkansas.—Henry S. Williams. Amer. Jour. Sci., ser. 3, vol. 43, pp. 325-331. Oct., 1894.

The Siluric fauna near Batesville, Arkansas; pt. I, Geologic relation.—Gilbert van Ingen. School of Mines Quart., vol. 22, pp. 318-328. 1901.

California

(For Lower California see Mexico.)

Brief notes on the manganese deposits of individual counties may be found in the reports of the "Mines and Mineral resources of * * *" the various counties, which are published as a series by the State Mining Bureau, 1915 to date.

Hausmannite, crednerite, braunite, pyrolusite, manganite, psilomelane. *In* Minerals of California.—E. S. Eakle. California State Min. Bureau, Bull. 67, pp. 84-89. 1914.

Manganese and chromium in California. Calif. State Min. Bureau, Bull. 76. 1918.

Manganese in California.—Don Carlos Billick. Min. & Sci. Press, vol. 114, pp. 327-328. Mar. 10, 1917.

New manganese phosphates from the Gem tourmaline field of Southern California.—W. T. Schaller. Wash. Acad. Sci., Jour., vol. 2, p. 143. 1912.

Owl head manganese deposit, San Bernardino County, California. —R. L. Mann. diagr. Min. & Eng. Wld., vol. 44, pp. 743-744. April 15, 1916.

Colorado

The downtown district of Leadville, Colorado.—Samuel F. Emmons and John D. Irving. U. S. Geol. Surv., Bull. 320. 1907. 75 pp.

Geology and mining industry of Leadville, Lake County, Colorado. —Samuel F. Emmons. U. S. Geol. Surv., 2d Ann. Rept., pp. 201-290. 1882.

Geology and ore deposits of Red Cliff, Colorado.—A. H. Means. Econ. Geol., vol. 10, pp. 1-27. Jan., 1915.

Leadville manganese resources. Min. & Sci. Press, vol. 115, p. 758. Nov. 24, 1917.

Manganese and manganese minerals. *In* Common minerals and rocks, their occurrence and uses.—R. D. George. Colo. Geol. Surv., Bull. 6, pp. 159-163. 1913.

Manganiferous iron ore occurrences at Red Cliff, Colorado.—J. B. Umpleby. Eng. & Min. Jour., vol. 104, pp. 1140-1141. Dec. 29, 1917.

Siderite and sulphides in Leadville ore deposits.—Phillip Argall. Min. & Sci. Press, vol. 109, pp. 50-54, 128-234. July 11, 25, 1914.

Manganese in Colorado. U. S. Geol. Surv. Bull. 427, pp. 137-151.

Georgia

Description of the Ellijay quadrangle.—L. La Forge and W. C. Phalen. U. S. Geol. Surv., Folio 187. 1913. 18 pp., maps, diagr.

Geological relations of the manganese ore deposits of Georgia.— Thomas L. Watson. Amer. Inst. Min. Eng., Trans., vol. 34, pp. 207-253. 1903. maps, diagr.

Manganese ore deposits of Georgia.—Thomas L. Watson. Econ. Geol., vol. 4, pp. 46-55. Jan., 1909. Abstract of same, Min. & Eng. Wld., vol. 30, pp. 643-644. April 3, 1909.

Manganese ores in the Cartersville district, Georgia.—C. W. Hayes. *In* U. S. Geol. Surv., Bull. 213, p. 232. 1913.

A preliminary report on the manganese deposits of Georgia.—Thomas L. Watson. Ga. Geol. Surv., Bull. 14. 1908. 195 pp. illus., maps.

Kansas

Manganese in the Dakota sandstone of central Kansas.—W. A. Whitaker and W. H. Twenhofel. Econ. Geol., vol. 12, pp. 473-475. Aug., 1917.

Maryland

Manganese in Maryland. Md. Geol. Surv., Repts., vol. 9, pp. 325-327. 1911.

Some manganese mines in Virginia and Maryland.—D. F. Hewett. U. S. Geol. Surv., Bull. 640-C, pp. 37-71. 1916.

Minnesota

Cuyuna manganiferous iron ores.—E. C. Harder. Iron Trade Rev., vol. 61, pp. 653-654. Sept. 27, 1917.

Manganiferous iron ores of the Cuyuna district, Minnesota.—E. C. Harder. maps, diagr. Amer. Inst. Min. Eng., Trans., vol. 58, pp. 453-486. 1918.

Notes on the geology and iron ores of the Cuyuna district, Minnesota.—E. C. Harder and A. W. Johnston. map. U. S. Geol. Surv., Bull. 660-A, pp. 1-26. 1917.

Montana

Manganese at Butte, Montana.—J. T. Pardee. U. S. Geol. Surv., Bull. 690-E, pp. 111-130. 1918 Abstracts from same, Eng. & Min. Jour., vol. 105, pp. 1076-1079. June 15, 1918.

The manganese deposits at Philipsburg, Montana. Min. & Sci. Press, vol. 115, p. 725. Nov. 17, 1917.

Some manganese deposits in Madison County, Montana.—J. T. Pardee. U. S. Geol. Surv., Bull. 690-F, pp. 131-143. 1918.

Ore deposits at Butte, Montana.—Reno H. Sales. maps. Amer. Inst. Min. Eng., Trans., vol. 46, pp. 3-109. 1913.

Nevada

Manganese deposits of Clark County, Nevada.—F. A. Hale, Jr. illus. Eng. & Min. Jour., vol. 105, pp. 775-777. April 27, 1918.

Manganese deposits of White Pine County, Nevada.—Eng. & Min. Jour., vol. 106, p. 308. Aug. 17, 1918.

Manganese fluxing ore at Pioche, Nevada. Eng. & Min. Jour., vol. 104, p. 760. Oct. 27, 1917.

Manganese ore in Nevada. Iron Age, vol. 102, p. 241. July 25, 1918.

The minerals of Tonopah, Nevada.—Arthur S. Eakle. Univ. of Calif., Dept. of Geol., Bull. vol. 7, pp. 1-20. May, 1912.

A pleistocene manganese deposit near Golconda, Nevada.—R. A. F. Penrose, Jr. Jour. Geol., vol. 1, pp. 275-282. 1893.

New Jersey

Columnar manganocalcite from Franklin Furnace, New Jersey.—Wallace G. Levison. Amer. Mineralogist, vol. 1, p. 5. July, 1916.

Zinc and manganese deposits in Franklin Furnace, New Jersey.—J. E. Wolff. *In* U. S. Geol. Surv., Bull. 213, pp. 214-217. 1903.

Oklahoma

Iron and manganese. *In* A report on the geological and mineral resources of the Arbuckle Mountains, Oklahoma.—Chester A. Reeds. Okla. Geol. Surv., Bull. 3, pp. 54-59. 1910.

South Carolina

Manganese. *In* Catalogue of the mineral localities of South Carolina.—Earle Sloan. So. Carol. Geol. Survey, Bull., ser. 4, no. 2, pp. 95-98. 1908.

Manganese in South Carolina.—Claud Hafer. Eng. & Min. Jour., vol. 98, p. 1135. Dec. 26, 1914.

Manganese in South Carolina.—Reginald W. Petre. illus. Eng. & Min. Jour., vol. 101, pp. 1019-1020. June 10, 1916.

Tennessee

Manganese deposits of Bradley County.—A. H. Purdue. Resources of Tenn., vol. 8, pp. 46-47. Jan., 1918.

Manganese deposits of East Tennessee; part I.—G. W. Stose and F. G. Schrader. Resources of Tenn., vol. 8, pp. 153-207. July, 1918.

Manganese in Tennessee.—Joel H. Watkins. illus. Eng. & Min. Jour., vol. 102, pp. 545-546. Sept. 23, 1916.

A new manganese deposit in Tennessee.—Wilbur A. Nelson. illus., map. Resources of Tenn., vol. 1, pp. 220-228. Dec., 1911.

Notes on manganese in East Tennessee.—A. H. Purdue. Resources of Tenn., vol. 6, pp. 111-123. April, 1916.

Texas

Description of the Llano and Burnet quadrangles.—Sidney Paige. U. S. Geol. Surv., Folio 183. 1912. 16 pp. illus., maps.

Mineral resources of the Llano-Burnet region, Texas.—Sidney Paige. U. S. Geol. Surv., Bull. 450. 1911. 103 pp. maps.

Vermont

Manganese deposits of South Wallingford, Vermont.—R. W. Jones. Eng. & Min. Jour., vol. 105, p. 779. Apr. 27, 1918.

Virginia

Geological notes on the manganese ore deposits of Crimora, Virginia.—Charles E. Hall. Amer. Inst. Min. Eng., Trans., vol. 20, pp. 46-49. 1892.

Manganese ores. Va. Geol. Surv., Bull. 6, pp. 23-26. 1911.

Manganese ore in Virginia.—Marshall Haney. illus. Iron Age, vol. 101, p. 1659. June 27, 1918.

Manganese ores of Virginia.—Marshall Haney. illus. Iron Age, vol. 100, pp. 884-893. Oct. 11, 1917.

New manganese district in Virginia. Eng. & Min. Jour., vol. 104, p. 990. Dec. 8, 1917.

Possibilities for manganese ore on certain undeveloped tracts in the Shenandoah Valley, Virginia.—D. F. Hewett, G. W. Stose, F. J. Katz, and H. D. Miser. U. S. Geol. Surv., Bull. 660-J, pp. 271-296. 1918.

Production of Virginia manganese.—E. A. Schubert. illus. Iron Trade Rev., vol. 60, pp. 1032-1034. May 10, 1917.

Some manganese mines in Virginia and Maryland.—D. F. Hewett. U. S. Geol. Surv., Bull. 640-C, pp. 37-71. 1916.

Undeveloped manganese ore tracts of the Shenandoah Valley, Virginia. Manufacturer's Record. Jan. 3, 1918.

Washington

Some manganese and copper developments in the Olympic Mountains, Washington. Pacific Mining Jour., July, 1913. pt. I.

Two manganese deposits in northern Washington.—Olaf P. Jenkins. Eng. & Min. Jour., vol. 105, p. 1082. June 29, 1918.

Africa

Manganese in West Africa.—Stanley H. Ford. illus. Min. Mag., vol. 17. Dec., 1917.

Australia

Iron and manganese ore in Victoria, Australia. Iron and Coal Trade Rev., vol. 86. 1913.

Manganese.—B. Dunstan. Queensland Govt. Min. Jour. June 15, 1917.

Report on the occurrence of manganese ores and barytes at Pernatty, Lagoon. So. Aus. Dept. of Mines, no. 25. 1917.

Brazil

The geology of Central Minas Geraes, Brazil.—E. C. Harder and R. T. Chamberlin. maps, illus. Jour. of Geol., vol. 23, pp. 341-378, 385-424. May-Aug., 1915.

High-grade manganese ores of Brazil.—Joseph T. Singewald, Jr., and Benjamin L. Miller. map, illus. Iron Age, vol. 97, pp. 417-420. Feb. 17, 1916.

Manganese deposits of Moro da Mina, Brazil.—Joquim Lustosa and J. C. Branner. illus. Eng. & Min. Jour., vol. 86, pp. 1196-1197. Dec. 19, 1908.

Manganese ore in Brazil.—K. Thomas. Amer. Inst. Min. Eng., Bull. 129, pp. xiii-xxi. Sept., 1917. (Not printed in the Transactions.)

Manganese ores of the Lafayette district, Minas Geraes, Brazil.—Joseph T. Singewald, Jr., and Benjamin L. Miller. illus. Amer. Inst. Min. Eng., Trans., vol. 56, pp. 7-30. 1916.

On the manganese ore deposits of the Queluz (Lafayette) district, Minas Geraes, Brazil.—Orville A. Derby. Amer. Jour. Sci., ser. 4, vol. 12, pp. 18-32. July, 1901.

On the original type of the manganese ore deposits of the Queluz district, Minas Geraes, Brazil.—Orville A. Derby. Amer. Jour. Sci., ser. 4, vol. 25, pp. 213-216. March, 1908.

Bukowina

Manganese ores of the Bukowina.—Herbert K. Scott. maps. Iron & Steel Inst. Jour., vol. 94, pp. 288-305. 1916. Abstract of same, Iron Trade Rev., vol. 59, pp. 738-741. Oct. 12, 1916. Another abstract, Eng. & Min. Jour., vol. 102, pp. 935-937. Nov. 25, 1916.

Bulgaria

Notes on some Bulgarian mineral deposits.—Herbert K. Scott. map. Inst. Min. & Met., Trans., vol. 22, pp. 597-615. 1913.

Canada and Newfoundland

The Cambrian manganese deposits of Conception and Trinity Bays, Newfoundland.—Nelson C. Dale. maps, illus. Amer. Philos. Soc., Proc., vol. 54, pp. 371-456. 1915.

Investigations of some manganese ore deposits in Nova Scotia and New Brunswick. *In* Canada, Mines Branch, Summary Rept., 1909.

A list of Canadian mineral occurrences.—Robert A. A. Johnston. Canada Geol. Surv., Memoir 74. Ottawa, 1917. 273 pp.

Manganese. *In* Bathurst district, New Brunswick.—G. A. Young. Canada Geol. Surv., Memoir 18-E. Ottawa, 1911. p. 77.

Manganese deposits of Conception and Trinity Bays.—Nelson C. Dale. Geol. Soc. of Amer., Bull., vol. 25, pp. 73-74. 1914.

Mineral resources of Canada: manganese. Ottawa, 1904. 24 pp. (Reprinted from Ann. Rept. of the Section of Mines for 1902.)

On the occurrence of manganese at New Ross in Nova Scotia.—R. E. Kramm. map, illus. Can. Min. Inst., Trans., vol. 15, pp. 210-217. 1912. Abstract of same, Eng. & Min. Jour., vol. 95, p. 1249. June 21, 1913.

Cuba

Manganese deposits of Santiago, Cuba.—A. C. Spencer. *In* U. S. Geol. Surv., Bull. 213, pp. 251-255. 1903.

Manganese deposits of Santiago Province, Cuba.—A. C. Spencer. diagr. Eng. & Min. Jour., vol. 74, pp. 247-248. Aug. 23, 1902.

Manganese prospects in eastern Cuba. Eng. & Min. Jour., vol. 105, pp. 779-780. Apr. 27, 1918.

Resena historica sobre la mineria en Oriente, Cuba. Havana, Bol. de Minas, Jan., 1918. 36 pp. illus.

Costa Rica

Manganese deposits in Costa Rica.—Allen H. Yonge. illus. Eng. & Min. Jour., vol. 104, pp. 739-741. Oct. 27, 1917.

England

Notes on the occurrence of manganese ore near the Arenigs, Merionethshire.—Edward Halse. Fed. Inst. Min. Eng., Trans., vol. 3, pp. 940-952, and vol. 4, pp. 167-168. 1892.

India

A manganese deposit in southern India.—R. O. Ahlers. map, diagr. Inst. Min. & Met., Trans., vol. 18, pp. 133-152. 1908. Abstract of same, Eng. & Min. Jour., vol. 87, p. 955. May 8, 1909.

Manganese in India.—T. H. Holland and L. L. Fermor. India Geol. Surv., Records, vol. 39, p. 128. 1910.

The manganese ore deposits of India.—L. L. Fermor. India Geol. Surv., Memoirs, vol. 37. 1909. 4 pts.

The mode of occurrence of manganite in the manganese ore deposits of the Sandur State, Bellary, Madras, India.—A. Ghose. illus. Fed. Inst. Min. Eng., Trans., vol. 35, pp. 685-691. 1908.

Notes on the petrology and manganese ore deposits of the Sausar tahsil, Chhindwara, Central Provinces.—L. L. Fermor. India Geol. Surv., Records, vol. 33, pt. 3, p. 159. 1906.

On manganite from the Sandur hills.—L. L. Fermor. India Geol. Surv., Records, vol. 33, pt. 3, p. 229. 1906.

Italy

Le Miniere di manganese Italiane.—Gaetano Castelli. Rassegna Mineraria, Apr., 1918.

Mexico

Deposits of manganese in Lower California.—H. Vincent Wallace. illus. Min. & Eng. Wld., vol. 35, pp. 103-104. July 15, 1911. Same, Min. & Sci. Press, vol. 103, pp. 201-202. Aug. 12, 1911.

Informe sobre los depositos de manganeso cerca del pueblo de Mulege, Baja California.—H. Vincent Wallace. illus. Mexico, Bol. Minero, vol. 1, pp. 209-212. Apr. 1, 1916.

Minas de manganeso en Puenta Concepcion, municipalidad de Mulege, Baja California.—C. A. McQuesten. Mexico, Bol. Minero, vol. 1, pp. 232-235. Apr. 15, 1916.

Los minerales de manganeso. Mexico, Bol. Minero, vol. 4, pp. 366-368. Oct. 1, 1917.

Notes on the occurrence of manganese ores near Mulege, Baja California, Mexico.—Edward Halse. Fed. Inst. Min. Eng., Trans., vol. 3, pp. 934-939. 1892.

Panama

The manganese industry of the Department of Panama, Republic of Columbia.—E. G. Williams. maps, diagr. Amer. Inst. Min. Eng., Trans., vol. 33, pp. 197-234. 1902.

MINING AND ORE DRESSING

Agglomeration of manganiferous limonite ore.—F. Witte. diagr. Eng. & Min. Jour., vol. 90, pp. 216-217. July 30, 1910.

Concentration of low-grade manganese ores. Iron Age, vol. 100, p. 607. Sept. 13, 1917.

The Crimora manganese mine.—E. K. Judd. Eng. & Min. Jour., vol. 83, p. 478. Mar. 9, 1907.

The Ladd manganese mine.—Samuel H. Dolbear. illus. Min. & Sci. Press, vol. 110, pp. 258-259. Feb. 13, 1915.

The Las Vegas Manganese mine. Min. & Oil Bull. June, 1918.

Manganese concentrator at Philipsburg, Montana. Met. & Chem. Eng., vol. 18, p. 625. June 15, 1916.

Manganese deposits in the Caucasus.—Fred W. Cauldwell. Min. & Sci. Press, vol. 105, pp. 113-114. July 27, 1912.

Manganese from low-grade ores.—C. S. Vadner. Eng. & Min. Jour., vol. 104, p. 884. Nov. 17, 1917.

The manganese industry in California.—Samuel H. Dolbear. illus. Min. & Sci. Press, vol. 110, pp. 172-175. Jan. 30, 1915.

The manganese mines of Las Cabesses, Pyrenees, France.—C. Algernon Moreing. Inst. Min. & Met., Trans., vol. 2, pp. 250-277. 1894.

Manganese mining in Arkansas.—Tom Shiras. illus. Eng. & Min. Jour., vol. 104, pp. 1079-1080.,Dec. 22, 1917.

Manganese mining in British India.—Herbert A. Carter. Min. & Sci. Press, vol. 103, pp. 834-835. Dec. 30, 1911.

Manganese mining in the Caucasus.—August Muls. Min. Mag., vol. 2, pp. 439-440. June, 1910.

Manganese mining in the Magdalena mining district, New Mexico. —R. H. West. Eng. & Min. Jour., vol. 106, p. 435. Sept. 7, 1918.

The manganese ore industry of the Caucasus.—Frank Drake. map, illus. Amer. Inst. Min. Eng., Trans., vol. 28, pp. 191-207. 1898.

Manganese washing plant of the Eureka Company, Arkansas.—Tom Shiras. illus. Eng. & Min. Jour., vol. 105, p. 778. Apr. 27, 1918.

Manganiferous iron mining in the Cuyuna district, Minnesota.—P. M. Ostrand. illus. Eng. & Min. Jour., vol. 105, pp. 269-273. Feb. 9, 1918.

Mining manganese at Crimora, Virginia.—Marshall Haney. Eng. & Min. Jour., vol. 105, p. 875. May 11, 1918.

Mining of manganese ore in Virginia. illus. Iron Age, vol. 97, pp. 776-777. Mar. 30, 1916.

METALLURGY AND USES

Die Bedeutung der Mangan- und Manganeisenerze fur die Deutsche Industrie.—L. Scheffer. Stahl und Eisen, vol. 34, pp. 1246-1254, 1336-1341. July 23, Aug. 6, 1914.

The chemical and mechanical relations of iron, manganese, and carbon.—J. O. Arnold and A. A. Read. illus. Iron and Steel Inst., Jour., vol. 81, pp. 169-184. 1910.

Electric ferromanganese. Iron Age, vol. 102, p. 747. Sept. 26, 1918.

The electric furnace and the melting of alloys.—R. S. Wile. Iron Age., vol. 95, pp. 1068-1069. May 13, 1915.

Ferromanganese and spiegeleisen.—George C. Stone. Eng. & Min. Jour., vol. 105, pp. 75-76. Jan. 12, 1918.

Ferromanganese in the iron and steel industry.—Robert J. Anderson. Jour. Franklin Inst., vol. 183, pp. 579-592. May, 1917.

How to make manganese bronze. Foundry, vol. 46, p. 29. Jan., 1918.

Liquid ferromanganese in steel making. Iron Age, vol. 102, pp. 208-209. July 25, 1918.

Magnetic properties of manganese and special manganese steels. Min. & Sci. Press, vol. 117, p. 126. July 27, 1918. (Abstract of a paper by Sir Robert Hadfield, C. Chenveau, and C. Geneau, in Proceedings of the Royal Society, London.)

Manganese and its effect on iron and steel.—H. I. Coe. Staffordshire Iron and Steel Inst., Proc., vol. 25, pp. 16-47.

Manganese conservation in steel making.—C. R. Ellicott. Iron Age, vol. 101, pp. 1484-1486a. June 6, 1918. (Abstract of a paper presented at annual meeting of Amer. Iron & Steel Inst.)

Manganese in slags and its incorporation in steel. Iron Age, vol. 101, p. 373. Feb. 7, 1918.

The manganese-silver problem.—Walter Neal. Met. Chem. & Min. Soc. of So. Africa, Jour., vol. 17, pp. 9-18, 39-41, 70-71, 100.

Aug.-Nov., 1916. Abstract. Min. & Sci. Press, vol. 114, pp. 158-160. Feb. 3, 1917.

Manganese steel and the allotropic theory.—Albert Sauveur. illus. Amer. Inst. Min. Eng., Trans., vol. 30, pp. 501-514. 1914.

Manganese steel with special reference to the relation of physical properties to microstructures and critical ranges.—W. S. Potter. illus., diagr. Amer. Inst. Min. Eng., Trans., vol. 50, pp. 437-475. 1914.

The manufacture and use of wrought manganese bronze.—J. L. Jones. Amer. Inst. Metals, Trans., vol. 9, pp. 264-272. 1915.

The manufacture and uses of alloy steels.—Henry D. Hibbard. U. S. Bur. Mines, Bull. 100. 1916. 77 pp.

Metallurgy of ferromanganese.—Robert J. Anderson. Iron Trade Rev., vol. 60, pp. 723-726. Mar. 29, 1917. Same, Eng. & Min. Jour., vol. 103, pp. 971-973. June 2, 1917.

Opportunity for metallurgists. Met. & Chem. Eng., vol. 17, pp. 110-112. Aug. 1, 1917.

The possible treatment of manganese ores in California.—E. A. Hersam. Min. & Sci. Press, vol. 117, p. 52. July 13, 1918. (Abstract of a Bulletin of the Univ. of California.)

The preparation of carbon-free ferromanganese.—E. A. Wraight. illus. Iron & Steel Inst., Carnegie Scholarship Memoirs, vol. 1, pp. 143-160. 1909.

Research with regard to the non-magnetic and magnetic conditions of manganese steel.—B. Hopkinson and Sir Robert Hadfield. Amer. Inst. Min. Eng., Trans., vol. 50, pp. 476-500. 1914.

The role of manganese in alloy steels.—Henry M. Howe. Amer. Soc. for Test. Mater., Proc., vol. 17, pt. 2, pp. 5-8. 1917. Same, Eng. & Min. Jour., vol. 104, pp. 467-468. Sept. 15, 1917.

Significance of manganese in American steel metallurgy.—F. H. Willcox. Amer. Inst. Min. Eng., Trans., vol. 56, pp. 412-431. 1916.

The situation in regard to manganese, sulphur, pyrite, and some other war minerals.—J. E. Johnson, Jr. Eng. Soc. West. Pa., vol. 33, pp. 644-652. Jan., 1918. Excerpt: Utilization of low-grade manganese deposits a metallurgical problem. Eng. & Min. Jour., vol. 104, pp. 1027-1030. Dec. 15, 1917.

Spiegeleisen in place of ferromanganese.—E. F. Cone. Iron Age, vol. 101, pp. 40-41. Jan. 3, 1918.

A study of the manganese sulphides and silicates in iron and steel. —Donald M. Levy. illus. Iron and Steel Inst., Carnegie Scholarship Memoirs, vol. 3, pp. 260-317. 1911.

The use of liquid ferromanganese in the steel processes.—Axel Sahlin. illus. Iron & Steel Inst., Jour., vol. 90, pp. 213-231. 1914.

Use of spiegel in meeting manganese specifications.—R. K. Clifford. Iron Age, vol. 102, pp. 98-99. July 11, 1918.

Utilization of highly siliceous iron and manganese minerals.—N. Tarugi. Eng. & Min. Jour., vol. 96, p. 64. July 12, 1913. (From Chem. Zeitg., vol. 38. Apr. 26, 1913.)

Utilization of manganese ores in Sweden.—J. Harden. Met. & Chem. Eng., vol. 17, pp. 701-704. Dec. 15, 1917. Abstract of same, Iron Age, vol. 101, pp. 938-940. Apr. 11, 1918.

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

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.