SOME DEPOSITS OF MANGANESE ORE IN COLORADO.

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INTRODUCTION.

For many years large quantities of manganiferous silver ore have been mined from the oxidized parts of the lead-silver deposits of the Leadville district, Colo., for use as flux, and from time to time some of this ore has been converted into spiegeleisen by the Colorado Fuel & Iron Co., at Pueblo. The first shipment of high-grade manganese ore from Colorado was made in 1915, but the known high-grade deposits are small and not readily accessible, and so far only a few hundred tons has been shipped. Notwithstanding the small production of manganese ores the search for new deposits has been energetically carried on, and to the end of 1918 many discoveries were reported to the United States Geological Survey and to the Colorado Geological Survey. In order to obtain data for an estimate of the quantity and grade of manganese ore available in this country, the United States Geological Survey during the war assigned several geologists to the examination of deposits in the Western States. In August, 1917, J. B. Umpleby made brief visits to the Leadville and Red Cliffs districts, Colo., and the results of his investigations were made known in articles published in the mining press in the fall of 1917. Other deposits that were on record in the United States Geological Survey—situated in Chaffee County near Salida, in Gunnison County near Iola, in Saguache County near Moffat, and in western San Miguel County—were visited by the writer early in August, 1917. After that examination many more discoveries were reported, and the deposits were examined by the Colorado Geological Survey in 1918. The new localities examined include many in Gunnison and Hinsdale counties; the Ouray district, Ouray County; the Rico district, Dolores County; the Westcliffe district, Custer County; and near Needleton, La Plata County. The present report treats only of the principal features of the manganese deposits visited by the writer, but some of the valuable data obtained by the Colorado Geological Survey are incorporated in the descriptions of the types and geologic occurrence of manganese deposits in the State.

GEOLOGIC OCCURRENCE.

Deposits of manganese ore occur in Colorado in sedimentary and igneous rocks representing a wide range in geologic age. The sedimentary rocks inclosing them range in age from pre-Cambrian slates through Paleozoic, Cretaceous, and Tertiary formations to Quaternary sandstone, and the igneous rocks range in age from pre-Cambrian to Tertiary.

TYPES OF MANGANESE DEPOSITS.

The manganese deposits of Colorado occur (1) in veins and brecciated zones; (2) as replacement deposits; and (3) as probable original bedded deposits.

VEINS AND BRECCIATED ZONES.

The veins and brecciated zones constitute by far the most numerous type of manganese deposits in Colorado, but economically they have proved of little importance. They occur in both igneous and sedimentary rocks which range from pre-Cambrian to Tertiary in age. The deposits of this type may be further classified into (*a*) those in which the manganese minerals are of hypogene origin or are the oxidized products of hypogene minerals, and are associated with silver and gold ores, and (*b*) those in which the manganese minerals are of supergene origin and are associated with no other metallic minerals except iron oxides. The Colorado Geological Survey reports deposits of manganese minerals of hypogene origin associated with silver-gold ores in the Cripple Creek, Ouray, and Rico districts, and deposits of supergene origin as widespread in Tertiary lavas in Gunnison and Hinsdale counties. The origin of manganese oxides in Tertiary lavas is obscure. That the oxides were derived from widely disseminated manganese minerals appears doubtful to the writer.

REPLACEMENT DEPOSITS.

Replacement deposits of manganese ores occur principally in the oxidized parts of lead-silver deposits in the Leadville district and of deposits containing zinc and iron sulphides in the Red Cliff district. In both localities the deposits are in Carboniferous limestone, and the manganese ores are derived from the oxidation of manganiferous siderite. Small replacement deposits occur along the bedding of Paleozoic limestone near Salida, in sandstone and tuff beds associated with Tertiary lava flows in Gunnison and Hinsdale counties, and in sandstone of Upper Triassic age in San Miguel County.

BEDDED DEPOSIT.

A deposit of manganese ore which probably represents the oxidized and enriched part of an original sedimentary bed occurs in sandstone and shale in western San Miguel County.

MANGANESE MINERALS.

The manganese ores are composed dominantly of the oxides pyrolusite, manganite, psilomelane, and wad, generally mixed with iron oxides. In the deposit east of Moffat, in Saguache County, hausmannite was noted. In the most valuable deposits the oxides are the residual products of the weathering of manganiferous siderite, rhodochrosite, and manganiferous calcite, but in a number of places they have been deposited at some distance from their source by meteoric waters. According to the Colorado geologists, the oxides in the veins and breccias in Tertiary lavas and in the deposits that replace associated tuff and sand beds were probably laid down by meteoric waters which dissolved the manganese contained in small quantities in ferromagnesium minerals of the lavas.

DEPOSITS.

CHAFFEE COUNTY.

LOCATION.

Several small manganese deposits occur near Salida, in the western slope of the Sangre de Cristo Range east of Arkansas River. One deposit, owned by W. Higham & Sons, is 10 miles north of Salida, and the Boyer & Frankenberry property and several other claims are in a small canyon draining to Arkansas River 8 miles south of Salida and a few miles east of Wellsville, a station on the Denver & Rio Grande Railroad. The outcrops of manganese ore have long been known, and claims were staked over them many years ago, but it was not until 1916 that they were exploited as sources of manganese ore. During that year six carloads were shipped from the Higham property and a small quantity from the Boyer & Frankenberry deposit. No work was being done on either property at the time of the writer's visit in August, 1917. The Higham deposit is accessible from Salida by a wagon road 10 miles long, and the Boyer & Frankenberry deposit from Wellsville by a wagon road 2 miles long.

SURFACE FEATURES.

The region is high and extremely rugged; the crest of the Sangre de Cristo Range east of Salida is well above 10,000 feet in altitude,

and many of the peaks reach 12,000 feet or more. Barometric readings at the manganese deposits gave altitudes from 7,500 to 9,300 feet. The deposits are in canyons that contain intermittent streams draining to Arkansas River. In none of them has water level been reached in the workings.

The climate is characterized by short summers and long winters, with heavy snowfall. Cedar and several other varieties of coniferous trees are fairly abundant in the higher mountains.

GEOLOGY.

The inclosing rocks of most of the manganese deposits are massive, thick-bedded gray Paleozoic limestones, but one deposit occurs in aplite. The limestones are well exposed near Wellsville, where Arkansas River cuts through them, and they extend northward along the Sangre de Cristo Range to and beyond the Higham property. Sandstone, gritstone, and shale overlie the limestones east of Wellsville, where the sediments strike a little west of north and dip eastward. At the Higham property the limestones are apparently horizontal.

Various kinds of igneous rocks were observed, including diorite, aplite, rhyolite, and andesite, but no attempt was made to determine their relations.

ORE DEPOSITS.

The manganese deposits are fissure fillings in limestone and aplite and replacement deposits in limestone adjacent to fissures. The ore bodies disclosed by the mine developments are small, and the known deposits contain from a few tons to a few thousand tons of ore. The manganese oxides are principally wad, pyrolusite, and psilomelane. These oxides in the limestone are associated with coarsely crystalline carbonates and with much secondary calcite. One of these carbonates is siderite, which decomposes to limonite and wad. Iron oxides are abundant in the ore from the Higham deposit, but in the deposits east of Wellsville only a small percentage of iron is present.

MINES AND PROSPECTS.

LIBERTY HILL CLAIMS.

The Liberty Hill group of two claims, owned by W. Higham & Sons, of Salida, is 10 miles north of Salida and 1 mile south of the Calumet iron mine, formerly worked by the Colorado Fuel & Iron Co. The claims were located in January, 1916, and in that year six carloads of manganiferous iron ore, containing 20 per cent of manganese, were shipped to the Colorado Fuel & Iron Co. at Pueblo, to

Perth Amboy, N. J., and to Pittsburgh. The workings are on a gently sloping surface at an altitude of 9,200 feet and are several hundred feet lower than the summit of a mountain a short distance east of the claims. They consist of a number of shallow holes and a shaft 50 feet deep within an area 150 feet in diameter. The deposit is contained in a flat bed of massive gray limestone, probably of Paleozoic age. The ore is in lenses and irregular masses from 1 to 4 feet thick, which occur a few feet beneath the surface and adjacent to an irregular vein exploited by the 50-foot shaft. The deposit yields a mixture of soft brown oxides of manganese and iron which contains about 20 per cent of manganese and more iron. The mechanical separation of the manganese and iron oxides does not seem to be possible. The material on the dump from the shaft contains a considerable quantity of a coarsely crystalline carbonate that is undergoing decomposition to yellowish iron oxides and therefore is probably siderite. It is regarded as the source of the manganese oxides. Several hundred tons of the manganiferous ore is exposed by the workings. Without some economical method of beneficiation it is doubtful whether any profit can be made from these ores.

IRON MOUNTAIN CLAIMS.

The Iron Mountain group of two claims is in Wells Canyon, 2 miles east of Wellsville, at an altitude of 7,700 feet. The claims are owned by Boyer & Frankenberry and were located January 1, 1916. Two carloads of ore were shipped to the Colorado Fuel & Iron Co., of Pueblo, one in 1916 and the second in June, 1917. The smelter settled for the second carload on the basis of 39.42 per cent of manganese, 3.60 per cent of iron, 3.80 per cent of silica, and 0.03 per cent of phosphorus. The deposit is explored by a tunnel 150 feet long, with short drifts and a raise that extends from the tunnel level 65 feet to the surface on the dip of the vein.

The manganese deposit is contained in beds of a massive gray limestone, which at the outcrop strike N. 20° W. and dip 35° E. At the tunnel level the strata are sharply flexed and broken and the deposit and inclosing beds are flat or dip gently to the north. The ore was formed mainly by the replacement of a bed of coarsely crystalline limestone and clay from 2 to 6 feet thick, but where the strata are broken the ore also extends in irregular masses into the limestone. At the outcrop the ore is a crustiform mass of manganese oxides composed of an aggregate of short columnar rods with rounded ends. The center of each column is pyrolusite as a soft black powder, which is surrounded by a thin shell of hard psilomelane. The ore is of high grade, but the deposit is only 1 foot thick.

Much secondary calcite occurs in and above the ore. In the tunnel a section of the deposit is as follows:

Section at Iron Mountain manganese claim.

	Ft.	in.
Soft, decomposed limestone or clay		6
Crusted calcite in small white crystals		6
Soft black manganese oxides	1	
Crystalline limestone or carbonates, partly replaced by iron and manganese oxides or altered to them	1	
Banded brown clay with streaks of soft black manganese ore and lenses of hard ore	3	

The soft black oxides are of high grade and the hard crusts—which are coarse crystals of carbonates partly replaced by manganese and iron oxides—are medium or low grade ore. Pyrolusite and wad are the dominant oxides, but psilomelane is also present. Loosely coherent masses of secondary calcite in delicate white crystals, some of them 2 feet thick, generally occur above the topmost ore stratum, and smaller masses are scattered through the deposit. The source of the manganese oxides is not apparent. A specimen of coarsely crystalline calcite is impregnated with dendritic growths of manganese oxides and clearly shows that the manganese was not derived from the decomposition of the calcite of the specimen; but in other parts of the deposit coarsely crystalline carbonate is partly replaced by manganese and iron oxides in such a manner as to suggest that the oxides were derived from the decomposition of the carbonate.

The ore is prepared for shipment by screening, for the fine material and a smaller quantity of hand-sorted lumps contain about 40 per cent of manganese. The deposit has been only partly explored, but enough work has been done to show a reserve of 2,000 tons of material containing about 40 per cent of manganese.

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, redlike 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 depths 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 & VREELAND CLAIMS.

Two claims owned by Galpin & Vreeland are 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 are 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, in which manganese oxides form veinlets as much as 4 inches thick. The oxides are psilomelane and pyrolusite, and they have not only 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 crop out.

GUNNISON COUNTY.

POTTER CLAIMS.

Several claims located for manganese by J. G. Potter are 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 constitute 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 2 miles along the canyon in which the manganese deposits are situated and merges into the outlying ridges of the higher mountains. The mesa is underlain by sandstone, tuffs, and agglomerate, which are capped by lava flows, and all the rocks are probably of Tertiary 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 clay gouge 6 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

thick—not think enough for commercial exploitation. In places small sandstone nodules partly replaced by manganese oxides project from the weathered surface. A tunnel 70 feet long driven on the fissure explored by the open cut disclosed no ore.

SAGUACHE COUNTY.

IRON KING PROSPECT.

The Iron King prospect, owned by the Miller Mining & Milling Co., is in Saguache County, about 15 miles east of Moffat, on Cedar Creek, a small stream that flows westward to San Luis Valley. From the prospect to the valley, 3 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, the company shipped 10 tons of ore 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 developments disclose little ore. The property is opened by several short tunnels driven in the mountain side at altitudes ranging from 9,200 to 9,700 feet and by open cuts and trenches.

Quartzite, conglomerate, 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. Manganese minerals occur in several localities as replacement deposits 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 the manganese oxide occurs in narrow veins associated with fluorite and quartz. Some specimens show manganese oxides incrusted 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.

SAN MIGUEL COUNTY.

CLAIMS OF COLORADO MANGANESE MINING & SMELTING CO.

Location.—Deposits of manganese minerals occur in the western part of San Miguel County, in a basin at the head of a gulch that drains to Disappointment Creek near Cedar. The principal outcrops of manganese minerals have been included in a group of five claims owned by the Colorado Manganese Mining & Smelting Co., of Denver. The claims were located in 1914, and in 1915 several small lots of ore aggregating 120 tons were shipped to Chicago. No mining has been done on the property since 1915. Most of the develop-

ment work on the group is centered in the Black Diamond claim, from which the shipments were made, and consists of two tunnels 90 feet apart, driven on the outcrop of the bed. One tunnel is driven eastward 150 feet, and the other tunnel is connected to it by a drift or gallery 65 feet from its portal. About 250 feet of development work has been done.

The deposits are approximately 50 miles by wagon road from Placerville, a station on the Denver & Rio Grande Railroad. The road goes by way of Norwood, 18 miles from Placerville, and to that point it is in excellent condition, but beyond Norwood it is little traveled and in many places is steep and rocky. The road passes within half a mile of the mine, and the material was packed to the road by burros. It is at once apparent that unless more favorable transportation facilities are afforded the deposit can not be worked at a profit.

Surface features.—The deposits of manganese minerals occur in the rim rocks which mark the eastern and southern boundaries of a basin, and in steeply folded rocks in the northern part of the basin. The floor of the basin is about 6,400 feet in altitude, and the highest point on the eastern rim is about 7,100 feet. The western rim is much lower than the eastern, and in two places branches of a gulch have eroded channels through it and find outlet to Disappointment Creek. Within the basin there is a spring, but the nearest perennial stream is Disappointment Creek, 6 miles distant.

The climate is arid, but the rainfall is sufficient to support a growth of piñon and cedar.

Geology.—The rocks in the vicinity of the manganese deposits are all sedimentary and consist of gray, red, and brown sandstone, with interbedded red and green shale, which overlie fossiliferous limestone and shale exposed in the floor of the basin. A maximum thickness of about 800 feet of sediments is exposed in the eastern rim of the basin. A deposit of gravel 75 feet thick lies on a ridge northeast of the prospect. The series of rocks is known as the Dolores formation, which is of Upper Triassic age.

Structure.—The basin has been formed by the erosion of an anticline that plunges toward the southeast. On its eastern, southern, and western borders are the hard rim rocks of sandstone, which in places in the eastern rim form cliffs 50 feet high. The floor of the basin is underlain by softer shale, clay, and limestone. From the manganese prospect southwestward across the basin to the opposite sandstone rim the distance is approximately 1 mile. On the eastern rim at the prospect the rocks are flat or dip gently east. Southward from the prospect the dip gradually swings toward the southeast, and at the south end of the basin the beds dip 20° S. The average dip

of the beds in the western rim is about 25° W. At the north end of the basin the limestones and shales underlying the sandstones are compressed into a sharp fold, with dips of 60° to the northeast and southwest on either side of the axis.

Ore deposits.—Three types of manganese deposits are found here—(1) a thin-bedded deposit between sandstone and shale in the eastern rim of the basin, (2) small irregular lenses and nodules in a brown sandstone bed at the south end of the basin, and (3) small veins in the closely folded shales at the northwest end of the basin.

The bedded deposit is the only one of commercial importance, and from it the shipments were obtained. The bed is overlain by red clay and underlain by red sandstone. In the tunnels it dips about 10° E. or lies flat with local undulations. From the workings the bed can be traced southward for about 1,500 feet, but at no place other than that where the development work was done does it show evidence of yielding ore in commercial quantities.

As it comes from the mine the material is in rather soft lumps of finely granular pyrolusite, though cavities in it are lined with short, minute velvety crystals that are probably manganite. The best material is said to contain 80 per cent of MnO_2, corresponding to about 50 per cent of manganese. Calcite occurs in varying amounts in the deposit; small quantities of secondary origin are found in the thoroughly oxidized part of the bed near the portals of the tunnels, but it is increasingly abundant toward the faces of the tunnels, where it represents the unweathered part of the bed. The limit of rich oxides is reached about 100 feet from the portal. At the face, 150 feet from the portal, the bed, which is about 6 inches thick, is only partly decomposed and replaced by manganese oxides. Here the bed consists of coarsely crystalline calcite in shades that range from white to brown. In a specimen obtained from the face of the tunnel decomposition of the carbonate and replacement by manganese oxide have set in at the top of the bed and extend for 2 inches, yielding a brownish-black substance in which some of the crystal faces of the original carbonate are preserved. Below this decomposition band the calcite is spotted with minute brown needles of manganese oxides, and in a few places nests of manganite crystals are found. A film of manganese oxides is locally formed on the cleavage faces of the calcite. Some small calcite fragments which were apparently free from the brown specks were tested and found to yield a small quantity of manganese. Several hundred feet south of the main workings the bed contains barite and here and there stains of copper carbonate in addition to the manganese oxide, but the deposit is too thin and of too low grade to be valuable. Red and green chert nodules are also associated with the bed at this locality.

The deposit has been opened for about 100 feet along the outcrop, and the depth of commercial ore is approximately 100 feet. The thickness of the bed ranges from a few inches to 2 feet, with a probable average of 10 inches in the workings. In all, probably 2,000 tons of ore containing about 40 per cent of manganese could be obtained from the deposit. Of this quantity 50 tons would probably yield 50 per cent of manganese.

Origin.—The interbedding of the coarsely crystalline calcite and the manganese oxides suggests that the calcite is of sedimentary origin, but its coarsely crystalline texture would suggest vein filling. Although tests of apparently fresh calcite showed the presence of manganese, the quantity was very small and certainly not enough to account for the richer portions of the deposit. Manganese in solution, therefore, probably came from some unknown outside sources and replaced the calcite bed, proceeding from the top downward, as shown by the specimen obtained at the face of the main tunnel.

The manganese deposits of the replacement type are found at the south end of the basin, where they are exposed through a vertical distance of 20 feet, and for several hundred feet along a cliff exposure of brown sandstone. The deposits yield small irregular masses of manganese oxides, some of which lie along the bedding in tabular form and have a maximum length of 15 feet and thickness of 1½ feet, vertical tabular masses, chimneys, and boulder-like nodules of various sizes. The line between the ore bodies and unreplaced brown sandstone is sharply marked. The manganese oxides are principally manganite as needle-like crystals about a quarter of an inch long and as short prismatic crystals in granular aggregates. Pyrolusite is a minor constituent of the ore. The needle-like crystals were formed in the larger bodies, and barite crystals are commonly found in the centers of the masses. The smaller nodules represent incomplete replacement of the sandstone by manganese oxides, for they contain some unreplaced quartz grains. The manganite in these nodules is in short prismatic crystals which usually form cellular masses.

The evidence of the origin of these manganese oxide bodies is obscure, but the most feasible explanation appears to be that the manganese minerals in the form of oxide or carbonate were originally disseminated in the sandstone and through processes of concentration and replacement have attained their present forms. The nodules and masses of manganese ore are so sparsely distributed in the sandstone beds that it is very doubtful if they can be profitably mined, even under the most favorable conditions.

No manganese deposits have been found on the west side of the basin, although a vein composed principally of coarse-grained calcite

and barite with small amounts of copper carbonates and native copper occurs there.

At the north end of the basin manganese oxides occur in small fissures and veinlets which strike N. 75° W. and dip steeply north. The inclosing rocks are a grayish or faint purple limestone and underlying shale beds which strike N. 80° W. and dip 50° S. One vein whose maximum width is 8 inches was traced for 75 feet, but there is not enough material in sight to encourage exploitation of the deposit. The manganese oxides are pyrolusite and manganite, and they are associated with calcite and small amounts of barite.