DEPOSITS OF MANGANESE ORE IN MONTANA, UTAH, OREGON, AND WASHINGTON.

By J. T. Pardee.

DEPOSITS IN MONTANA.

HISTORY AND PRODUCTION.

One of the surprises of the war period was a large production of manganese ore in Montana. Although since 1870 the Butte and Philipsburg districts had produced large quantities of the ores of copper, silver, and other metals, the fact that large bodies of manganese ore formed part of the mineral deposits of these districts was not generally known and hardly suspected. In 1916 general attention was first directed to the manganiferous deposits by the shipment of rather large quantities of high-grade manganese oxide ore from Philipsburg. In 1917 the production in that district so greatly increased that Montana jumped far ahead of the other States producing manganese ore. In the same year a moderate amount of manganese oxide ore was mined from the lodes at Butte, and rather unsuccessful attempts were made to concentrate the large amount of highly siliceous manganiferous material they contain. Apparently because the carbonate of manganese was new to the ore trade the bodies of rhodochrosite at Butte, which are among the largest and most valuable sources of manganese in the country, were overlooked for several months after the mining of the oxide ores had begun. In 1918 a further great increase in output was made at Philipsburg, and Butte, having begun the mining of its rhodochrosite bodies, became, next to Philipsburg, the most productive district in the United States. Although manganese minerals are known in several other mining districts in Montana (see fig. 27), only a very small production has so far been made elsewhere than at Butte and Philipsburg.

Except a small shipment reported in 1900,[1] no manganese ore is known to have been mined as such in Montana prior to 1916. Ore shipments reported for the period 1916–1919 are as follows:

[1] U. S. Geol. Survey Mineral Resources, 1900, pp. 116, 123, 1901.

Manganese ore produced in Montana, 1916–1919, in gross tons.

	1916	1917	1918	1919	Total.
Philipsburg	6,380	58,427	127,415	23,112	215,334
Butte		2,544	72,381	3,650	78,575
Other districts		138	136		274
	6,380	61,109	199,932	26,762	294,183

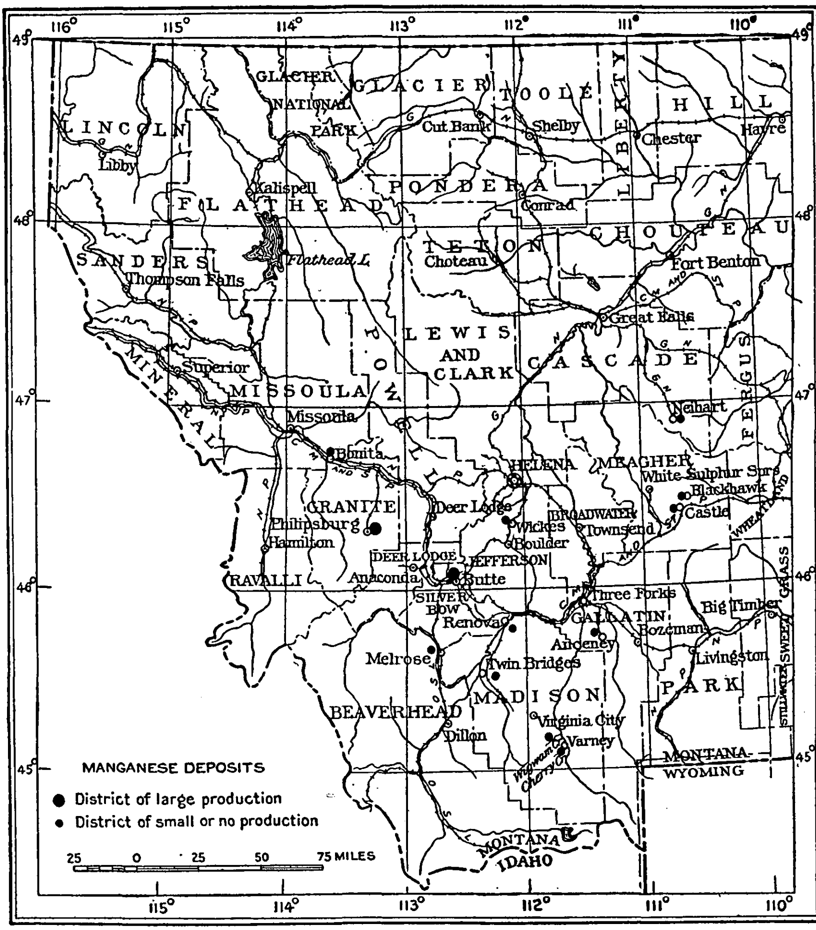


FIGURE 27.—Map showing location of manganiferous deposits in Montana.

Montana supplied during 1917 and 1918 nearly two-thirds of the total domestic production of manganese ore and nearly one-sixth of the amount of the domestic production and imports combined. Most of this product was smelted to ferromanganese for use in making steel. At the rate of 3 tons of ore to 1 ton of alloy all the ore produced in Montana would have yielded about 87,000 tons of alloy, or an amount sufficient to manufacture 15,000,000 tons of steel, just about one-sixth of the total amount made in the country during the years mentioned. In 1919 Montana produced nearly half of the total output in the United States.

The shipments reported from Butte and Philipsburg from 1917 to 1919, inclusive, were made up partly of concentrate derived from siliceous material carrying between 10 and 40 per cent of manganese. In 1918 about 10 per cent of the Butte product and 20 per cent of the Philipsburg product was concentrate; that from Philipsburg was derived from oxidized material and that from Butte partly from oxide and partly from carbonate material. In 1919 most of the material shipped was concentrate. No manganiferous iron ore or ferruginous manganese ore was reported to be produced in Montana, but material capable of being classified as manganiferous iron ore was mined near Renova [2] several years ago and used for flux at Butte. Manganiferous ore, in which the manganese was valuable only for its fluxing qualities, has been mined in several Montana districts, a large amount having been produced at Butte.[3]

RESERVES.

The conditions of the war period called for the prompt mining of all possible ore, and the uncertainty as to the future discouraged most operators in the development of any considerable reserves. Therefore, few of the deposits not yet mined can be measured on more than one or two faces. Estimates made in October, 1918, based upon fairly trustworthy information, show that the Philipsburg district contains a minimum reserve of 130,000 tons of manganese ore and a prospective additional reserve of 350,000 tons. In this district material that contains less than 30 per cent of manganese and is suitable for concentration is not particularly abundant, the amount being roughly estimated at 50,000 to 230,000 tons. At Butte a rather small amount of high-grade manganese oxide ore was estimated to be in reserve in 1917, and in addition about 400,000 tons of highly siliceous material that was possibly capable of concentration.[4] At that time the occurrence of mixed carbonate and silicate ores was pointed out and the probable existence of large amounts of these ores indicated.[5] Reports from the operators in 1918 show a minimum reserve of 125,000 tons of high-grade carbonate ore and an additional very large amount in prospect. In the other districts of the State the known reserves of manganese ore are small, but some of the deposits contain large amounts of manganiferous material. The total amount

[2] U. S. Geol. Survey Bull. 690, p. 142, 1918.
[3] Idem, p. 113.
[4] Idem, pp. 125–126.
[5] Idem, pp. 127–130.

of high-grade manganese ore, including the carbonate and oxide varieties, in Montana is at least 250,000 tons, or somewhat more than one-third of the total amount estimated for the country.[6] The writer believes that the expectation of finding very large additional amounts of carbonate ore is warranted. At Butte the workable bodies of rhodochrosite are known to extend at least 1,000 feet in depth, and only a small part of the zone in which they occur has been explored. At Philipsburg only the oxidized ores have been exploited. These give place at moderate depths to carbonate bodies of unknown but probably large size.

LITERATURE.

Until the war manganese ore had little or no value in Montana, a fact that probably explains why manganese receives but scanty consideration in the otherwise comprehensive metalliferous reports published before 1916. Since then some brief descriptions of the manganiferous deposits have appeared, and these, together with the earlier reports that give the most information, are listed below in the order of their publication.

Peters, E. D., jr., The mines and reduction works of Butte City, Mont.: U. S. Geol. Survey Mineral Resources, 1883–84, pp. 374–396, 1884. Describes manganese minerals in the oxidized parts of the Butte lodes.

Blake, W. B., The Rainbow lode: Am. Inst. Min. Eng. Trans., vol 16, pp. 65–80, 1887. Notes the extensive occurrence of rhodochrosite and rhodonite in one of the lodes at Butte.

Weed, W. H., and Pirsson, L. V., Geology of the Castle Mountain mining district, Mont.: U. S. Geol. Survey Bull. 139, 1896. Mention the occurrence of manganiferous ores in the Blackhawk and other mines.

Weed, W. H., Geology of the Little Belt Mountains, Montana: U. S. Geol. Survey Twentieth Ann. Rept., pt. 3, pp. 271–461, 1900. Describes the manganiferous carbonate gangue of the silver-lead ores at Neihart.

Harder, E. C., Manganese deposits of the United States: U. S. Geol. Survey Bull. 427, 1910. Describes a deposit of bog manganese ore near Wickes and discusses briefly the occurrence of manganiferous silver ores at Butte and Neihart. Mentions the occurrence of manganese oxides at Castle.

Weed, W. H., The geology and ore deposits of the Butte district, Mont.: U. S. Geol. Survey Prof. Paper 74, 1912. Notes the abundance and wide distribution of manganese carbonate and silicate in many of the lodes.

Emmons, W. H., and Calkins, F. C., Geology and ore deposits of the Philipsburg quadrangle, Mont.: U. S. Geol. Survey Prof. Paper 78, 1913. Discuss the occurrence and genesis of manganese minerals in the lodes of the Philipsburg district and mention the presence of a large amount of rhodochrosite in the Trout mine and of a large body of manganiferous ore in the Terrid (Coyle) mine.

Sales, R. H., Ore deposits at Butte: Am. Inst. Min. Eng. Trans., vol 46,, pp. 3–106, 1914. Discusses zonal arrangement of the different metals, including manganese.

[6] Harder, E. C., and Hewett, D. F., Recent studies of domestic manganese deposits: Am. Inst. Min. and Met. Eng. Trans., preliminary report, 48 pp., 1919.

Winchell, A. N., Mining districts of the Dillon quadrangle, Mont.: U. S. Geol. Survey Bull. 574, 1914. Mentions a deposit of manganese oxide ore near Twin Bridges and notes the occurrence of pyrolusite in several of the mining districts.

Umpleby, J. B., The manganese deposits of Philipsburg, Mont.: Min. and Sci. Press, vol. 115, p. 758, 1917. Describes the deposits briefly and gives an estimate of the amount of ore in reserve.

Pardee, J. T., Manganese at Butte, Mont.: U. S. Geol. Survey Bull. 690, pp. 111–130, 1918. Discusses the occurrence of manganese in the lodes and gives an estimate of the ore reserves.

Pardee, J. T., Some manganese deposits in Madison County, Mont.: U. S. Geol. Survey Bull. 690, pp. 131–143, 1918. Describes manganese ore found on Wigwam and Cherry creeks and manganiferous iron ore found near Renova and gives estimates of the amounts in reserve.

Harder, E. C., and Hewett, D. F., Recent studies of domestic manganese deposits: Am. Inst. Min. and Met. Eng. Trans., preliminary report, 48 pages, 1919. Discuss briefly the characteristics and occurrence of the manganiferous deposits and give tables of production and reserves.

FIELD WORK.

Field examinations in Montana were made by the United States Geological Survey in 1917 and 1918 for the purpose of estimating available domestic supplies of manganese and other so-called war minerals. In October, 1917, a brief examination of the Philipsburg district was made by J. B. Umpleby.[7] In August, 1917, the writer examined the Butte district and deposits on Wigwam and Cherry creeks and near Renova, and in the fall of 1918 he examined the Philipsburg district.

DISTRIBUTION AND GENERAL CHARACTERISTICS OF THE MANGANIFEROUS DEPOSITS.

Bodies of manganese ore and of manganiferous material that may be capable of beneficiation are found in several of the mining districts (fig. 27). Their distribution coincides in general with that of the ores of silver, lead, and zinc, but small amounts of manganese and manganiferous ores are found in some areas that have not produced the other metals. The great bulk of the manganese ore so far discovered is in the Philipsburg and Butte districts, outside of which the deposits are comparatively unimportant.

Most of the Montana deposits, including those at Philipsburg and Butte, are merely parts of the metalliferous quartz veins and may be classified under the general head of deposits formed by the replacement of country rock by carbonate and silicate minerals superficially oxidized. They contain more or less vein quartz and noteworthy amounts of silver, zinc, or lead, and show a large vertical range as compared with deposits of other types. The oxidized bodies

[7] Min. and Sci. Press, vol. 115, p. 758, 1917.

have a cavernous texture. These deposits are found in Tertiary and older rocks, but all are thought to be of Tertiary age. Since they came to place parts of them have been oxidized without noteworthy changes in their manganese content. Their origin must have been due to a body of intrusive rock, the presence of which is generally shown or indicated by the local geology.

Deposits formed by oxide minerals filling open spaces are found on Wigwam Creek, in Madison County, and at a few other places. They are small but yield ore of exceptionally good grade. They are characterized by a banded or layered structure and a dense texture. Presumably they were formed in Tertiary time, and the manganese was derived from the adjoining country rock by circulating waters.

PHILIPSBURG DISTRICT.

HISTORY OF MANGANESE MINING.

Until 1916 the Philipsburg district, which in 1917 and 1918 supplied about half of the manganese ore produced in the entire country, had not been generally thought of as a source of manganese. The reports previously published describing the district mention the occurrence of manganese minerals but give no adequate idea of their abundance. Since 1865 Philipsburg has been known as a silver-mining camp, and about 1890 it ranked as the most productive silver district in the country. For several years after the decline in the value of silver in 1892 mining was at a low ebb, and many of the mines, notably the Algonquin, that have since produced manganese ore, were abandoned for long periods, during which their workings became more or less damaged. Some, among which are the Trout and Coyle mines, were operated intermittently and kept partly in repair. The two largest silver mines in the district, the Granite-Bimetallic and Hope, are just outside the area of productive manganese deposits.

The first recorded attempt to market manganese ore from Montana as such was a small and presumably unprofitable shipment made to Chicago from the Coyle mine in 1900. In 1916, as a result of a general increase in the price of manganese ore, mining in the Sharktown, Algonquin, and a few other deposits was begun, and by the end of the year a total of about 6,000 tons had been shipped. This rather large production drew general attention to the district. In 1917 mining activity greatly increased, and several operators new to the district acquired mining properties, among them a representative of the Cambria Steel Co. In 1918 the Philipsburg Mining Co. completed and put in operation a large mill designed to concentrate the lower grades of ore with jigs and tables, and the Beaver

Creek Mining Co. built a smaller plant to operate on the principle of magnetic separation. Although hindered at times by labor troubles, production increased rapidly until the break in the market that followed the signing of the armistice. However, partly because some contracts had not expired and partly because the manufacturers of dry-cell batteries and chemicals were beginning to use the Philipsburg ore, several mines were able to continue work on a reduced scale.

PRODUCTION.

The total shipments of manganese ore from the Philipsburg district reported to December 31, 1919, are as follows:

Ore and concentrate containing 35 per cent or more of manganese shipped from the Philipsburg district.

Year.	Gross tons.	Reported value at mine.	Value per ton.
1900	137	$514	$3.75
1916	6,380	37,642	5.90
1917	58,427	1,718,922	29.42
1918	127,415	2,947,109	23.13
1919	23,112	....	....
	215,471	4,704,187	....

The decrease in the value per ton in 1918 was due to the lower average grade of the material shipped. In 1919 the reported price at the mines for ore suitable for dry cells was between $40 and $50 a ton.

RESERVES.

Owing to the conditions that prevailed during the war period, only a moderate amount of ore was at any time blocked out in advance of mining. The exploratory work done prior to November, 1918, was sufficient, however, to make reasonably certain the existence of a minimum reserve of 130,000 tons of oxide ore, with an additional possible reserve of 350,000 tons. These estimates represent the ore bodies confined to the oxidized zone, which extends from the surface to a depth ranging from 100 to 200 feet. At greater depths manganese carbonate is the prevailing variety of ore, and although these lower parts of the deposits have been only slightly explored, there is reason to think that they are extensive and capable of yielding a large quantity of ore. Material that contains less than 25 per cent of manganese but is suitable for concentration is moderately plentiful in the district. Estimates made in October, 1918, of the amount of such material in reserve range from a minimum of 56,000 tons to a maximum of 230,000 tons.

FUTURE OF MANGANESE MINING.

The Philipsburg district possesses several advantages that partly overcome its handicap of great distance from the principal consuming centers. Perhaps the most potent of these is the fact that the ores are suitable or may be readily made suitable for the manufacture of dry-cell batteries. The price of ore that can be used for this purpose is commonly two or three times as large as the price paid for ore of ordinary grades, and the annual consumption of such material, which is increasing because of the demand for dry cells for automobiles, is estimated at 25,000 to 50,000 tons. Other advantages are the presence of adequate facilities in the district for milling the crude ore and at Great Falls for smelting ferromanganese; the close association of the manganese deposits with bodies of silver ore, the exploration of one tending to develop the other; and the large size of the deposits, which permits them to be easily mined. Therefore, despite changes in the manganese market after the armistice was signed, which caused most of the other districts to shut down completely, manganese mining at Philipsburg was able to continue and appears for the present at least to have become firmly established.

GEOGRAPHY.

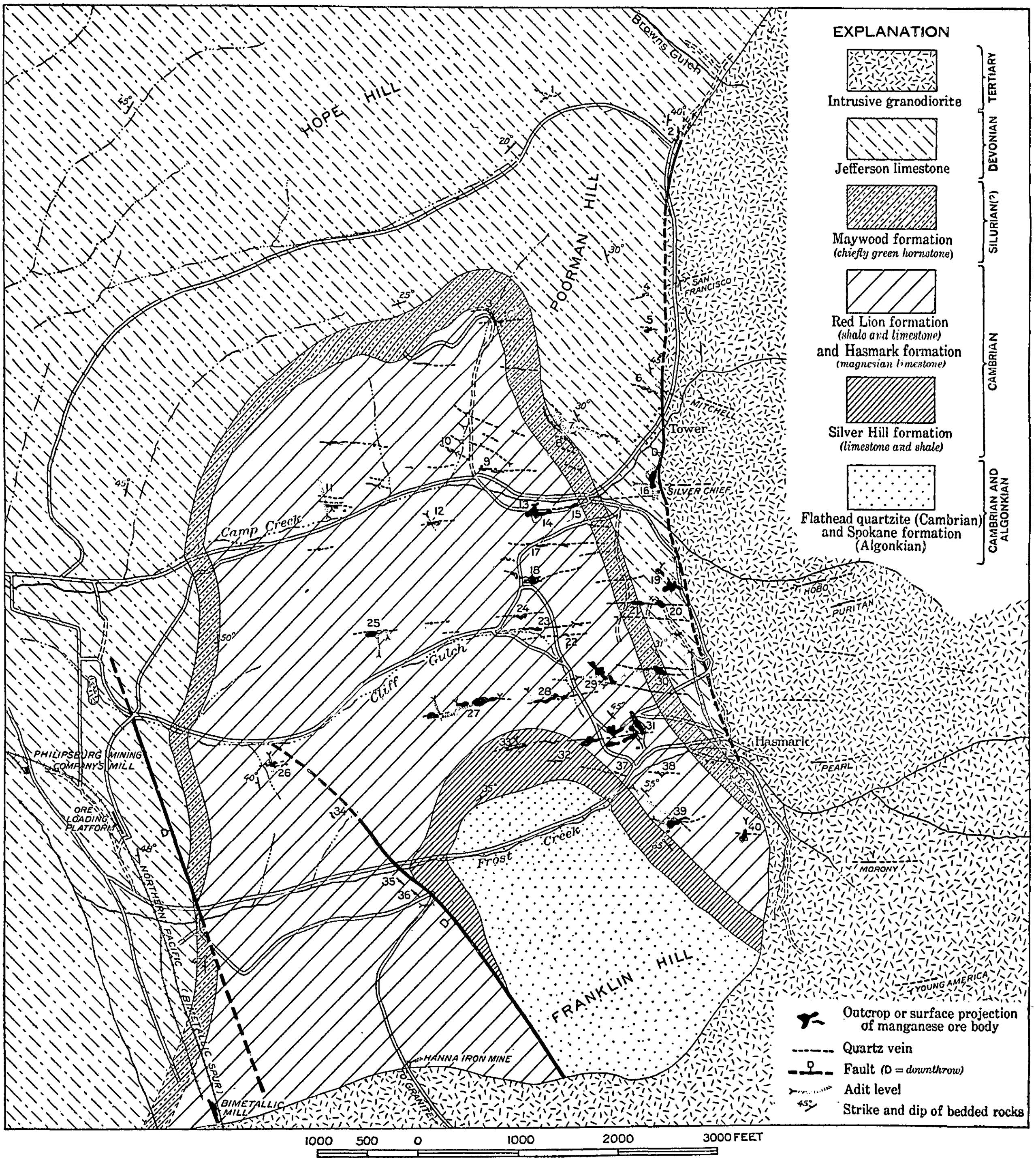
The geography of the Philipsburg district and of neighboring areas is described in detail by Calkins.[8] Philipsburg, which is about 50 miles northwest of Butte, is built along the eastern edge of Philipsburg Valley, at the foot of the Flint Creek Range. The mining district is on the west slope of this range, and many of the deposits are within an area 2 miles square (Pl. VII) that lies just east of the town. Most of this area is drained by Camp Creek and Frost Creek, small streams that emerge from the mountains at Philipsburg. Tower, on Camp Creek, and Hasmark, on Frost Creek, are small mining settlements in the eastern part of this area. The altitude of Philipsburg is about 5,200 feet; Tower and Hasmark are, respectively, 700 and 800 feet higher. The local relief ranges from 200 to 1,000 feet. The distance by road from the deposits of manganese ore to loading platforms on the Northern Pacific Railway at Philipsburg ranges from 1 to 3 miles.

GEOLOGY.

STRATIGRAPHY.

Most of the western two-thirds of the district is underlain by Paleozoic sedimentary rocks; the remainder is occupied by granodiorite of probable Tertiary age. The sedimentary rocks consist

[8] Emmons, W. H., and Calkins, F. C., U. S. Geol. Survey Prof. Paper 78, pp. 19–23, 1913.



MAP OF PHILIPSBURG MINING DISTRICT, MONT.

chiefly of marbleized limestone, with moderate amounts of quartzite and rocks that are composed largely of garnet and other silicates. Their sequence and principal characteristics are as follows:

Sedimentary rocks in part of the Philipsburg mining district.[a]

Age.	Formation.	Thickness (feet.)	Characteristics.	
			Philipsburg quadrangle in in general.	Philipsburg district.
Devonian.	Jefferson limestone.	1,000±	Pale-gray to dull-black, thick-bedded, somewhat magnesian limestone, locally flaggy near base.	Near the granodiorite contact a medium-grained blue-gray to cream-white marble.
Silurian(?).	Maywood formation.	250±	Thin-bedded gray and light-green to purple or red magnesian limestones and calcareous shale, commonly stained yellow. Some calcareous sandstone near the base.	Chiefly green hornstone.
Cambrian.	Red Lion formation.	280	Chiefly limestone with wavy siliceous laminae. Black to olive-green shale at base.	Partly green to brown hornstone and garnet rock.
	Hasmark formation.	1,000	Chiefly magnesian limestone, with dark shale of variable thickness near the middle. Limestone above the shale mostly cream-white; that below mostly blue-gray.	Almost everywhere a medium-grained cream-white marble. The shale appears to be absent.
	Silver Hill formation.	100-600	Banded green and brown calcareous shale, interbedded with gray limestone having thin siliceous laminae.	An irregular, commonly coarse-textured rock made up chiefly of brown garnet and other complex silicates. Locally rich in magnetite.
	Flathead quartzite.	0-200	Thick-bedded vitreous white to pale-gray quartzite.	Mostly brownish-gray quartzite.
Algonkian.	Spokane formation.	9,000±	Shale and sandstone, prevailingly red.	Mostly reddish-gray quartzite showing pale-gray spots.

[a] From columnar section in U. S. Geol. Survey Geol. Atlas, Philipsburg folio (No. 196).

The limestones occupy much the larger part of the sedimentary area (Pl. VII), the quartzites being confined to the relatively small patch on Franklin Hill and the silicate rocks to two rather narrow bands. The granodiorite exposed within the district is part of the Philipsburg batholith,[9] a large mass of intrusive origin. The contact between this mass and the sedimentary rocks trends south, parallel to the bedding, and passes through Tower and Hasmark to Franklin Hill, where it turns west and cuts across the bedding. A small outlying body of granodiorite is exposed in the lower course of Cliff Gulch.

Contact metamorphism is illustrated by changes of limestone to marble and shale to hornstone and garnet rock over much of the area.

[9] U. S. Geol. Survey Prof. Paper 78, pp. 97-101, 1913.

STRUCTURE.

The sedimentary rocks are bent into a rather broad and symmetrical arch, named the Philipsburg anticline,[10] that trends northward, its axis passing through Franklin and Hope hills. This fold pitches 20°–35° N., and the dips on its limbs generally do not vary far from 45°, but locally its east limb is inclined as much as 65°. It causes the outcropping bands of the different formations to take the forms of loops that open southward (Pl. VII).

Many eastward-trending fractures cut the sedimentary rocks and the granodiorite, but apparently they have caused no considerable displacement. They contain the quartz veins with which the manganese deposits are associated. From Hasmark north the contact plane between the granodiorite and the sedimentary rocks is a fault that dips about 45° E., toward the granodiorite. It cuts the veins and displaces them in the same way as a normal fault, or one whose hanging wall had fallen. Thus the True Fissure vein, which dips steeply south, is cut off by the contact fault, beyond which it presumably continues as the Silver Chief vein. If so, it has been displaced 50 feet or more to the north. However, it is difficult to conceive of the granodiorite as originally lying above the sedimentary rocks, in the position which it must have occupied for a mile or more if the fault is normal. Before such a fault could bring the rocks to their present relative positions a thick horizontal flange or sheet of granodiorite must have projected westward into the sedimentary rocks, a condition not supported by the field evidence. Therefore, the fault is regarded as a reverse fault in which the hanging wall moved obliquely upward and northward. This idea is supported by the facts that the rocks along the fault plane are extensively crushed and that, as shown in the True Fissure mine (p. 170), the movement included thrusting along a nearly horizontal plane that branches from the main fracture.

PHYSIOGRAPHY.

For some distance north of Philipsburg the valley is bordered by a moderately prominent terrace, across which gulches and small valleys have been eroded by the streams that emerge from the mountains. The town is built partly in a small valley of this kind that was excavated by Camp Creek and partly on the adjoining parts of the terrace. At the east edge of the town the terrace gives place to foothills, which are composed chiefly of sedimentary rocks and are succeeded at Tower and Hasmark by the main mountain slope, composed of granodiorite. The foothills are moderately smoothed and rounded, especially those formed of marbelized Hasmark lime-

[10] Idem, p. 173.

stone, which readily weathers to a carbonate sand. The granite area is characterized by rather steep slopes that are cluttered with large boulders or spheroidal masses produced by weathering. Where the valleys of Camp and Frost creeks cross the boundary between the granodiorite and the sedimentary rocks they are wider than elsewhere, and in general to the north of Hasmark the contact is marked by valleys and low saddles that apparently were formed because the rocks adjoining the contact fault were crushed and therefore made easily erodible. To a considerable depth the manganese ore bodies are completely oxidized (p. 155), a condition to be explained in part by the fact that they were uncovered by erosion in Tertiary time and have since remained exposed to the weather, while the surface has been lowered very slowly if at all. These conclusions are supported by the physiography, as is set forth below.

The terrace that borders the foothills is composed of late Tertiary sediments[11] that accumulated because the drainage of the Philipsburg Valley did not then have as low an outlet as at present. The surface of the terrace therefore marks a level below which the side valleys could not be developed at that time. Later, in Pleistocene time, the drainage outlet was lowered, and the streams—Camp Creek, for example—cut new valleys across the terrace and began to deepen their old valleys to correspond. Compared to the older erosion, however, this Pleistocene erosion seems to have been insignificant. It is measured by a lowering of the bed of Camp Creek that ranges from a maximum of perhaps 150 feet to practically nothing. As Camp Creek has not yet lowered the rest of its old valley to an adjustment with the present drainage level, its lower course is steeper than the upper course. Cliff Gulch (Pl. VII) is a short valley comparable in size with the neighboring valleys of Camp and Frost creeks. It is noteworthy because it emerges from the hills at the level of the terrace, its stream, unlike those of its neighboring valleys, having been unable to cut a trench across the terrace. Evidently this valley is older than the terrace, and its form has been modified little if any since the terrace was built, and therefore the Little Gem and other manganiferous bodies it exposes have been subject to weathering during most if not all of Pleistocene time.

MANGANESE ORE.

OCCURRENCE AND CHARACTERISTICS.

In the Philipsburg district, the ore deposits of which are described by Emmons,[12] manganese is a constituent of silver-bearing quartz lodes that cut the granodiorite and the limestones and limy

[11] U. S. Geol. Survey Prof. Paper 78, pp. 133–137, 1913.
[12] Emmons, W. H., U. S. Geol. Survey Prof. Paper 78, pp. 163–220, 1913.

shales adjoining it but not the quartzite. Most of the lodes are rather narrow but persistent tabular bodies that trend eastward and dip steeply south. Those in the granodiorite have filled open fissures and are generally very regular in form. Those in the limestone were formed largely by replacement of the wall rock and are therefore more or less irregular. Though noteworthy amounts of manganese are found in practically all the mines, the workable deposits of manganese, so far as known, are confined to the lodes in the limestones and limy shales, and most of them are within an area of less than a square mile that joins the granodiorite at Tower and Hasmark.

The workings indicate that the vertical range of the manganiferous bodies is about 650 feet, but the lower limits of the ore-bearing zone have not yet been found. However, as shown by development work in the neighboring Granite-Bimetallic lode, manganese minerals persist more than 600 feet below the level of the deepest workings in the manganiferous area. The present surface cuts off the quartz veins and some of the podlike bodies of the manganese ore, both of which were evidently of a greater vertical extent at a former time. As shown by the local relief, some of the lodes have been reduced by erosion as much as 300 feet. This is a minimum, and the maximum is doubtless much greater.

Manganese, zinc, and lead are plentiful in a central area or zone, outside of which they are scarce. Copper, which is practically absent from the central zone, is moderately plentiful in the outer zone, especially along the west. Silver is plentiful in both zones.

In the manganiferous area the quartz veins are accompanied and partly enveloped by numerous bodies of manganese ore whose outlines commonly suggest such forms as pipes or seed pods (figs. 28–30). A few, including those that occur in the shaly formations, are tabular. As a rule the boundaries of these bodies are sharply defined, gradational changes from ore to country rock being uncommon. Most of them are steeply inclined; some are truncated by the surface, and others end below it.

The form of these bodies is typical of replacement, and the material they contain shows no general banding or other structural features characteristic of deposition in open spaces. In the Hasmark and Jefferson limestones replacement by the original manganiferous carbonate was complete except for the quartz and clay present. In the Maywood and other formations made up of alternating layers of limestone and shale or its metamorphic equivalents the limestone layers were selected for replacement, and the deposits therefore assumed a tabular form, as illustrated by the Headlight ore body (pp. 170–172).

When the ore bodies were oxidized the newly formed oxides of manganese locally replaced a little of the vein quartz, as shown by specimens from the Sweet Home deposit, west of the Marie. The bodies so far developed consist almost wholly of oxide ore. This material is characteristically cellular or cavernous, a feature that is significant of its derivation from a carbonate, as explained on page 156. Commonly these bodies are aggregates of nodules or spheroids that range in size from that of an egg to that of a coconut or larger. In some places they show an irregular texture somewhat like that of a sponge, and in others the material composing them is loose and friable and apparently structureless.

MINERALOGY.

Much of the oxide ore is a rather indefinite mixture whose softness and other characteristics indicate that its chief constituent is pyrolusite, and in general that mineral appears to be the predominating manganese oxide. Psilomelane is next in order of abundance, and the two are roughly estimated to compose 90 per cent of the manganiferous material present. The remainder is chiefly manganite and wad, with a little braunite and one or more soft oxides of undetermined mineral species. The gangue is chiefly quartz, with more or less kaolin and a little calcite and iron oxides.

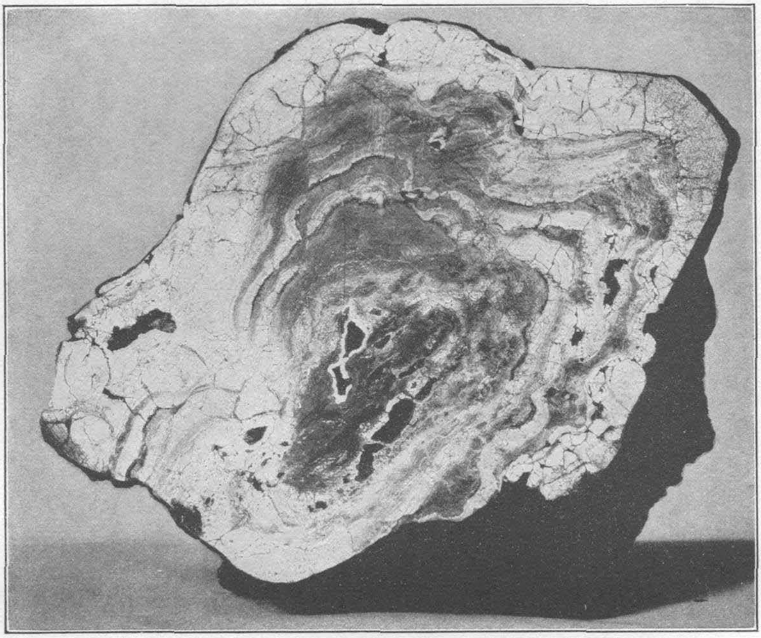
Pyrolusite generally occurs in finely granular masses and as small free crystals that line open spaces. Psilomelane is the principal constituent of many of the nodules, in which it forms layers that alternate with softer oxides (Pl. VIII). Manganite forms radial aggregates and small free crystals of a prismatic habit. The braunite shows rhombohedral cleavages. Wad is common on surfaces and in cavities as a brown powder deposited on the other minerals. In a nodule from the Bryant mine (Pl. VIII, *A*) its mode of occurrence suggests it to be an alteration product of psilomelane. An undetermined oxide found locally in the Bryant mine consists of long silky fibers; another occurring in cavities is an aggregate of fine scales that show a greasy luster like that of stove polish. Usually the parts of the tabular quartz veins that are enveloped by the manganiferous bodies are more or less broken, and their fragments are mixed with the manganese ore. In addition grains, threads, and veinlets of quartz are generally found throughout the manganiferous bodies. Kaolin with a little quartz and iron oxides forms a soft clayey material that partly fills the cavernous spaces. Calcite is not abundant. It occurs locally intergrown with manganese oxides and other minerals in the cavities.

The unoxidized ore is chiefly a dense aggregate of rhodochrosite with more or less quartz and a little pyrite or other sulphides. Specimens from the Trout mine range from pink and coarse grained to pale yellow and fine textured and contain noteworthy amounts of magnesia. Fine grains of pyrite and locally zinc blende and galena are thinly scattered through the carbonate. Specimens from the Scratch Awl mine show rhodochrosite, quartz, and sulphides of one generation cut by the same minerals of a later generation.

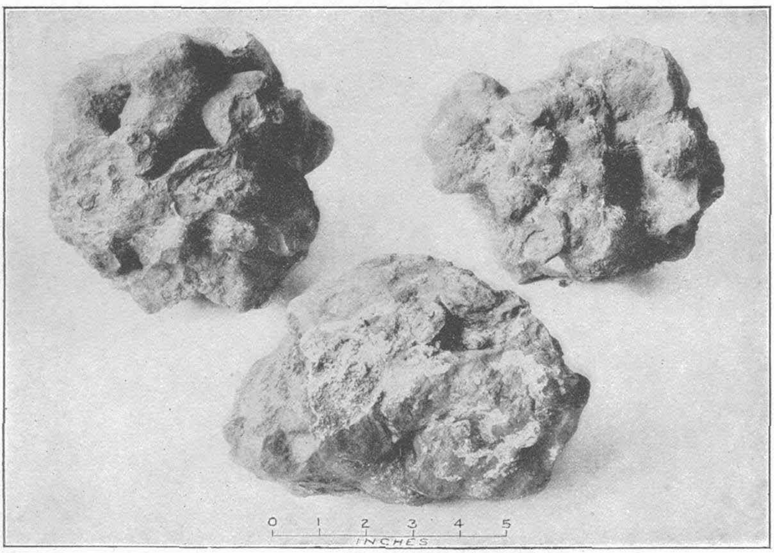
If the whole district is considered, the bulk of the lode matter is quartz, but in the area of productive manganese deposits the manganese minerals exceed all other constituents of the lodes combined. Generally the manganese minerals and quartz together compose more than 90 per cent of the lode matter, the remainder consisting chiefly of calcite, kaolin, and iron, lead, and zinc minerals. Silver, the most valuable product of the district, forms but a very small part of the lodes.

COMPOSITION.

Car samples of most of the ore shipped in 1917 and 1918 show a general average of about 43 per cent of manganese, 17.5 per cent of silica, and less than 2 per cent of iron. Phosphorus is low. The range in composition, which is due partly to differences in the methods or skill employed in mining, amounts to as much as 10 per cent for manganese and silica, but most of the ore as mined for shipment does not vary greatly from the average given. Less care is necessary in mining ore that is to be concentrated before shipping. Ore from the Bryant, Horton, and other mines intended for treatment at the Philipsburg Mining Co.'s mill generally contains from 32 to 38 per cent of manganese and 20 to 25 per cent of silica. As this ore is mined without much selection, its analyses more nearly represent the average composition of the ore bodies than the analyses of the crude ore selected for shipment. Analyses of a few samples representing the general run of ore from the district show from 1 to 3 per cent of iron, very little phosphorus, about 2 per cent of alumina (Al_2O_3), and no lime (CaO), magnesia (MgO), or baryta (BaO). Ore that contains many fragments from the main quartz veins is commonly rich in silver, but the general run of the manganese ore contains not more than 1 or 2 ounces of silver and a few cents in gold to the ton. Small amounts of lead and zinc are found in some of the ore, but copper is practically absent. Owing to its porous texture, the ore absorbs considerable water, and most of it shipped under ordinary conditions contains 8 or 10 per cent of moisture. Concentrate made in 1918 from the oxide ores carried from 48 to 50 per cent of manganese and 12 per cent or less of silica. Milling also eliminates some of the iron and alumina. In general, the oxide ore contains at least 50 per cent of manganese oxide (MnO_2), and much of it can be selected to carry more.



A. SECTION OF MANGANESE NODULE FROM BRYANT MINE, PHILIPSBURG DISTRICT, MONT.



B. MANGANESE NODULES FROM BRYANT MINE, PHILIPSBURG DISTRICT, MONT.

OXIDATION.

In the Trout, Scratch Awl, and a few other mines manganese carbonate is found in places not far below the surface. Most of the manganiferous bodies, however, are completely oxidized as far as they have been explored, and in general oxidation appears to be complete to a depth of at least 150 feet. In the Algonquin mine a drift from the old shaft exposes a body of oxidized ore 200 feet below the adjacent valley of Frost Creek. This rather great extent of the oxidation is due to the slow development of the present surface, as described on page 151, and the free circulation of underground waters explained on page 156.

In the deeper mines the oxide ore is observed to change into carbonate ore, and the general similarity of the oxide bodies of all the mines indicates that rhodochrosite was everywhere their parent mineral. Specimens from the Trout mine show a progressive change from dense carbonate ore to porous oxide ore without any noteworthy migration of the manganese. The framework of the spongy-textured ore is commonly an irregular lattice that represents filled cracks in the original dense ore. Oxidation began along cracks, and as it progressed outward the manganese was transported toward the cracks and deposited in layers. As the carbonate was dissolved and its manganese carried away, clay and quartz were left behind as residual matter, partly filling the open spaces. Commonly the nodules that compose parts of the ore bodies are distributed as if they also had been formed along cracks. Each nodule contains one or more centers or nuclei around which the layers of oxides are arranged (Pl. VIII, *A*). The nodules apparently grew about centers distributed along cracks in the original ore. There was a short migration of the manganese and a net loss in volume, represented mostly by the spaces between the nodules, in which most of the residual clay and quartz remain. Thus the change from carbonate to oxide was accomplished without any noteworthy change in position of the bulk of the manganese. That a small amount of manganese has migrated is shown by thin streaks or stringers of manganese oxide that lead off from the main ore bodies for considerable distances into the walls. These veinlets are generally close textured and were therefore probably formed by material carried out in solution from the main bodies and deposited as oxide. If they had been originally filled with carbonate and afterward oxidized in place they should be cavernous like the main bodies themselves. Adjacent to some of the ore bodies irregular streaks and zones in the limestone show a brown discoloration, which on close examination proves to be caused by brownish-black particles of a manganese oxide that is thought to have been carried out from bodies during ovidation.

The cavernous texture of the oxide bodies is significant of their alteration from manganiferous carbonate and expresses the reduction in volume due to the loss of carbon dioxide (CO_2) and magnesia (MgO) and the increased density of individual particles of the final product. As estimated from rough measurements of some of the ore bodies compared with the amount of materials mined from them, the cells, cavities, and other unfilled spaces occupy more than half of the total volume. In general, the bodies contain about 1 ton of material to 20 cubic feet. If they were packed with dense oxide material, each 20 cubic feet would contain from 2 to 3 tons. The condition described agrees very closely with what would be expected as the result of the oxidation of a carbonate ore like that in the Trout mine, described on page 162. The theoretical reduction in volume due to the loss of carbon dioxide and change of density amounts to about 44 per cent. For the Trout ore 10 per cent or more should be added to this for the loss of magnesia.

Most of the mine workings, including some that extend below the levels of Camp and Frost creeks, are dry. Rather curiously, water stands in the Algonquin shaft about 50 feet below the level of Frost Creek and at least 150 feet above the lower limit of the oxidized ore. In the True Fissure mine water that issues from the granodiorite sinks after it is led into the limestone by a drift 100 feet below the surface. These conditions are the result of generally unhindered circulation of ground water in the limestones and a free outlet that is probably represented by springs in Philipsburg Valley, 700 or 800 feet lower than Hasmark or Tower.

ORIGIN.

The lodes of the Philipsburg district, of which the manganiferous bodies are integral parts, are regarded as emanations from a deep-seated intrusive body that is probably a part of the Philipsburg granodiorite batholith itself. In both the limestones and the granodiorite the tabular parts of the lodes as distinguished from the podlike bodies are composed largely of quartz, with more or less manganese and other minerals, which in the unoxidized zone consist of rhodochrosite and sulphides. This aggregate of minerals is cut by veinlets of rhodochrosite with small amounts of sulphides and quartz. As pointed out by Emmons,[13] this fact shows that after the veins had been filled with quartzose material they were fractured and reopened and received from below a new accession of material that was predominantly manganiferous. The podlike bodies, which consist mainly of rhodochrosite or minerals derived from it, though found only in the limestones or limy shales, are very near the grano-

[13] Emmons, W. H., U. S. Geol. Survey Prof. Paper 78, pp. 178–179, 1913.

diorite contact. It is therefore concluded that the podlike bodies are of the same origin as the second generation of material in the tabular parts of the lodes and probably represent a continuing phase of the deposition of that material. During this phase a great volume of manganiferous matter ascended. It soon filled and sealed all available cracks or open spaces in the quartz veins and, being unable to find any other channels in the granodiorite, was forced to turn wholly aside into the comparatively open permeable and replaceable limestone. Thus the source of the manganese appears to have been moderately deep and within the granodiorite.

The limestones are magnesian and probably to be regarded as a source of the magnesia in the rhodochrosite that replaced them. Available specimens of the rhodochrosite, however, contain rather more magnesia than the limestones generally, a condition that suggests the introduction of some of the magnesia from an outside source, presumably the granodiorite.

MINES AND PROSPECTS.

The deposits described in the following pages are typical and illustrative of the Philipsburg district. Several mines not described for lack of sufficient detailed information are equally worthy. Of these the Horseshoe and Myrtle Fraction, operated by the Beaver Creek Mining Co., and the Chicago, operated by Danaher & Byrne, have produced rather large amounts of manganese ore. Smaller though noteworthy outputs have been made by the Imperial Millsite, Midnight, Two Percent, True, and a few other mines. Several claims from which no shipments have been made contain promising outcrops and prospective ore reserves of considerable size.

ALGONQUIN.

The Algonquin mine, on the north bank of Frost Creek just below Hasmark, was worked from 1878 to 1882 for silver. During that period a shaft was sunk 250 feet, from which drifts aggregating several hundred feet were turned at different levels. Along the hillside just back of the shaft the grading of a road uncovered the lode for a considerable distance and exposed a large body of manganese oxide ore. From 1882 to 1916 the mine was closed, and long before the end of that period the underground workings had become ruined and inaccessible. However, the body of manganese ore along the old road remained in view and was therefore one of the first deposits in the district to be worked when a demand for manganese was created by the war. In 1916 the Philipsburg Mining Co., the present owner, began mining manganese ore from this body, and in 1917 and 1918 it developed several other productive bodies along the same lode.

In 1918 the company built a mill near Philipsburg to concentrate the lower grades of ore from the Algonquin and other mines it was operating and thus permit a greatly increased rate of ore production. Immediately after the armistice was signed operations were curtailed, but production at a moderate rate was continued.

During the years 1916 to 1918, inclusive, the Algonquin mine produced about 55,000 tons of manganese ore. Part of this was marketed as it came from the mine, and part was beneficiated at the company's mill before shipment. The total amount of crude ore and concentrate marketed was between 30,000 and 40,000 tons, practically all of which was shipped to the East to be used in making steel.

The workings through which the manganese ore was developed and removed consist of a large open cut or pit made in the ore body exposed along the road back of the old shaft, adits that extend from the pit, and a new shaft adjacent to it on the southwest. The pit was excavated by benching to a level near that of Frost Creek. It extends into the hill north of the stream about 300 feet, averages about 50 feet in width, and is 75 feet deep at the back. Along the east wall 50 feet above the floor the ruined collar of the old shaft appears. The main adit is a drift at the level of the pit floor that extends westward 500 feet along the lode. Crosscuts, raises, and other workings connected with it aggregate 1,000 or 1,200 feet. In October, 1918, the new shaft had attained a depth of 100 feet, and short drifts east and west had been turned from it at this level. Its collar is about 50 feet lower than that of the old shaft.

The country rock is the lower magnesian limestone of the Cambrian Hasmark formation. The beds are upturned along the east limb of the Philipsburg anticline, so that they strike N. 15°–20° W. and dip about 45° E. At the northeast end of the pit the rocks are crushed along a zone that strikes about N. 35° W. Probably some faulting has occurred along this zone, but the amount of displacement is not shown. At the Bryant mine, about half a mile farther along on the same course, there is a similar crushed zone, but whether it is a continuation of that at the Algonquin was not ascertained. Joints and small fault or slip planes are moderately abundant in the limestone as exposed by the Algonquin workings.

The lode consists of a narrow but persistent and well-defined quartz vein and several large bodies of manganese ore that are attached to it. The quartz vein is a tabular body that strikes about S. 85° W., dips 75°–80° S., and ranges from a few inches to several feet in width but is generally not more than a foot or two. West of the old shaft it crops out at intervals for 700 or 800 feet, and its continuity underground for at least 500 feet is shown by the development workings. The vein exposed in the West Algonquin workings, about 1,200 feet from the old Algonquin shaft, is probably a continuation of that in the Algonquin. East of the old shaft there are no surface exposures, but according to a statement attributed to Harvey Showers, who was foreman during the early development of the Algonquin mine, the lode continues eastward at least 140 feet on the 250-foot level.

The manganiferous bodies are irregular in detail, but their general forms are somewhat like cylinders, pipes, or pods (fig. 28). Most of them envelop parts of the vein from which they extend out-

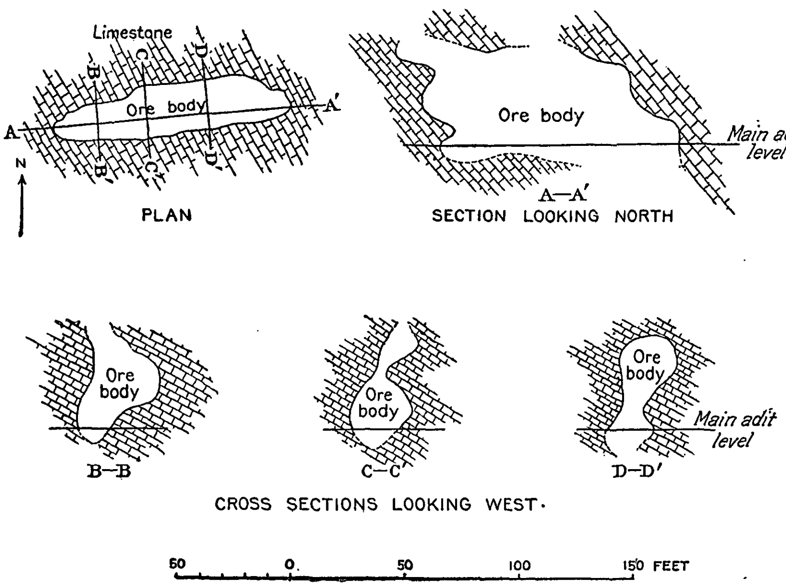


FIGURE 28.—Plan and sections of manganese ore body at Algonquin mine, Philipsburg district, Mont.

ward and upward, and collectively they greatly exceed the quartz vein in volume. The body mined through the pit is from 30 to 50 feet wide, 150 feet long, and at least 60 feet in pitch length, its lower limit not being shown. The original upper limit was higher than the present surface. It extends from the vein northward into the footwall parallel to the bedding, which dips 45° E.

West of the pit four other bodies are explored by the main adit and its branches. Three of these are chiefly in the hanging wall and one in the footwall. One, which begins near the portal of the adit (fig. 28), extends from the vein 100 feet southeastward and slightly upward into the hanging wall. It is about 20 feet wide and extends 8 to 12 feet above the floor of the adit but ends below the surface. The other bodies are incompletely developed but are comparable in size with those described. They extend undetermined distances below the drift level, and some of them may be coextensive with bodies penetrated by drifts 100 feet lower from the new shaft.

Oxidation is complete on the 100-foot level so far as the bodies have been explored. The 250-foot level east from the old shaft, equivalent to a 200-foot level from the new shaft, is reported to have cut at one place a body of manganese oxides 6 feet wide and at another a body of manganese carbonate 10 feet or more wide. Water level is met in the new shaft at a depth of 50 feet, or considerably below the level of Frost Creek.

The bodies of oxide ore are cavernous throughout. Unfilled spaces, most of which are the size of a walnut or smaller, commonly occupy half or more of the total volume. In places the bodies are made up of nodules that range from small pebbles to boulders a foot or more in diameter and that may be either loosely aggregated or tightly grown together. In places the bodies show a coarse spongelike porosity (Pl. IX, *A*). In general the spaces are partly filled with a loose clayey material consisting chiefly of kaolin and quartz lightly stained with iron oxides.

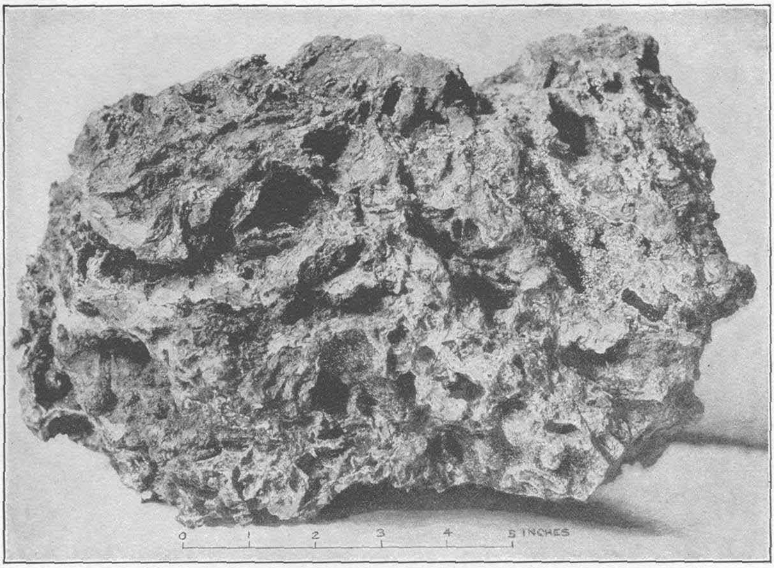
Some of the ore appears to be an indefinite mixture of oxides, but the bulk of it consists of pyrolusite and psilomelane, commonly arranged in thin but distinct alternating layers. Small free crystals of pyrolusite and a little wad are found in many of the cavities. Fragmentary streaks and veinlets of quartz are embedded in the manganese oxides, and films of chalcedony coat some of the surfaces. The main quartz vein, which in places contains noteworthy amounts of silver, zinc, and lead, is more or less broken and recemented with the manganiferous material.

Parts of the oxidized bodies described are selectively mined to yield ore containing from 40 to 45 per cent of manganese and 16 per cent or less of silica. Most of the mine product, however, carries from 30 to 40 per cent of manganese and 20 per cent or more of silica. This material is milled to a concentrate carrying about 48 per cent of manganese and 13 per cent or less of silica. Both the crude ore and the concentrate are said to contain about 1.5 per cent of iron and very little phosphorus.

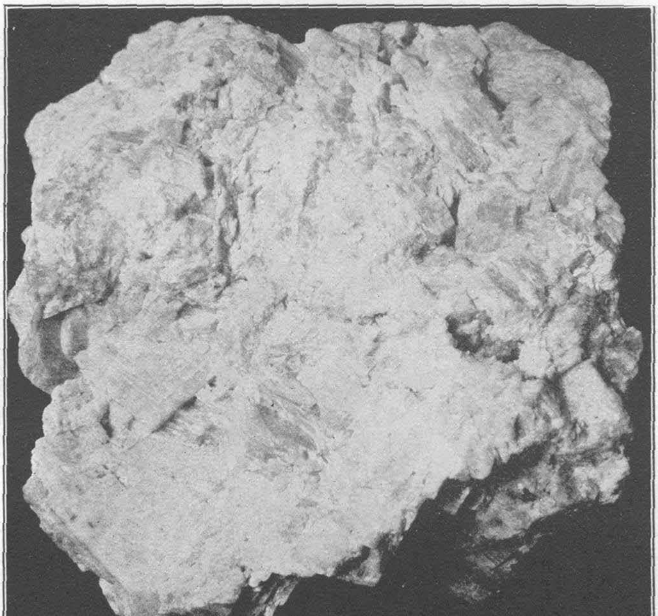
A large amount of ore remains in sight and in prospect.

COYLE.

The Coyle mine comprises the John Coyle and Torrit claims, on the north slope of Franklin Hill just above Frost Creek and opposite the Algonquin mine. The lode was discovered about 1876 and was worked for many years by Peter Coyle for silver. In the course of this work an adit that penetrated a large body of manganese oxide ore was driven near the creek level. A shipment of 160 tons from



A. CAVERNOUS MANGANESE OXIDE ORE FROM ALGONQUIN MINE, PHILIPSBURG DISTRICT, MONT.



B. RHODOCHROSITE FROM EMMA MINE, BUTTE DISTRICT, MONT.

this mine to South Chicago, mentioned by Emmons,[14] was probably the same lot reported in 1900[15] and the first manganese ore to be produced as such in Montana. Manganese mining was unprofitable at that time, but when the price of the ore was increased because of the war the Coyle ore body was one of the first to be extensively worked. From October, 1916, to November, 1918, the shipments made from it amounted to more than 30,000 tons. During this period the mine was operated first by Courtney Bros., as lessees, and afterward by James Gillie for the owner, Mrs. Lalor.

The rocks that inclose the Coyle ore body are magnesian limestones of the Silver Hill formation and the lower part of the Hasmark formation. The beds are involved in the east limb of the Philipsburg anticline, and therefore strike 30°–40° W. and dip 55°–60° NE. A short distance to the east the limestone is cut off by granodiorite.

The principal working is an adit about 600 feet long near the level of Frost Creek. It is connected with a shorter adit and a shaft respectively 165 and 275 feet higher by raises and stopes. In addition there are several hundred feet of drifts and crosscuts.

The workings expose an irregularly flattened pipe or podlike body from 25 to 100 feet in greater diameter and at least 300 feet in pitch length, its extent below the main adit not being determined. Its volume is at least 1,000,000 cubic feet, and its total content of manganiferous material at least 50,000 tons. It pitches steeply northeastward, parallel to the bedding of the limestone, and is associated with an irregular quartz vein. Just above the main adit level the body gives off a branch of undetermined extent. As shown by a winze, the water level is 50 feet below the main adit.

The body is wholly oxidized, cavernous, generally devoid of structure, and composed chiefly of soft fine-grained or amorphous mixed oxides of manganese. Locally there are concretionary or mammillated masses made up chiefly of psilomelane in layers as thin as paper, with a few thicker layers composed of manganite prisms.

The ore as mined does not vary much from an average content of 43.5 per cent of manganese and 17.5 per cent of silica. The amount of phosphorous present is said to be generally less than 0.25 per cent and of iron about 1 per cent. Considerable material rejected in mining carries from 25 to 40 per cent of manganese and 20 per cent or more of silica.

CLIMAX.

The Climax mine, on the north slope of Franklin Hill, a short distance east of the Coyle mine, was operated during 1918 by the Climax Mining Co., which produced a few thousand tons of manganese oxide ore and developed a considerable reserve. The ore

[14] U. S. Geol. Survey Prof. Paper 78, p. 211, 1913.
[15] U. S. Geol. Survey Mineral Resources, 1900, p. 116, 1901.

consists of cavernous material much like that composing the Coyle, Algonquin, and other ore bodies in the district. It is inclosed in limestone of the Hasmark formation not far from the granite and has the form of an irregular flattened pipe, about 40 by 15 feet in cross section, that pitches steeply southeast and extends to a depth of at least 100 feet. The ore shipped averaged about 40 per cent of manganese and 20 per cent of silica.

TROUT.

The Trout mine, a quarter of a mile northwest of Hasmark, on the divide between Frost Creek and Camp Creek, has been worked intermittently for silver since about 1870. In the fall of 1917, after it had been idle a long time, the mine was acquired by the Western Ore & Mining Co., which proceeded to repair the upper levels and explore a body of manganese ore that adjoins the shaft. Before the end of 1918 considerable ore had been produced and an additional large quantity developed. The principal working is a shaft 635 feet deep, from which several levels are turned that have a total length of at least 2,000 feet. The bottom of the shaft is about 250 feet lower than the adjacent valleys of Frost Creek and Camp Creek and is also somewhat lower than the bottom of the old Algonquin shaft.

The manganese ore body is associated with a nearly vertical vein of silver-bearing quartz that cuts steeply tilted beds of the Hasmark, Red Lion, Maywood, and Jefferson formations. It is in the east limb of the Philipsburg anticline, about 600 feet west of the granite contact. Incomplete explorations show that the body has somewhat the form of a flattened cylinder with an irregular cross section about 20 feet wide and 80 feet long. It extends from the surface to a depth of at least 140 feet, its longer diameter is parallel to the bedding of the limestone, and its axis pitches steeply southeast. The lower levels are reported by persons familiar with them to expose large amounts of both manganese oxide and manganese carbonate ore. The lowest or 635-foot level is said to penetrate a body of carbonate ore 15 feet wide. Emmons[16] notes the occurrence of abundant rhodochrosite surrounding fragments of quartz on the 150-foot level.

So far as it is explored the ore body is a rather indefinite mixture of manganese oxides of a cavernous, somewhat spongelike texture. It contains masses of incompletely oxidized material that show very clearly the transition from the dense carbonate to the porous oxide ore. The unaltered carbonate is crystalline, of medium grain, dense, and pale pink to yellow. It is peppered with specks of metallic sulphides, chiefly pyrite. The color of the yellow specimens is due to stains of a basic sulphate of iron derived from the decomposition of the pyrite. Microscopic and chemical examinations show the rock

[16] Emmons, W. H., op. cit., p. 209.

to be an aggregate of crystalline carbonate grains composed of 70 to 100 per cent of manganese carbonate and the remainder of magnesium carbonate. Apparently oxidation of the sulphides is the first step in the change from carbonate to oxide ore. The next is a blackening along seams and clouding of the adjacent carbonate grains, without much change in the volume or density of the rock. In a more advanced stage all surfaces are blackened and the clouding of carbonate grains has become general. Many small cavities have opened, some of which suggest shrinkage and others solution and removal of material. All gradations may be seen between this phase and that of complete oxidation, in which the cavernous or spongelike texture is fully developed.

Ore selected in mining the oxidized body averages about 42 per cent of manganese and 14 per cent of silica. The carbonate ore, of which no shipments had been made up to November 1, 1918, is said to carry as much as 40 per cent of manganese, with very little silica and iron.

GEM.

The Gem mine, a short distance southwest of the Trout, has been worked in a small way for silver at times during the last 30 or 40 years. From September, 1917, to November, 1918, a deposit of manganese ore in the western part of the Gem and Trout claims was mined through the main Gem adit level by the Western Ore & Mining Co., more than 30,000 tons of ore being produced and a large reserve developed.

The deposit is in the upper part of the Hasmark formation, on the east limb of the Philipsburg anticline. It comprises two irregular bodies, one of which adjoins the Gem vein and the other lies on the north or footwall side and extends into the Trout claim. The northern body is at least 150 feet in pitch length, 200 feet in maximum width (stope length), from 10 to 50 feet in thickness, and in its longer horizontal dimension parallel with the bedding. The other body is smaller. Both pitch steeply northeastward, parallel with the dip of the limestone, and consist of cavernous, wholly oxidized material, much like that of the Trout, Pocahontas, and other deposits near by. Representative specimens consist of rather soft, fine-grained mixed oxides of manganese. Vugs and pores in the mass contain more or less clayey matter and a little soft amorphous oxide. The ore as mined contains about 40 per cent of manganese, 18 per cent of silica, and very little iron and phosphorus.

POCAHONTAS.

The Pocahontas mine, at the head of Cliff Gulch, a short distance northwest of the Algonquin, produced several thousand tons of manganese ore in 1917 and 1918, being operated at first by Patten

Bros. and afterward by the Western Ore & Mining Co., the present owner. A silver-bearing quartz vein that trends N. 80° E. and cuts limestone of the Hasmark formation is developed by underground workings to a depth of 85 feet and a length of 500 feet. Within these limits several lenslike bodies of manganese oxide ore are found along the vein. They range from 40 to 100 feet in length and 5 to 8 feet in thickness, are cavernous, and consist chiefly of pyrolusite, psilomelane, and manganite more or less intimately mixed together. In places there are considerable masses of finely crystalline unmixed pyrolusite. In a few specimens of the ore braunite was identified, and in others manganite and psilomelane form very thin alternating layers. Cavities in the ore contain kaolin and quartz, with some iron oxides and wad.

The ore as mined for shipment averages about 42 per cent of manganese and 18 per cent of silica.

LITTLE GEM.

The Little Gem mine, on the south slope of Cliff Gulch, a short distance west of the Pocahontas, has produced somewhat more than 12,000 tons of manganese ore. It was developed by Hynes & Wells in the fall of 1916 and operated afterward for a year by the Manganese Mining Co. and for a short time by the Western Ore & Mining Co. In August, 1918, the mine was idle. At the surface three separate bodies of manganese ore (fig. 29) are associated with a small, nearly vertical quartz vein that trends east and cuts limestone of the Hasmark formation across the axis of the Philipsburg anticline. The largest ore body is 175 feet long and from 10 to 80 feet wide at the surface. It lies parallel with the quartz vein and extends downward about 100 feet, tapering out gradually like a wedge. The two smaller bodies are of similar form. The ore was removed chiefly through open cuts, in which considerable rather siliceous ore remains. At the east end of the largest body a short adit exposes a variety of manganese oxide ore that consists of rather coarse grained calcite and manganese oxide grown together. In general, however, the ore is cavernous and similar in appearance and composition to the ore from the Algonquin and other mines near by. Most of the ore produced carried from 38 to 45 per cent of manganese, about 16 per cent of silica, 1.5 per cent of iron, and very little phosphorus.

WEST ALGONQUIN AND BERNARD.

The West Algonquin and Bernard claims, owned by Hynes & Mullin, are on the divide between Frost Creek and Cliff Gulch, west of the Algonquin and Levi Burr mines. They are mostly underlain by limy shale of the Silver Hill formation, which has been largely changed by contact metamorphism to a rock composed of garnet, epidote, and other silicates. The claims lie across the axis of the Philipsburg anticline, which pitches north and therefore causes the strike to range from northwest through west to southwest. The dip is 30°–40°, and its direction ranges from N. 71° E. through north to northwest according to the changes in the strike.

The manganiferous deposits are tabular bodies that replace the country rock and locally, at least, are confined to certain beds. One

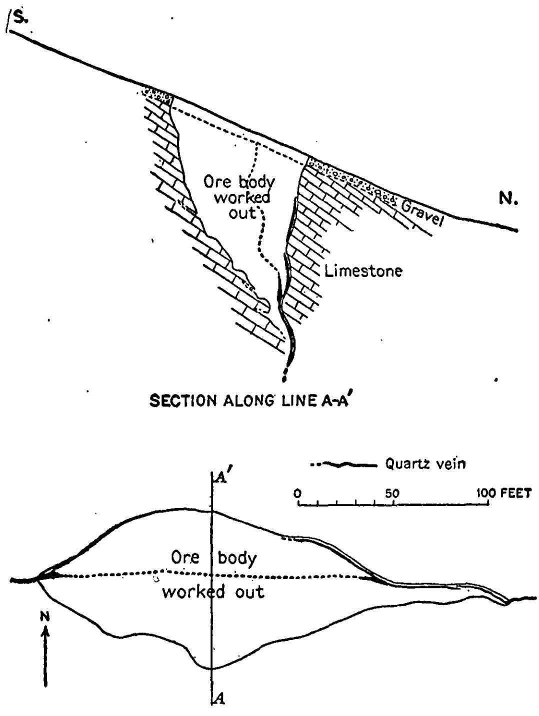


FIGURE 29.—Plan and section of manganese ore body at Little Gem mine, Philipsburg district, Mont.

on the Bernard claim is exposed by an inclined shaft 65 feet deep at the top of the cliff-like slope north of Frost Creek, near the summit of the anticline. This deposit is from 5 to 15 feet thick, at least 50 feet in stope length, of cavernous texture, and made up of manganese oxides, clayey material, and undecomposed silicate rock. The manganese oxides form an indeterminate mixture that is rather soft and probably consists largely of pyrolusite. To judge by its appearance the body does not average more than 30 per cent of manganese and is rather high in silica. Probably a considerable part of it could be selected in mining to carry 35 per cent or more of manganese.

At the working mentioned the body strikes about east, toward a deposit of manganese oxides and silver-bearing quartz on the Levi Burr claim, about 600 feet away, that is probably a part of the same lode.

The West Algonquin deposit is explored by a crosscut adit run southward on the slope of Cliff Gulch about 300 feet northwest of the Bernard shaft. It replaces a bed of the Silver Hill formation stratigraphically a short distance from that replaced by the Bernard body. As shown by the drifts at a level about 50 feet below the surface the deposit is 120 feet long and averages 6 feet in thickness. It is similar to the Bernard body in texture and composition. Ore mined by the Western Ore & Mining Co. contained in round figures 34 per cent of manganese and 31 per cent of silica. This deposit accompanies a narrow but persistent quartz vein that is apparently the westward continuation of the Algonquin vein.

The two deposits contain a moderately large reserve of manganiferous material and an additional large amount in prospect.

BRYANT.

The Bryant mine, which comprises the Bryant, Lady Byron, and Seal Rock claims, is about a quarter of a mile southwest of Tower, on the divide between Camp Creek and Cliff Gulch. Prior to the war these claims were worked in a small way at different times for silver-bearing quartz. During 1918 the present owner, the Philipsburg Mining Co., developed a large body of manganese ore on the Bryant claim from which it produced about 13,000 tons. Smaller bodies were developed elsewhere, and a small additional amount of ore was produced from the Seal Rock claim.

The deposits are in the upper part of the Hasmark formation and lie a short distance east of the axis of the Philipsburg anticline. Workings that partly explore the Bryant ore body consist of a large pit or glory hole along the side of which is a shaft 100 feet deep with several drifts and stopes. So far as these workings extend they show the ore body to range from 50 to 150 feet in stope length and to be 40 feet wide in one place. The mine is dry, the ore is wholly oxidized, and the body is decidedly cellular or cavernous. The ore consists mainly of rather closely packed nodules (Pl. VIII, *B*) that range from an inch or two to a foot or more in diameter. Spaces between them are partly filled with a soft clayey material that consists chiefly of kaolin and quartz with a little iron oxide. The nodules show a concentric structure (Pl. VIII, *A*), with radial shrinkage cracks and fractures along which small dislocations have taken place. They consist mainly of psilomelane arranged in thin mammillated layers. Small amounts of wad are distributed throughout the mass, part of it in thin layers that alternate with the psilomelane. In some of the nodules wad occurs as small grains and specks distributed in such a way as to suggest a decay spreading outward from a central point (Pl. VIII, *A*). Commonly fragments of quartz veinlets are embedded in the nodules. In places the Bryant ore body contains small bunches of an undetermined manganese oxide that shows a grayish-brown color and gives a brown streak. It occurs as very fine, silky, rather brittle fibers 2 or 3 inches long. The aggregate of fibers is very soft, but this may be due to a well-developed cleavage.

Part of the ore is mined selectively to carry 45 per cent or more of manganese and not more than 16 or 17 per cent of silica. The bulk of the product, however, contains about 38 per cent of manganese and 20 per cent or more of silica. This is treated at the company's mill at Philipsburg, and the resultant concentrate contains 48 per cent or more of manganese and not more than 12 per cent of silica.

A large amount of ore remains in reserve.

CLIFF.

The Cliff mine, the property of the Philipsburg Mining Co., is in Cliff Gulch between the Gem and Bryant mines. The development workings, which were made several years ago in a search for silver, consist of an adit 400 feet long, a shorter adit at a higher level, and a shaft sunk 100 feet below the level of the longer adit. In addition a block below the longer adit, 150 feet long and 300 feet deep, has been explored by a diamond drill. The shaft was not accessible for examination in 1918. The workings explore a quartz vein that strikes N. 80° E., stands nearly vertical, and cuts across the upper part of the Hasmark formation. Bodies of manganese oxide ore from 1 to 6 feet wide and from 50 to 100 feet or more in stope length are closely associated with the quartz vein. The ore is similar in general appearance to that found in the neighboring mines. A sample lot treated in the company's mill near Philipsburg contained about 35 per cent of manganese and 33 per cent of silica. It yielded a concentrate carrying 48 per cent of manganese and 12 per cent of silica. The mine contains a rather large prospective reserve of milling ore.

WHITE HORSE.

The White Horse mine, on the north side of Cliff Gulch a short distance below the Cliff mine, is in the upper magnesian limestone of the Hasmark formation near the axis of the Philipsburg anticline. The principal working is an adit level 185 feet long, from which near the face short drifts are turned, a shaft is sunk 80 feet, and a raise extends 80 feet to a short adit. The drifts, shaft, and raise, which are wholly in the oxidized zone and above the water level, explore an irregular body of manganese ore (fig. 30) from 3 to 12 feet thick and at least 150 feet in pitch length, its lower limit not being shown. At the level of the main adit it is 50 feet wide (stope length), but a short distance above this level it narrows rather abruptly to an irregular crooked pipe or neck about 3 feet in average diameter that extends to the upper adit, within a few feet of the surface. The body pitches about 45° W. and partly incloses a narrow branching vertical quartz vein that is probably the westward extension of the Cliff vein. Like the other bodies of manganese oxide ore in the district, it is cavernous throughout, and in structure and composition it is similar to the bodies in the Bryant and Algonquin mines. Ore selected for

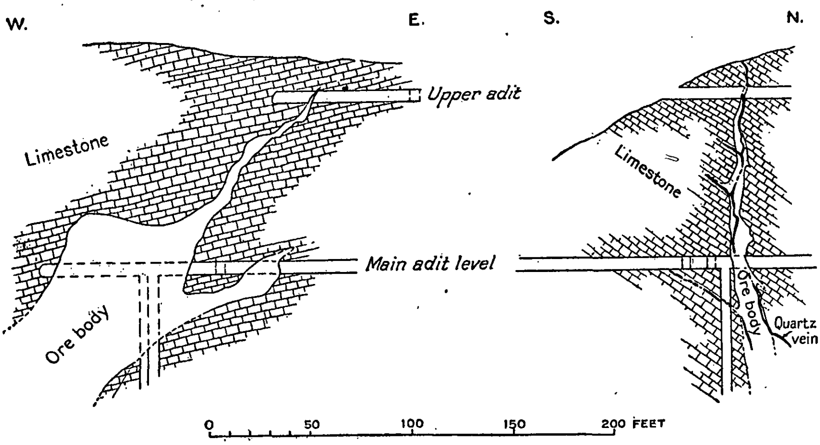


FIGURE 30.—Projections of ore body at White Horse mine, Philipsburg district, Mont.

shipment carries 43 per cent or more of manganese, about 17 per cent of silica, and very little iron or phosphorus.

Considerable ore was produced prior to the decline of the manganese market in November, 1918, and a large amount remains in sight and in prospect.

SCRATCH AWL.

The Scratch Awl mine, about midway between Tower and Hasmark, was worked in a small way for silver many years ago. After a long period of idleness the mine was reopened in the fall of 1917, and a moderate amount of manganese ore was produced during that season and the following year. The manganese ore body is part of a quartz vein that trends east, dips 70° S., and cuts across shale and limestone belonging to the Red Lion, Maywood, and Jefferson formations. It is of tabular form, from 3 to 5 feet wide, with minimum stope and pitch lengths of 180 and 100 feet, respectively, of cavernous texture, and composed of mixed oxides of manganese, with more or less vein quartz and a few streaks of iron oxides. Car and mine samples show from 36 to 42.5 per cent of manganese and 17 to 25 per cent of silica. In one place, a body of unoxidized ore valuable for silver extends within 50 feet of the surface. It consists of fine-grained quartz, zinc blende, galena, and rhodochrosite, with a little quartz and sulphides.

SHARKTOWN.

The Sharktown mine, a short distance south of Tower, was operated for manganese during a part of 1916 and most of 1917 by the Montana Manganese Co. and during 1918 by the Beaver Creek Mining Co., the present owner. The total production is about 16,000 tons of manganese ore, most of which was shipped East in the crude form for use in steel making. The deposit is in marbleized Jefferson limestone near the granodiorite contact. The main working, known as the Sharktown tunnel, is an adit several hundred feet long, with drifts, raises, and stopes, made several years ago in a search for silver. About 250 feet from the portal it penetrates an irregular body of manganese oxide ore 20 or 30 feet in average width, about 100 feet in stope length, and at least 150 feet in pitch length. Another body 20 by 60 feet in cross section and of indeterminate pitch length is exposed by the short adit. Both are cavernous, composed mainly of mixed oxides, and associated with quartz veins. The ore produced by selective mining averages about 40 per cent of manganese and 14 per cent or more of silica.

HORTON.

A large body of manganese ore in the Horton mine, south of Camp Creek about a quarter of a mile below Tower, was developed in 1918 by the Philipsburg Mining Co. The workings are a shaft 160 feet deep, drifts, and stopes, and despite the fact that the lowest level is about 100 feet lower than the adjacent bed of Camp Creek no water was met. The ore body stands nearly vertical, trends east, averages 20 feet or more in width, and is at least 200 feet in stope length. At the shaft it is 100 feet wide at the surface, but it tapers downward to 17 feet at a depth of 160 feet. The ore is completely oxidized, is of cavernous texture, and consists of mixed oxides, chiefly psilomelane and pyrolusite, with more or less quartz and bunches of clayey matter. The average material mined carries about 35 per cent of manganese and 30 per cent or more of silica. It is run through the company's mill near Philipsburg and yields a concentrate containing about 48 per cent of manganese and not more than 12 per cent of silica.

TRUE FISSURE.

The True Fissure mine at Tower, the property of the Philipsburg Mining Co., produced about 20,000 tons of manganese oxide ore during 1917 and 1918. Most of this was shipped East in the crude form for use in making steel; the remainder was concentrated before shipment in the company's mill near Philipsburg. The workings comprise a large open pit or glory hole and a shaft 200 feet deep, with drifts and crosscuts at the 100-foot and 200-foot levels; the drift on the 100-foot level is an adit. The rocks consist of intrusive granodiorite and the Jefferson limestone, which strikes north, dips 45° E., and has been altered by contact metamorphism to a white marble. The two formations are separated by a fault plane that dips about 40° E. and strikes north, like the limestone. The granodiorite forms the east or hanging wall. The west drift at the 200-foot level exposes a branch fault that cuts the limestone and dips east at a small angle. Both faults are accompanied by several feet of crushed rock and gouge.

Most of the workings described were made to explore a nearly vertical silver-bearing quartz vein that extends westward through the limestone several hundred feet and is possibly continuous with the veins in the Imperial and Midnight mines. On the 200-foot level the vein is from 6 to 12 inches wide and consists chiefly of quartz and zinc blende, with some galena. It is cut off by the contact fault, beyond which its eastern continuation is probably the Silver Chief vein, about 50 feet to the north. The vein is also cut off by the flat branch fault mentioned. The contact fault fissure contains some small veins of barite that carry a little iron and manganese. Adjacent to the vein the limestone is cut by stringers of calcium-magnesium carbonate that carry a little manganese and a few grains of pyrite. Near the manganese ore body described below the limestone becomes soft and shows a brown discoloration caused by finely divided manganese oxides that were probably introduced into the limestone when the ore body was oxidized.

The manganese ore forms an irregular body that has somewhat the form of a wedge or inverted pyramid. Its cross section at the surface is about 150 feet long and 30 or 40 feet wide, and at a depth of 160 feet it wedges out completely. It lies approximately parallel to the bedding and just north of the True Fissure quartz vein. The ore is completely oxidized, cavernous, and generally similar in appearance to the ore in the Algonquin and other mines near by. Shipments from this body averaged about 45 per cent of manganese, 17 per cent of silica, and very little iron or phosphorus. The milling ore contained between 30 and 40 per cent of manganese and as much as 30 per cent of silica. In August, 1918, this body had been practically exhausted, only a moderate amount of medium or low-grade material remaining in reserve.

HEADLIGHT.

The Headlight mine is at Tower, on the slope west of Tower Creek, about 1½ miles east of Philipsburg. For many years it was operated intermittently for silver, and during most of 1917 and

1918 it was worked for manganese in succession by the Beaver Creek Mining Co., the Hickey-Kroger Leasing Co., and the Moorlight Mining Co. A total production of about 7,000 tons of manganese ore is reported.

The Jefferson limestone occupies the slope, and the Maywood formation, which consists of magnesian limestone and shale that is hardened and partly changed to a silicate rock by contact metamorphism, appears along the summit. The beds, which are involved in the east limb of the Philipsburg anticline, range in strike from north to N. 15° W. and dip about 33° E.

The workings consist of several adits, drifts, and stopes. At the foot of the slope, at an altitude of 5,800 feet, an adit is driven westward about 500 feet. Near its end are drifts and a raise, but no connection with the workings above had been made when the writer visited the mine in August, 1918. At levels approximately 100, 160, and 200 feet higher are adits connected with one another and with an open cut on top of the hill by raises and stopes.

The lowest adit follows a narrow silver-quartz vein that has been described by Emmons.[17] It strikes N. 60°–70° W., dips steeply south, cuts across the Jefferson limestone, and is dislocated by several faults parallel to the bedding. It has not been found to continue with an unchanged course through the Maywood formation, but either dies out upon reaching that formation or, as suggested by the position of similar quartz veins in the upper workings, turns to follow the bedding plane that carries the manganese ore body.

The manganese deposit is a tabular body from 3 to 6 feet thick that replaces a bed of limestone in the Maywood formation. In the upper adits it is from 60 to 300 feet or more in stope length, the maximum not being shown. From its outcrop the body is developed by stopes and raises to a depth of 400 feet on the slope. The body is a cavernous mass made up chiefly of manganese oxides, with more or less clayey material and silver-bearing vein quartz. The manganese oxides form a rather indefinite mixture, whose properties suggest that pyrolusite is an abundant constituent. Small amounts of limonite and grains of calcite are common throughout. About two-thirds of the mass is selected in mining as ore. Shipments reported by the Moorlight Co. carried from 38 to 48 per cent of manganese and from 11 to 25 per cent of silica and averaged 43 per cent of manganese, 18 per cent of silica, and 2.5 per cent of iron. As determined in a few samples, phosphorus is very low, silver ranges from 1 to 26 ounces to the ton, and gold from 50 cents to $1 to the ton.

[17] Emmons, W. H., U. S. Geol. Survey Prof. Paper 78, pp. 171, 219, 1913.

A moderately large amount of ore was estimated to be in reserve in August, 1918, and a large additional amount was considered to be in prospect.

SAUNDERS.

The Saunders mine, just north of Tower, was operated in 1918 by the Moorlight Mining Co., which produced a small amount of manganese ore. The country rocks are intrusive granite and marbleized Jefferson limestone, which form the east and west walls, respectively, of a fault fissure that dips about 40° E., carries 10 feet or more of crushed rock and gouge, and is apparently the northward continuation of the fault exposed in the True Fissure mine. The workings consist of an adit that begins in granite and extends across the fault into the limestone. The adit follows a vein which trends west through the granite and is cut off by the fault and probably displaced about 50 feet to the south. About 70 feet higher than the adit level open pits and a short adit in the limestone expose two or three bodies of manganese oxide ore, the largest of which is about 6 by 15 feet in area. Its position suggests that it is continuous with a streak of manganese oxides exposed by a south crosscut from the main adit. The ore is cavernous and of nodular structure in general and consists chiefly of psilomelane mixed with the softer oxides. The cavities are partly filled with a soft claylike material that consists chiefly of kaolin and quartz, with a little iron oxide. Some of the nodules indistinctly show a concentric structure and consist mainly of psilomelane. Thin streaks of vein quartz are common throughout the body. Mining of the manganese ore developed one streak that carries 20 ounces or more of silver and a few cents in gold to the ton.

MARIE.

A moderate amount of manganese oxide ore was produced at times in 1917 and 1918 from the Marie mine of N. G. Ringeling, on the divide between Camp Creek and Browns Gulch, about half a mile north of Tower. Most of the development workings, which comprise open pits, a shaft, and an adit with a winze 60 feet deep, were made prior to 1917 in a search for silver. One car of manganiferous material is said to have been shipped in 1898 to Helena for use as a flux in lead smelting. The country rocks are the Jefferson limestone and intrusive granite, separated from each other by a continuation of the fault exposed in the Saunders mine. The deposit is found in the limestone near the granite and so far as it is explored appears to be of tabular form, 4 or 5 feet wide, 200 feet in stope length, and at least 60 feet in pitch length, its lower limit not being determined. The ore is completely oxidized and cavernous and carries about 42 per cent of manganese and 18 per cent of silica.

N. G. GROUP.

Manganiferous deposits on a group comprising the N. G., Mountain View, Manganese Fraction, and other claims on the north side of Camp Creek, about halfway between Philipsburg and Tower, were developed in 1917 by the Western Minerals Co. and in 1918 by Collins & Winninghoff. A moderate production of crude ore and concentrate made at the mine by jigging is reported. The deposits are associated with narrow veins of silver-bearing quartz that trend east, pitch steeply south, and cut limestone of the Hasmark formation. On the N. G. claim a short distance east of the Mystery tunnel a short adit with drifts and raises exposes a body of manganese oxide ore 8 feet wide, 50 feet in stope length, and 20 to 50 feet or more in pitch length, its lower limit not being shown. This body is associated with a quartz vein that is exposed by pits here and there for 200 feet or more. It ranges from 2 to 6 feet in width and consists of quartz and manganese oxides. In parallel veins of similar composition 30, 80, and 500 feet farther north a little ore has been developed. In all the deposits the ore is a cavernous mixture of manganese oxides, largely psilomelane, and is generally similar in appearance to the ore from most of the other mines in the district. Ore mined from the deposit in the N. G. vein contains from 38 to 44 per cent of manganese and from 13 to 20 per cent or more of silica. Jig concentrate made at the mine averages about 48 per cent of manganese and 13 per cent of silica.

WENGER NO. 2.

The Wenger No. 2 mine, on the south side of Cliff Gulch, about half a mile southeast of Philipsburg, is on the outskirts of the manganiferous area. It was worked at times by the Manganese Mining Co. in 1917 and by Collins & Winninghoff in 1918; each operator produced a small amount of ore. The deposit is in the upper part of the Hasmark formation, on the west limb of the Philipsburg anticline, and is associated with a quartz vein that has yielded considerable silver ore. An adit level and other workings partly expose a cavernous body of manganese oxide that is 20 feet wide in one place and at least 40 feet long. A considerable part of this body is estimated to contain from 20 to 35 per cent of manganese. A small amount of ore that was selectively mined carried from 40 to 43 per cent of manganese and 20 per cent of silica.

REDEMPTION.

The Redemption mine is on the lower west slope of Franklin Hill, at the sharp turn in the road from Philipsburg to Granite known as the Jackknife Bend. From 1904 to 1906 this mine was worked by Cape Bros. & Coulter, who produced considerable iron ore that was used in copper smelting at Butte. In 1906, according to report, 22 cars of manganese ore was shipped to Sandpoint, Idaho, where it was used as a flux in smelting lead. Manganese ore for use in steel making was mined in 1917 and 1918 from the Redemption mine by the Auerbach Mining & Supply Co., and its successor, the Butte & Plutus Co., which took possession September 4, 1917. The total production of manganese ore prior to November 1, 1918, was about 2,000 tons.

The workings consist of shafts 175 and 150 feet deep and about 1,000 feet of adit levels and drifts. The deposits of manganese and iron ore, though near together, are separate and distinct bodies situated in the lower part of the Hasmark formation, about 1,500 feet from the granite contact. The iron ore body consists chiefly of magnetite of contact-metamorphic origin. Associated with it is an uncommon mineral, ludwigite, a borate of magnesia and iron, described by Emmons and Calkins.[18] The manganese body is incompletely explored, but the workings show it to be at least 160 feet in pitch length and 6 feet or more in width. It pitches northwest and is associated with a small irregular quartz vein that carries silver and lead. The ore is completely oxidized and similar in general appearance to that produced elsewhere in the district. The manganese ore shipped in 1906 for flux contained from 35 to 44 per cent of manganese and from 3 to 7 ounces of silver and about 60 cents in gold to the ton. The ore produced for use in making steel in 1917 and 1918 averaged about 38 per cent of manganese and carried from 17 to 20 per cent of silica.

BUTTE DISTRICT.

In a report[19] published in 1918 attention was drawn to the fact that the lodes at Butte contain a very large total quantity of manganiferous material, and the probable occurrence of large amounts of manganese ore was pointed out. Since that report was written mining developments have shown that some of the mines contain bodies of manganese ore that are formed on the same grand scale as the other ore deposits of this famous district. These deposits consist of rhodochrosite, the carbonate of manganese, a mineral that until late in 1917 had been entirely overlooked as a source of the metal. Before that time, as an incident to the development of zinc and silver ores, more or less rhodochrosite was unavoidably extracted from several of the mines, but it was regarded merely as waste rock. As late as August, 1917, quantities of it were being used to grade a road near the Washoe sampler. Once the operator realized the value of this

[18] U. S. Geol. Survey Prof. Paper 78, pp. 162–220, 1913.

[19] Pardee, J. T., Manganese at Butte, Mont.: U. S. Geol. Survey Bull. 690, pp. 111–136, 1918.

material, however, he proceeded to find a market without delay, and by the end of the year trial shipments of rhodochrosite had been made to steel manufacturers in the East. During 1918, the value of rhodochrosite having been demonstrated, the production of manganese ore at Butte rapidly increased. In fact, in that year the output of this district was about three times as great as that of California, next to Montana the most productive State, and nearly seven times as great as that of Virginia, formerly the principal manganese-producing State in the country.

HISTORY AND PRODUCTION.

In the past considerable manganiferous silver ore was mined from the upper parts of the Butte lodes and reduced at the local smelters, where the manganese was considered valuable only as a flux. From available information it is estimated that possibly as much as 100,000 tons of highly manganiferous material of this kind was produced in the period from 1879 to 1895. The mining of manganese ore as such was not begun until 1917, and then only the oxide ores were sought. In the upper parts of the lodes, however, but little material was found that could be marketed in the crude form, and attempts to concentrate the abundant but very siliceous material that forms the bulk of the lodes were not uniformly successful. Therefore only a small production of crude ore and concentrates was made in 1917. The next year, rhodochrosite having become firmly established in the ore trade, production increased until October, when the shipments averaged more than 400 tons a day.

In 1918 the Anaconda Co. built at Great Falls, Mont., an electric smelter capable of making 90 tons of ferromanganese a day and designed to utilize chiefly the rhodochrosite ore from Butte. As it happened this plant was completed in time for only a short run before the sudden decline in the market that followed the signing of the armistice. The smelter was then closed, and the mining of manganese ore at Butte was largely suspended.

From the beginning of 1917 to the end of 1919 the total production of manganese ore at Butte was more than 78,000 tons, worth in round figures $2,000,000. Of this about 4,000 tons was crude oxide ore, 9,000 tons concentrate, chiefly rhodochrosite, and 65,000 tons crude rhodochrosite.

RESERVES.

In August, 1917, the oxidized parts of the lodes were estimated to contain 1,000 tons of high-grade ore and about 400,000 tons of siliceous manganiferous material that was possibly amenable to concentration. The reserve of high-grade oxide ore was probably depleted more or less during 1918, but only a small part of the low-grade material has been removed. The quantity of rhodochrosite ore reported as actually developed early in November, 1918, was more than 125,000 tons. To this reserve should be added an unknown and presumably very large amount in prospect. In addition the lodes contain an almost unlimited quantity of low-grade material consisting of the carbonate and silicate of manganese and quartz mixed in different proportions. This constitutes a reserve from which, if the necessity arose, the country's needs might be largely supplied. With improvements in the methods of reduction much of it might even become valuable under ordinary conditions.

FUTURE OF MANGANESE MINING.

The Butte manganese deposits possess the advantages of being large and economically mined. Most of them can be developed and the ore removed without additions to the workings needed to exploit the ores of other metals. With abundant facilities available for concentrating the ore and making ferroalloys the operators are in a position to take advantage of any favorable market without delay. Although Butte is rather far from the principal steel manufacturing centers of the country, it will therefore probably be profitable to mine manganese ore in this district for some time to come, or until trade conditions revert, if they ever do, to what they were before the war.

MANGANIFEROUS DEPOSITS.

OCCURENCE AND CHARACTERISTICS.

The manganiferous deposits of Butte are parts of the quartz lodes that have been mined chiefly for zinc and silver. The lodes, which are described in the reports listed on pages 144–145, are formed along steeply pitching fractures in granite (quartz monzonite) and extend to great depths. Manganese minerals are widely distributed, both horizontally and vertically, but they are comparatively scarce in that part of the district known as the central copper zone and plentiful in an adjacent peripheral belt a mile or more wide called the silver-zinc zone.

Below the oxidized zone huebnerite, the tungstate of manganese, is found in some of the mines, but manganese occurs chiefly as the carbonate, rhodochrosite, and the silicate, rhodonite. As a rule these minerals form a very considerable part of the vein matter, and they are generally mixed with vein quartz, metallic sulphides, and other minerals. In places, however, rhodochrosite forms large, practically unmixed bodies similar to the shoots of zinc and silver ores. The total vertical range of the rhodochrosite bodies is at least 2,000 feet.

Rhodonite probably forms large unmixed bodies also, but no very definite knowledge of them is available. The rhodochrosite is dense, and its texture ranges from coarse (Pl. IX, *B*) to fine, and its color from rose-pink to pale yellowish-pink. Oxide ore containing 35 per cent or more of manganese forms comparatively small indefinitely bounded tabular and lenslike bodies, and oxidized material that carries from 12 to 35 per cent of manganese forms a large part of the lodes. Generally the lower limit of the oxidized material is from 20 to 200 feet below the surface. In much of the ore the manganese oxides are rather indefinitely mixed with one another, but pyrolusite appears to be the most abundant. Psilomelane is plentiful, but manganite and wad are comparatively scarce, though widely distributed. The gangue is chiefly quartz, with a little iron oxide and a few other substances.

COMPOSITION.

Oxide ore selected for shipment carries from 40 to 49 per cent of manganese and from 4 to 26.5 per cent of silica. In the highly siliceous material that is possibly amenable to concentration manganese averages between 11.5 and 24 per cent. As a rule both the richer and the poorer grades of ore carry 3 or 4 per cent of iron and a few ounces of silver to the ton. Analyses of a few samples show a very little phosphorus, from 2 to 7 per cent of alumina (Al_2O_3), and traces only of lime (CaO), silver, and gold. The rhodochrosite ore generally carries from 35 to 37 per cent of manganese and 8 per cent or less of silica. Analyses of a few samples show about 2 per cent of iron, 1 per cent of alumina, 2 per cent of magnesia, and practically no lime or baryta.

ORIGIN.

The lodes at Butte are typically representative of the bodies generally believed to have been deposited by solutions rising from cooling granitic magmas. The distribution of the metals, including manganese, suggests a central source from which they were carried upward and outward, their deposition in concentric zones being caused by the lowering of temperature and pressure or other changing conditions. In general, the bulk of the manganese minerals was introduced later than the other vein filling and together with more or less quartz and sulphides was deposited as several successive generations.

DEPOSITS OUTSIDE THE PHILIPSBURG AND BUTTE DISTRICTS.

Manganiferous deposits that are parts of metalliferous quartz lodes, presumably derived from deep-seated intrusive rocks, are found in several places in Montana outside the Philipsburg and Butte districts. Most of them carry noteworthy amounts of silver, lead, or zinc, and several are fairly rich in iron. They have yielded a considerable amount of manganiferous silver ore in which the manganese was valuable as a flux in lead or copper smelting, but only a very small amount of manganese ore has been mined from them as such. In the aggregate these bodies contain a moderate amount of material that may be considered a possible future source of manganese. The lodes in the Castle district are reported by Prof. C. H. Clapp[20] to contain rather large amounts of a jaspery material that carries more or less manganese and iron and a few ounces of silver to the ton. Analyses of this material show that it contains from 6 to 13 per cent of manganese. Some of it may have a future value for making spiegeleisen.

The existence of a body of manganese oxide ore at Blackhawk, near Castle, is mentioned by Weed and Pirsson.[21]

At Neihart the most abundant of the gangue minerals accompanying the silver-lead-zinc ores is a mixed carbonate[22] of the same type as that found in the Trout mine at Philipsburg (p. 162). It contains in round figures from 21 to 41 per cent of manganese carbonate ($MnCO_3$), with various amounts of the carbonates of iron, calcium, and magnesium.

At Wicks veins in andesite reported by R. H. Sales[20] contain moderate amounts of siliceous ferruginous manganese ore, analyses of which show in round figures from 15 to 40 per cent of manganese, 13 to 20 per cent of iron, and 6 to 34 per cent of silica. A report by J. H. Hall, describing another vein near Wickes, shows the presence of considerable material carrying 21 per cent of manganese, 21 per cent of silica, 19 per cent of iron, and 2 ounces of silver to the ton.

A vein in gneiss and schist, 3 miles northwest of Anceney, Gallatin County,[23] contains a little high-grade manganese oxide ore. On Trapper Creek, 9 miles west of Melrose,[23] a body of manganese oxides associated with a quartz vein has yielded a few tons of ore.

In Dry Georgia Gulch, east of Twin Bridges, a vein of manganese oxide ore, mentioned by Winchell,[24] is locally 10 feet thick.

Small amounts of manganese ore were shipped in 1917 and 1918 from Cook's claim, about 1 mile north of Bonita, Granite County, described by Grimes and Rosenkranz.[25] This deposit consists of pyrolusite and wad that fill open spaces in badly faulted and broken Paleozoic limestone. The ore shipped, which was carefully selected in mining, contained from 41 to 47 per cent of manganese and from 6 to 17 per cent of silica. Average samples of the lode material show

[20] Personal communication.
[21] Weed, W. H., and Pirsson L. V., U. S. Geol. Survey Bull. 139, p. 161, 1896.
[22] Weed, W. H., and Pirsson, L. V., U. S. Geol. Survey Twentieth Ann. Rept., pt. 3, p. 409, 1900.
[23] Reported by R. H. Sales.
[24] Winchell, A. N., U. S. Geol. Survey Bull. 574, p. 158, 1914.
[25] Unpublished manuscript.

from 11 to 30 per cent of manganese, from 33 to 60 per cent of insoluble matter (probably chiefly silica), 1 to 9 per cent of lime (CaO), 3 to 8 per cent of iron, and traces of gold and silver. Only a little ore remains in reserve.

Deposits of manganese ore thought to be derived from sedimentary rocks are found at Wigwam and Cherry creeks[26] and about 4 miles west of Melrose.[27] They consist chiefly of pyrolusite and psilomelane that fill cracks and cavities in limestone. They yield small amounts of high-grade ore that is unusually free from silica. Only a little ore remains in reserve. A moderate reserve of manganiferous iron ore is found in a deposit near Renova.[28]

DEPOSITS IN UTAH.

HISTORY OF MANGANESE MINING.

Manganese ore was first mined in Utah in 1901. In that year deposits in the Little Grande district, southeast of Green River, were exploited by the Colorado Fuel & Iron Co., which shipped a quantity of the ore to furnaces at Pueblo and Chicago for use in making steel. At times thereafter a little ore was produced, but mining was unprofitable, and for several years after 1906 the district was idle. In 1915 rising prices caused by the war stimulated the district to renewed activity. Ore production was resumed and continued with few interruptions until the market declined shortly after the signing of the armistice in November, 1918. The high prices of this later period, together with the general publicity given in 1917 and 1918 to the country's need for manganese, led to the development of several deposits elsewhere in Utah, the most productive of which were in the Tintic and other metal-producing districts in the western part of the State. In general mining activity increased gradually during 1917 and the first half of 1918. The cessation of fighting was followed by an abrupt decline of the market, and before the end of the year practically all manganese mining was reported to have ceased.

PRODUCTION.

The total amount of manganese ore produced in Utah from 1901 to 1918, inclusive, was about 16,000 tons. Of this somewhat less than 4,000 tons, presumably all of which came from the Little Grande district, was produced during the period 1901 to 1906. The comparatively small extent of the manganese-mining industry in the United States at that time is shown by the fact that Utah's small production

[26] Pardee, J. T., U. S. Geol. Survey Bull. 690, pp. 131–139, 1918.
[27] Reported by R. H. Sales.
[28] Pardee, J. T., op. cit., pp. 139–143.

amounted to more than 10 per cent of the total for the country during the period mentioned. In the years 1915 to 1918, inclusive, three-fourths of the 12,000 tons produced in Utah came from the Little Grande district. During this period manganese mining increased so greatly elsewhere in the country that Utah's contribution, though three times as large as before, made but 2.5 per cent of the total.

About nine-tenths of the manganese ore produced in Utah was shipped East. Of this the greater part was used in making steel, the remainder being sold to manufacturers of dry batteries and chemicals.

Manganiferous iron ore and manganiferous silver ore are said to have been produced at different times in the last 30 or 40 years in the Tintic and other metal-producing districts and used as flux at lead and copper smelters, but the amounts are not known.

RESERVES.

A total reserve of about 11,000 tons of ore containing 35 per cent or more of manganese was estimated to be available in Utah in June, 1918. Most of this was in the Little Grande district, and the remainder in the Tintic and Erickson districts and a few other places. In addition a reserve of at least 20,000 tons was estimated as possibly available in the Little Grande district, though the cost of production would be greater than had previously been allowable. Further development work may be expected to reveal considerable additional ore in the Erickson and other districts in the western part of the State.

Material containing less than 35 per cent of manganese is found in moderate quantities in most of the mining districts. Part of it is high in silica and part high in lime. A little manganiferous iron ore is found in the Little Grande district and is reported in other places, and a considerable amount of manganiferous silver ore is doubtless present in the mining districts of western Utah.

FIELD WORK AND REPORTS.

In 1908 the Little Grande district was visited by Harder, whose report [29] also mentions deposits in Juab and Iron counties. Recently some deposits in Sevier and Piute counties were examined and described by Heikes.[30]

The writer examined the Little Grande district in May, 1918, and deposits in the Tintic and Erickson districts in the latter part of June.

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[29] Harder, E. C., Manganese deposits of the United States: U. S. Geol. Survey Bull. 427, pp. 145–147, 157, 1910.

[30] Heikes, V. C., U. S. Geol. Survey Press Bull. 370, July, 1918.

ORE DEPOSITS.

DISTRIBUTION.

Deposits of manganese ore are rather widely though irregularly distributed in Utah. (See fig. 31.) Most of the known deposits in

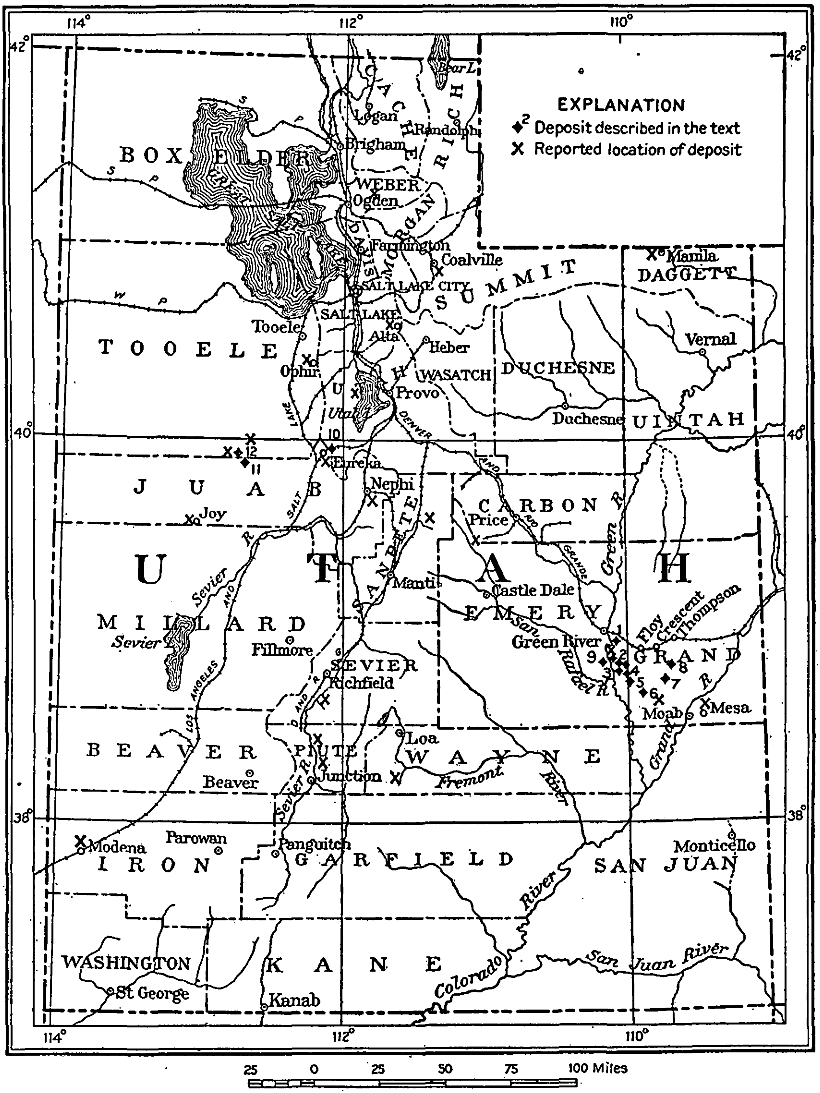


FIGURE 31.—Map showing location of manganiferous deposits in Utah. Little Grande district: 1, Mongol; 2, Salt Lake; 3, C. F. & I.; 4, Black Bear; 5, Duma; 6, Gustavus; 7, Court House; 8, Stockton; 9, Sunrise; several others not shown because of small scale of map. Tintic district: 10, Tip Top tunnel. Erickson district: 11, Black Jack; 12, Baby Elephant.

the eastern part of the State are within a narrow belt 15 or 20 miles long that lies in the Little Grande district, southeast of the town of

Green River. Those in the western part of the State are mostly in the Tintic and Erickson and some of the other metal-producing mining districts. The remaining deposits are scattered here and there, some of them many miles from a railroad.

CLASSIFICATION.

The manganiferous bodies may be classified as deposits interbedded with sediments, deposits formed by the replacement of country rock by carbonate and silicate minerals, and residual deposits.

Deposits interbedded with sediments.—Deposits interbedded with sediments are found in the Little Grande district and presumably occur at other places in the eastern part of the State. None are known in the western part. In the Little Grande district they are associated with limestone and gypsum found at a certain horizon in the Mesozoic McElmo formation. The predominating minerals are oxides, chiefly pyrolusite and manganite, with small amounts of some other oxides and locally a little rhodochrosite and manganocalcite.

The ore bodies are flat-lying lenslike or tabular masses commonly known as blanket veins, most of which are from 3 to 6 inches thick and from 50 to 100 feet long. Commonly they yield ore that carries 45 to 50 per cent or more of metallic manganese, 70 per cent or more of manganese dioxide, moderate amounts of silica, and very little iron and phosphorus. In the form of carbonate the manganese was deposited as an original constituent of the limestone, but its ultimate source is unknown. The workable bodies of oxides presumably were concentrated by surface waters acting on the limestone after it had been exposed by erosion in Tertiary or later time.

Deposits formed by replacement.—Most of the manganiferous bodies in western Utah may be classified as deposits formed by the replacement of country rock by carbonate and silicate minerals that have become superficially oxidized. They generally form parts of metalliferous quartz lodes, particularly the lodes valuable for silver, lead, and zinc. The bodies are irregular in form, but many may be generalized as resembling pods or pipes. Some of these are as much as 15 or 20 feet in diameter and 100 feet or more in length, and generally the longer axis is steeply inclined. The depth of oxidation varies according to local conditions. Commonly it is 100 feet or more. The oxidized parts of the bodies are characteristically cavernous and consist mainly of psilomelane, pyrolusite, and wad, with more or less vein quartz and decomposed country rock. Selective mining generally yields ore that carries 40 per cent or more of manganese, but is rather high in silica. The unoxidized parts of these bodies are dense and composed chiefly of rhodonite, rhodochrosite, and quartz, commonly with one or more of the minerals pyrite, zinc blende, and galena. So far these unoxidized parts have yielded no ore. The manganiferous bodies, together with the quartz lodes of which they form a part, are thought to have been formed by solutions ascending from some deep-seated intrusive rock.

Residual deposits.—Workable deposits consisting of ore fragments scattered over the surface and in the soil are found in the Little Grande district. The ore consists mainly of manganite and pyrolusite, with more or less quartz and calcite, and generally carries about 40 per cent of manganese. Ore-laden soil covers several hundred acres but varies in richness from place to place. Commonly it is less than 1 foot thick, and in places the surface is paved with a thin layer of ore fragments. These deposits are derived from the blanket veins by weathering and erosion, especially by the process termed wind deflation. The country rock is less resistant than the ore and breaks down to a rather uniform fine sand. The climate being very dry and vegetation scarce, the sand is readily blown away. The deposits are thus analogous to ordinary placers, wind instead of water being the concentrating agent.

LITTLE GRANDE DISTRICT.

LOCATION AND ACCESSIBILITY.

Manganese ore is found at several places south of the Denver & Rio Grande Railroad between the towns of Thompson and Green River. The most productive deposits are within the Little Grande district, in a narrow belt about 15 miles long that lies from 10 to 15 miles south of Floy. This area lies across the valleys of White Wash and Tenmile Wash and includes the long flat spur between them, known as Duma Point. East of Tenmile Wash it covers a prominent headland back of the conspicuous knobs known as The Needles. West of White Wash it includes the spur on which the C. F. & I. mine is situated and the shallow valley of Salt Wash north of it.

The area described is easily reached by automobile from the towns of Green River and Thompson. The roads are generally level but are in many places soft and sandy. All heavy hauling so far has been done with horses or mules, a trial with a motor truck being reported unsatisfactory.

PRODUCTION.

The first manganese mining in Utah was done in the Little Grande district in 1901 by the Colorado Fuel & Iron Co., which developed the deposits now known as the C. F. & I. mine. In that year and in 1903, 1904, and 1906 a total of somewhat less than 4,000 tons of ore was produced. Part of this ore was shipped to Pueblo and Chicago for use in making steel, and part was left at the mines or in heaps beside the railroad at Floy. A second period of mining activity began in 1915 and lasted until late in 1918. During this period several deposits were exploited in addition to the C. F. & I. mine, which, however, continued to be the chief producer. In May, 1918, three operators—the Green River Mining Co., the Needles Mining Co., and J. B. Fonder—were together producing ore at an average rate of about 500 tons a month. The total reported production of this later period is 8,000 tons. Practically all of this was shipped East. Most of it was used in making steel, and the remainder was sold under the trade name "dioxide ore" to manufacturers of dry batteries and chemicals.

ORE RESERVES.

In May, 1918, a total of 7,000 tons of available ore containing 35 per cent or more of manganese was estimated in reserve, and this amount was not greatly reduced by mining during the remainder of the year. An additional reserve that could be mined if necessary, but at a considerably greater cost than was allowable in 1918, was estimated at between 20,000 and 30,000 tons. The quantity of material that contains less than 35 per cent of manganese but is possibly useful because lime instead of silica is the chief impurity is estimated at 5,000 tons. Near the locality known as Court House there is also an undetermined quantity of highly siliceous material containing less than 35 per cent of manganese that might be capable of beneficiation, and a little low-grade manganiferous iron ore occurs on the east side of Duma Point.

MINING CONDITIONS.

Because the deposits or at least the workable parts of them, with one exception, lie upon the surface or beneath only a thin cover of soil and rocks, mining is a comparatively simple process. The principal operations are picking up ore fragments from the surface, screening them from the loose sandy soil, and uncovering the flat-lying deposits known as blanket veins by means of a plow and scraper or pick and shovel. The exception noted is a steeply pitching vein worked through an open cut and a shaft on the Mongol claim.

LITERATURE AND FIELD WORK.

A description of the area that includes the C. F. & I. mine was prepared by Harder [31] after a visit to the district in 1908. Later the geology of a wide region north of the mine was mapped by Lupton.[32]

[31] Harder, E. C., Manganese deposits of the United States: U. S. Geol. Survey Bull. 427, pp. 145–147, 1910.

[32] Lupton, C. T., Oil and gas near Green River, Grand County, Utah: U. S. Geol. Survey Bull. 541, pp. 115–133, 1914.

The principal manganese deposits were examined by the writer within the period May 10–25, 1918.

SURFACE FEATURES.

The area under consideration shows the fantastic cliffs and other land forms characteristic of the Plateau province of the western United States, of which it is a part. Most of the deposits described herein are near the southwest margin of a plain at an altitude of 4,500 feet that covers a large area south of the Book Cliffs and east of Green River. The northern part of this plain is crossed by the Denver & Rio Grande Railroad, from which the land near by appears generally level and unbroken. A few miles to the south are several low ridges that trend east or southeast. From the north they rise very gently, but their southern slopes are steep and cliff-like. One of these slopes, which presents a continuous escarpment about 200 feet high for 8 or 10 miles, forms the north side of Salt Wash valley. Two or three miles farther south the 4,500-foot plain ends definitely at a sinuous line of cliffs that will be referred to herein as the main escarpment. Here the general surface descends 400 or 500 feet to a plain that comprises parts of the valleys of Green River, White Wash, and Tenmile Wash.

From a point near Green River the main escarpment maintains a general southeast course for 20 miles or more, but its local departures are so numerous and extensive that their total length greatly exceeds that of the main course. White Wash and Tenmile Wash and their principal branches indent the escarpment deeply, carrying it back in long northeast reentrants. Superimposed on these are smaller indentations, notches, and scallops without number. In addition the escarpment is characterized throughout by horizontal shelf-like terraces. Each of these consists of a flat top or table supported by a vertical cliff, below which is a sloping pile of débris that rests on the terrace next below. The tables vary in width from place to place, being widest where they round spurs or other salients and narrowest in the reentrant angles. Where they are narrow the tables may be covered entirely by the sloping pile of débris from above. In most places two or three of the terraces are much larger than the average. The highest of these, which for convenience will be referred to as the upper terrace, is several hundred feet wide on the spur at the C. F. & I. mine, where it has an altitude of 4,400 feet. To the east it is developed on all prominent spurs at about the same elevation. Other wide terraces appear at the C. F. & I. mine at levels about 140 and 380 feet lower and on Duma Point about 50 feet lower (fig. 32).

The terraces are the result of erosion on nearly horizontal rock layers of different degrees of hardness. The weathering of the softer layers causes them to fall away from under the harder layers wherever a steep slope has been formed by erosion. Rain water descending through cracks in the hard layers also tends to wash away the soft material beneath. When undermined sufficiently the hard rock layers break off, but their recession always lags behind that of the softer layers, and as a result they project like shelves. This process is most effective in a dry climate like that of eastern Utah, because the surface is unprotected by vegetation, and the infrequent rains usually have a torrential character and thus remove the accumulated talus rapidly.

Green River, the only perennial stream in the district, flows along the west side of the manganiferous area at a level several hundred feet lower than that of most of the deposits. Springs are scarce, and the very scanty vegetation is chiefly of the sagebrush type.

GEOLOGY.

STRATIGRAPHY.

As described by Lupton[33] the formations of the region are the La Plata sandstone (Jurassic), McElmo formation (Cretaceous or Jurassic), Dakota sandstone (Cretaceous), and Mancos shale (Cretaceous). The area more particularly considered herein is underlain by the McElmo formation. On the north and south the Dakota and La Plata sandstones, respectively, crop out, and the plain extending northward to the Book Cliffs is underlain mostly by the Mancos shale. At the tops of the main escarpment and the escarpment north of Salt Wash there is a massive gray sandstone stratum called the Salt Wash sandstone member of the McElmo. Below it, forming the middle part of the McElmo, is from 50 to 350 feet of sedimentary rock consisting chiefly of thin-bedded, prevailingly red sandstone, with a thin layer of limestone and locally thick beds of gypsum. The base of the escarpment is massive red and gray sandstone that presumably forms the lower part of the McElmo. Details of the middle part of the McElmo formation as shown at the C. F. & I. mine, where the upper part is eroded, are as follows:

[33] Lupton, C. T., op. cit., pp. 123 et seq.

Section of rocks exposed at the C. F. & I. mine, Little Grande district, Utah.

Characteristic features.	Thickness (feet).	Topographic expression.
1. Gray sandstone, massive, pebbly, and cross-bedded. Two sets of vertical joints spaced from 10 to 40 feet.	20	Forms the summits of flat-topped knolls or mesas north of the main escarpment. Joint blocks rounded by weathering to huge spheroids.
2. Gray and green sandstone, thin bedded; locally contains a nonpersistent streak of manganese oxides less than 1 inch thick.	30	Outcrop subdued and generally concealed by loose material.
3. Gray sandstone, hard and massive	10	Locally forms a terrace. Weathered surface generally colored brown or black with a film of manganese oxide.
4. Variegated sandstone; red and chocolate-brown shades predominate; soft; contains nodules of secondary chalcedony showing streaks of bright red and yellow.	70	Outcrop subdued and generally concealed by loose material.
5. Limestone, gray and terra-cotta shades, compact. Layers 1 foot or less thick separated by red sandy clay that is commonly rich in gypsum and in places contains lenslike bodies of celestite a few inches thick. Locally one or more layers are replaced by manganese oxides that form workable bodies. At the bottom there is more or less reddish-brown chalcedony of secondary origin.	5-15	Underlies the upper terrace. Weathered masses of the limestone commonly show networks of open cracks that suggest shrinkage.
6. Terra-cotta sandstone; locally shows spots and streaks of chocolate-brown, pale green, and gray. Thin bedded, most of the layers ranging from an inch to a foot in thickness. Individual layers are broken by small closely spaced joints and in addition by large widely spaced or master joints that extend through several layers. Upper part locally contains small masses of manganese oxides.	60	Forms vertical walls that suggest old masonry. This appearance is due to the uniformity of the jointing in the individual layers and the fact that the joints and partings are opened and the projecting corners and edges are well rounded by weathering.
7. Gray sandstone, hard; very prominently developed, parallel vertical joints, spaced about 1 foot apart. Other joints subordinate or wanting.	1	Locally forms a narrow terrace. Breaks up into rectangular prisms, the regularity of which suggests quarried blocks.
8. Red sandstone, similar to No. 6	75	Similar to No. 6.
9. Gray sandstone	2	Forms a wide terrace.
10. Red sandstone, similar to No. 6	140	Similar to No. 6.
11. Red sandstone, massive, coarse-grained, and cross-bedded; locally shows areas of gray. Bottom not exposed.	200+	Forms rounded knobs and locally a massive terrace.

Stratum No. 1 probably corresponds to part of the Salt Wash sandstone member, Nos. 2 to 10, inclusive, to the middle part of the McElmo formation as described by Lupton,[34] and No. 11 to the lower part.

Between the C. F. & I. mine and the Gustavus claim, about 15 miles to the east, the middle part of the McElmo formation decreases in thickness to 50 feet. To the north and northwest, along Salt Wash valley, beds of gypsum and red gypsiferous clay more than 100 feet thick are associated with the limestone. Locally at the C. F. & I. mine celestite (sulphate of strontium) associated with limestone and gypsum forms nonpersistent beds 6 inches or less thick. The limestone stratum (No. 5) averages perhaps 2 or 3 feet in thickness. It is pinched out completely for short stretches and swelled to 10 or 15 feet in places. Most of the productive manganese deposits are in it or closely related to it, and therefore it is referred to frequently as

[34] Lupton, C. T., op. cit., p. 127.

the manganiferous stratum, and the position it marks in the geologic section is called the manganese horizon. The rock is fine grained, compact, and of a reddish-gray color. Most of the unweathered material shows small subangular spots in a gray background. Commonly there are numerous rather coarse phenocrysts of white calcite of a later generation than the groundmass. Heating the rock with free access of air causes the red spots to fade and small irregular streaks and specks of black manganese oxides to appear. The microscope shows the groundmass to be an aggregate of fine subangular grains. In places coarser and finer grains form indistinct wavy or crenulated bands that indicate a growth of the rock by layers successively added. In some specimens small areas along the margins of these bands are darkened slightly, suggesting manganese carbonate changing to oxides. Some of the specimens show abundant accidental impurities such as grains of kaolin and clastic quartz. Blowpipe tests give strong reactions for manganese, even in the material in which no manganese oxides can be seen. It is assumed, therefore, that the manganese occurs as carbonate. Where the rock has been exposed to the weather it shows streaks and specks of manganese oxides like the specimens that have been heated.

In most places the layer next above the limestone is a pale pinkish or greenish-gray sandstone streaked and mottled with red. It is composed of well-rounded small quartz grains bound together with a rather scanty calcareous cement. The red areas are colored by iron oxides that fill the pores of the rock and partly replace the sand grains, forming dendritic, nodular, and plumose bodies. Nearly everywhere there is a thin layer of dark-red iron-rich clay next below the limestone. In places lenticular bodies of opaque jaspery quartz as much as 1 foot thick and 50 feet or more in their greatest dimension replace one or more of the sandstone beds a few feet below the limestone layer. They are mostly a yellowish brown, but locally show various shades of red, some of which are very bright. Loose fragments of similar material are scattered over the weathered outcrops of the strata next below the Salt Wash sandstone.

Practically all the rocks of the middle part of the McElmo formation disintegrate to a loose sandy soil that is readily blown about by the wind. Extensive areas, particularly in White Wash valley, are covered with sand dunes. A representative sample of the dune sand from the east side of White Wash valley shows a pale terra-cotta color and is composed of well-rounded grains. Practically all the sample passed a No. 60 screen, and about 60 per cent passed a No. 100 screen. Most of the grains are white quartz, a few are pink or gray quartz, and there are a few specks of black magnetite. The color of the sand is due to thin films of iron oxides with which most of the grains are coated. The sand runs freely and appears not unlike that used in hourglasses.

STRUCTURE.

Along the main escarpment generally and throughout most of the plain to the north the rocks dip 3° or 4° N. Because of this fact the terraces developed on southward-facing slopes, such as prevail along the main escarpment, incline gently inward or backward from the rim, except where they are so narrow as to be covered entirely with débris from above. More extensive examples of dip slopes are found between the C. F. & I. mine and Salt Wash valley and on the north sides of many of the monoclinal ridges mentioned as rising above the plain.

About 2 or 3 miles north of the main escarpment a zone of faults crosses the plain in a N. 70° W. direction. Salt Wash valley is eroded along this zone, and the faulting, which has caused a net elevation of 300 feet[35] on the north, has indirectly given rise to the escarpment that forms the north wall of the valley. Whether the main escarpment is related to faulting was not determined. Apparently it owes its height solely to the lowering of the area in front of it by erosion.

MANGANIFEROUS DEPOSITS.

DISTRIBUTION.

Except for the negligible amounts found in the rocks generally, manganese is confined to certain geologic horizons near the middle and top of the McElmo formation. In places exposed surfaces of the Dakota sandstone are blackened by thin glossy films of manganese oxides, a coating known as "desert varnish," but the amount of manganese present is too small to be of possible economic value. On the Mongol claim, southeast of the town of Green River, near Court House, a locality on the road to Moab south of Thompson, manganese deposits are found in the variegated sandstone and shale near the top of the McElmo formation. Except fragments of ore scattered over the surface or in the soil, all the other deposits known in the district are either in the limestone near the middle of the McElmo or in the sandstone layers not far below it.

ORE BODIES.

Classification and occurrence.—The ore bodies consist of blanket veins that replace limestone, streaks and nodules that replace sandstone, and aggregates of loose fragments derived from deposits of these two classes.

[35] Lupton, C. T., op. cit., p. 130.

The limestone and its included blanket veins crop out along the outer edge or "rim" of the upper terrace. The veins are rather closely spaced in productive stretches a mile or more long at the C. F. & I. mine, The Needles, and around Duma Point. They are also abundant for a short distance at Fonder's camp, east of the C. F. & I. mine, and somewhat sparingly distributed for 5 or 6 miles along the north side of Salt Wash valley. Elsewhere workable bodies have not been found, though in the barren stretches the manganese horizon is marked by small amounts of ore or stains of manganese oxides. As a rule there is but one blanket vein in a given section of the manganiferous stratum, but in places, notably at the C. F. & I. and Salt Wash mines, several veins are closely spaced, one above another.

Streaks and nodules of ore are found commonly in the cliff just below the upper terrace or along a prominent terrace that is 50 or 60 feet lower. Their distribution is similar in general to that of the blanket veins, but in places they appear to be relatively increased where the veins are diminished.

The residual fragments are most plentiful near productive areas of the other deposits. At the C. F. & I. mine they are scattered over 1,000 acres or more and are very abundant in an area of 200 acres on the upper terrace. Elsewhere in the district the workable areas of residual deposits are comparatively small.

Character and composition.—The blanket veins are tabular bodies of very irregular plan. Most of them are betwen 20 and 100 feet in their greatest dimensions and 4 or 5 inches in average thickness. A few reach a maximum thickness of 3 feet, and one in the Gustavus claim is 6 feet thick. Most of them lie just beneath the flat top or table of the upper terrace and crop out along the edge or rim. Under thick cover at the back of the terrace most of them become thin or pinch out altogether. They are dense bodies composed chiefly of rather soft fine-grained manganese oxides, together with more or less calcite, quartz, gypsum, and barite. Manganocalcite and rhodochrosite were observed only in the deposit on the Gustavus claim at The Needles. The manganese oxides are chiefly manganite and pyrolusite, with small amounts of a soft brown material made up of fine scales. The manganite and the pyrolusite grade into each other without showing any change in their crystal form, and both are locally altered to the brown mineral. The chemistry of this change is not known, except that dehydration appears to have taken place. The calcite and gypsum occur as unreplaced fragments of the country rock and as crystals of later growth. The quartz is chiefly in the form of unreplaced sand grains. The manganese oxides, the barite, and part of the calcite were deposited at the same time. The manganocalcite and rhodochrosite and part of the calcite were deposited later. Iron oxides occur most abundantly in the clay and sandstone next below the ore and nearly everywhere are cleanly separated from the manganese. No material rich enough to be classified as iron ore was seen. Ore from the veins generally carries more than 40 per cent of manganese, less than 10 per cent of silica, and but very small amounts of iron and phosphorus. Commonly it carries as much as 70 per cent of manganese dioxide. It is interesting to note that 0.5 per cent or less of copper is reported in several of the samples.

The nodules are generally dense and of irregular form, and most of them are the size of a baseball or smaller. They are generally attached to streaks, most of which are nonpersistent and less than 1 inch thick. The streaks follow joints and bedding planes and are commonly distributed as a ragged fringe hanging from the blanket veins. The streaks and nodules contain much incompletely replaced quartz sand and a little calcite, but no manganocalcite or rhodochrosite was observed in them. Otherwise they are similar in mineralogy to the blanket veins and yield a rather siliceous ore.

The residual deposits may be regarded as thin tabular bodies lying on the surface. Compact workable areas several acres in extent are found in places. Commonly these deposits are concentrated by the wind, which blows away the soil and sand until enough ore fragments are exposed to cover the surface and thus protect it from further deflation. The fragments represent chiefly the harder and poorer parts of their parent bodies, much of the softer and richer material being broken to fine particles and lost during erosion. The fragments on the upper terrace at the C. F. & I. mine were derived almost wholly from thin blanket veins that lay just above the veins now being worked. Many of the fragments have been somewhat enriched by the solution and removal of calcite during weathering, but in general they yield ore of lower grade than that in the veins. Fragmental deposits derived largely from the streaks and nodules are highly siliceous.

Origin.—Although the ultimate source of the manganese is obscure, the facts set forth below indicate some of the steps by which the ore bodies were formed.

The blanket veins are dense bodies of manganese oxides that are generally thickest near the rim of the terrace and commonly pinch out short distances back from the rim. They replace a limestone bed that contains small amounts of manganese carbonate as an original constituent and is associated with beds of gypsum and red sandstone that have the features of subaerial deposits. Apparently in McElmo time, during the sedimentation of a basin that at times held a water body and at times became dry, a thin bed of limestone containing carbonate of manganese was deposited. Sedimentation continued for a long time thereafter, probably until the middle of the Tertiary period. Afterward the region was elevated and eroded, and in time the McElmo sediments were uncovered and carved into the fantastic escarpments, terraces, and other forms they show to-day. As the limestone became exposed it was attacked by surface waters, which, under conditions not clearly understood, dissolved the manganese and carried it back along the bedding planes, allowing some to escape through joints and cracks into the sandstone below. From solution the manganese was redeposited as dense bodies of oxide that replaced the limestone in the form of blanket veins and the sandstones in the form of streaks and nodules. Continued erosion broke down some of the earlier-formed bodies and scattered their fragments over the surface and through the soil. Possibly new bodies were forming at the same time in the limestone farther back. If the formation of the oxide bodies is going on at present, however, it is not keeping pace with erosion.

Irregularities in the distribution and occurrence of the ore bodies may be explained by accidents of erosion and variations in the thickness of the parent limestone. At the C. F. & I. mine and other places where the ore bodies are unusually large and numerous the limestone is unusually thick and has retarded lowering of the surface by its superior resistance to erosion. On the other hand, ore is almost universally absent around the heads of the deeper notches that break the front of the escarpment in many places. Here the corrasion of occasional floods has worn the limestone back too rapidly to permit solution and concentration of the manganese.

The Mongol deposit and the deposits at Court House differ somewhat from those just considered, but they are thought to be of essentially similar origin.

MINES AND PROSPECTS WEST OF WHITE WASH.

C. F. & I.

Location and history.—Several deposits of manganese ore along the main escarpment about 15 miles southeast of the town of Green River, owned by the Colorado Fuel & Iron Co., are known collectively as the C. F. & I. mine. The deposits were located prior to 1901 and sold to the company mentioned, which worked them at times in that year and in 1903, 1904, and 1906. Thereafter operations were suspended because of the low price of manganese ore and the long haul to market. Early in 1917 mining was begun by the Green River Mining Co. as lessee, which continued work until some time in the second half of 1918. Fifteen or twenty men and several teams were employed digging and hauling ore to the railroad when the writer visited the mine in May, 1918.

Considerable ore is said to have been dug by the Colorado Fuel & Iron Co., which shipped part of it East and left the rest in a pile at the railroad, where afterward it came into possession of the Green River Mining Co. During the later period of mining activity several thousand tons of manganese ore were produced, most of which was shipped East for use in making steel, the remainder being sold under the trade name "dioxide ore" to the manufacturers of dry batteries and chemicals.

Accessibility and mining conditions.—The mine is easily reached from the town of Green River by automobile over a road about 20 miles long. Floy, a siding on the Denver & Rio Grande Railroad 10 miles north of the mine, is the nearest shipping point. The roads are generally level but in many places soft and sandy. Hauling is done by mule teams. A motor truck is said to have been tried and found unsuited to the roads. The mine camp is at the back of the upper terrace, in a small cove between two knolls. Green River, the nearest perennial stream, is about 5 miles to the west and 400 feet lower. Water is hauled from a spring in White Wash valley about 3 miles to the east, but the road to the spring is nearly 6 miles long.

Mining operations consist of raking and picking up loose ore fragments from the surface, screening them from the loose, dry, sandy soil, and uncovering the more deeply buried bodies with a plow and scraper or a pick and shovel.

Surface features.—At the C. F. & I. mine the upper or 4,400-foot terrace is exceptionally well developed. On the Maine claim, at the east, it forms the top of a small spur, and farther west it covers virtually all of the large spur on which most of the mining ground is located. On the larger spur the top or table of the terrace shows a persistent northward slope of about 3°, corresponding to the dip of the underlying rocks. At its maximum on the larger spur the terrace is about half a mile wide, but only a strip from 50 to 500 feet wide along the outer edge or rim remains an unmodified flat surface. Back of this the surface is roughened by small ravines, and toward the west the terrace disappears entirely in an area of badlands. On the extreme point of the spur a small knoll or mesa, known as Candy Hill, rises slightly above the terrace level. At the back of the terrace a moderate slope that rises about 100 feet is surmounted by a chain of small flat knobs or mesas. Drainage from the top of the spur escapes partly to the south through ravines west of Candy Hill and partly to the north through Hogan Gulch, a shallow valley that leads to Salt Wash.

Two or more prominent terraces are developed at lower levels, where they form the tops of fantastic abutments to the principal spur (fig. 32).

Rock formations.—A condensed description of the rocks at the C. F. & I. mine is given in the tabular section on page 187. The limestone stratum (No. 5) crops out along the edge or rim of the upper terrace and underlies most of the flat top or table. In most places this stratum is between 2 and 5 feet thick, but on the southern and western extremities of the spur its thickness is increased to 15 feet or more, owing mainly to the presence of beds of gypsum. On Candy Hill it contains in addition a bed of celestite, the sulphate of strontium, 6 inches or less thick. The limestone itself shows a terra cotta color in most places and is generally mixed with considerable clay. At the bottom of the stratum, west of Candy Hill, there are

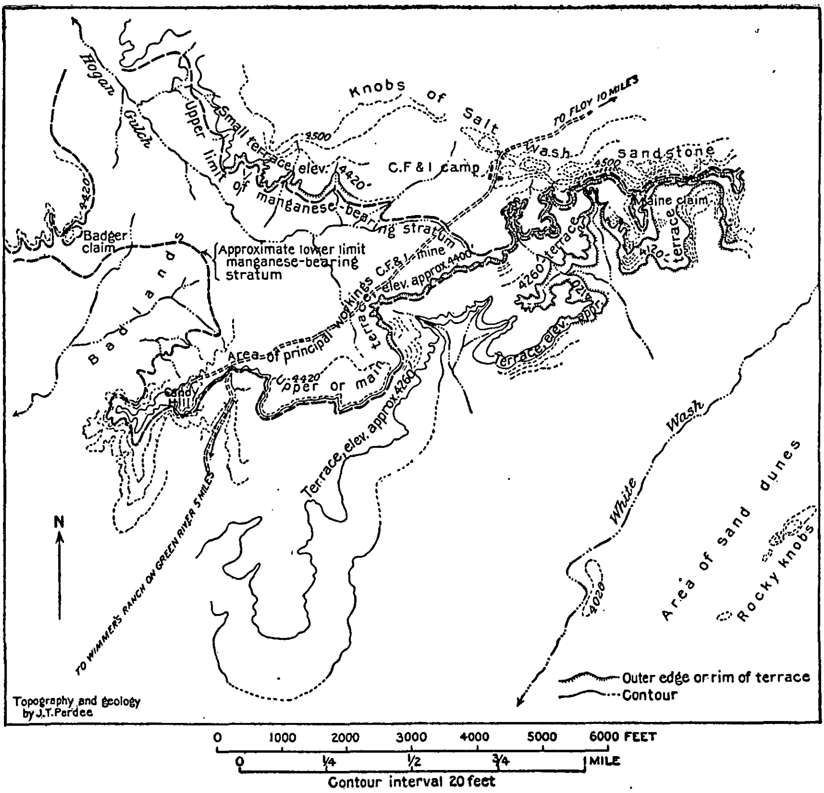


FIGURE 32.—Map showing terraces at the C. F. & I. mine, Little Grande district, Utah.

several bodies formed like blanket veins, composed of reddish-brown jaspery quartz. The gray sandstone and the massive red sandstone designated, respectively, No. 9 and No. 11 in the table on page 187 form prominent terraces at lower levels (fig. 32).

The dip of the rocks at the C. F. & I. mine averages about 3½° N. Northwest of the area, along Hogan Gulch, the dip increases somewhat and finally carries the manganese horizon below the deepest channel. However, as noted in the description of the Salt Wash mine on page 204, it is again brought to the surface a few miles farther north by a fault.

Except in a few places that are swept bare by the wind the upper terrace bears about a foot of loose, sandy red soil. Similar material covers many of the slopes and terraces below, and the eastern side of White Wash valley is occupied by migrating sand dunes.

Ore bodies.—Manganese ore occurs in blanket veins in the limestone stratum, irregular streaks or nodules in the underlying sandstone, and loose fragments in soils to which the decay of these rocks has contributed. The blanket veins are numerous and productive in a strip next to the rim of the upper terrace around the spur on the Maine claim and along the front of the larger spur for a distance of a mile or more. Around the notch that separates the two spurs the veins are rather scarce. The area back of this strip on the large spur and along the upper course of Hogan Gulch contains many veins, but few of them are thick enough to be workable. In the bad-land area west of Candy Hill, on the Badger claim, several veins of workable size crop out on top of knolls that reach the terrace altitudes.

The veins are very irregular in plan and intricate as to detail, but most of them may be generalized as tabular bodies from 20 to 100 feet long, half as wide, and from 3 inches to a foot in maximum thickness. Many are, of course, smaller than this, and one on Candy Hill is 3 feet thick. Generally but one vein is found in a stretch, but in places several are closely spaced one above another.

The streaks and nodules are in general of similar distribution to the blanket veins. Few of them appear to be workable, and their development so far has been incidental to mining the veins.

Loose fragments in the soil, residual from weathering of the rocks that contain the blanket veins, the streaks, and the nodules, are irregularly distributed over an area that includes the upper terrace, the floor of White Wash valley, and the intervening slopes and terraces. Over a large part of the upper terrace and in patches elsewhere they form workable deposits that have yielded about half of the ore produced to date. The fragments are angular and rough and range from small pebbles to boulders 1 foot in diameter; most of them, however, are the size of a hen's egg or smaller. On the upper terrace amounts ranging from 20 to 100 pounds to the square yard, equivalent to 45 to 220 tons to an acre, are separated from the dry soil by screens with three-eighths or one-half inch mesh. Below the upper terrace ore fragments are unequally distributed over a large area that comprises slopes, terraces, and extensive flats. Undoubtedly the amount in the aggregate is large, but generally the fragments are too widely scattered or too thinly mixed with waste to be workable under ordinary conditions. Several of the richer patches, some of which are probably workable, are roughly estimated to contain from 10 to 40 pounds of available ore to a square yard, or approximately from 22 to 88 tons to an acre.

In the ore bodies described the manganese occurs in the form of oxides. The blanket veins consist mainly of a dense fine-grained crystalline blue-black material, whose streak and hardness vary between those characteristic of pyrolusite and manganite. Fragments of unreplaced limestone are generally present, and locally one or more of the minerals calcite, barite, and gypsum are intergrown with the manganese oxides. Iron oxides are scarce in the ore bodies but rather plentiful in the adjoining rocks.

Generally ore and waste are sharply separated, but in places on the Maine claim and elsewhere the vein material shows gradations between unmixed manganese oxides on one hand and limestone on the other. The unmixed ore carries from 40 to 50 per cent of manganese, 10 per cent or less of silica, and very little iron or phosphorus. Much of it runs 70 per cent or more in manganese dioxide. The streaks and nodules are of similar composition except that they contain unreplaced sandstone instead of limestone and are therefore rather siliceous.

The residual fragments appear to be more largely composed of manganite than the bodies from which they are derived, a difference probably caused by the fact that pyrolusite is the softer and is therefore more readily broken to fine particles and lost during the transformation. Many of the fragments are roughened with small pits from which calcite has been dissolved by rain water. The samples of 35 carloads composed chiefly of residual fragments mixed with a small amount of ore from the blanket veins show an average content of 41.3 per cent of manganese and 10.6 per cent of silica. In 10 of the cars iron averages 1.5 per cent. Other constituents were not reported. Presumably the ore was rather high in lime and low in phosphorus.

SEVEN UP.

The Seven Up group of claims is along the main escarpment about a mile east of the C. F. & I. mine and may be reached over a branch from the road between that mine and Floy. In 1917 the claims were developed by the Burgess Minerals Co. under the direction of Gustave Sessinghaus, who produced a small quantity of dioxide ore. In May, 1918, the property was idle.

On the Seven Up claims the 4,400-foot or upper terrace is relatively prominent, the rocks are the same as those at the C. F. & I. mine, and the dip of the beds is also northward at a small angle. Likewise the terrace marks the position of a thin limestone bed in which most of the ore is found. The limestone is generally 1 or 2 feet thick, but in places it is much thinner or absent altogether. Microscopic examination shows it to be a compact aggregate of fine calcite grains, the outlines of which suggest crystal forms. In places there are larger grains that show the crystal outlines more distinctly.

The ore bodies are blanket veins that replace the limestone and irregular streaks and nodules that occur in the underlying sandstone and shale (fig. 33). They are most numerous and extensive on the points of projecting spurs, where the terrace is relatively wide. The veins range from 1 inch to 8 inches in thickness, and one covers an area of about 200 square yards. The other veins are of smaller area, and all are long and narrow and lie next to the rim of the terrace.

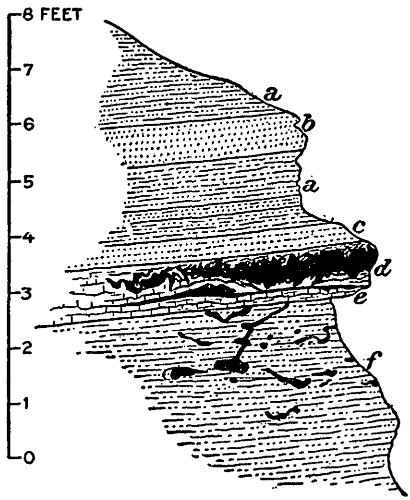


FIGURE 33.—Section of manganiferous stratum on Seven Up claim, Little Grande district, Utah. *a*, Sandy red shale; *b*, gray sandstone; *c*, gray sandstone with plumose streaks of iron oxides; *d*, limestone partly replaced by manganese oxides; *e*, brown shale; *f*, thin-bedded red sandstone with streaks and nodules of manganese oxides.

The ore is a dense, finely crystalline blue-black material that varies in hardness from place to place. The softer portions show a black streak and are probably pyrolusite. The harder portions give a brown streak and have other properties characteristic of manganite. The two varieties are not distinctly separated. Generally, the boundary between ore and waste is sharp, but in places the change from one to the other is gradational, and here replacement of the limestone by manganese oxides is plainly shown. Generally the manganese oxides attack the groundmass of the rock in preference to the larger calcite grains, which are left embedded in the ore. Ore selected from the veins is said to carry from 70 to 84 per cent of manganese dioxide, with very little iron, silica, or phosphorus.

The streaks and nodules consist of finely crystalline manganite with which commonly a little barite is intergrown. Most of them contain small cavities lined with free crystals of manganite and barite, and many of the cavities are partly filled with a soft brown material that is an aggregate of extremely small scales of an undetermined manganese oxide. No ore is reported as produced from the streaks and nodules. They contain unreplaced grains and are evidently high in silica.

Ore fragments residual from the weathering and erosion of the bodies described are rather plentiful in a few small areas and are estimated to form a small ore reserve. A small amount of available ore also remains in the blanket veins.

BLACK BEAR.

The Black Bear group of claims extends along the main escarpment about 2 miles east of the C. F. & I. mine, or a mile beyond the Seven Up group. In May, 1918, ore was being mined by J. B. Fonder, who reported a production of several carloads prior to that time.

Most of the ore bodies are found on a short spur that projects southward from the line of the escarpment and exhibits the characteristic cliffs and terraces. The rocks are the same as those at the Seven Up and C. F. & I. mines, above described, except that the limestone at the manganese horizon is rather thin and discontinuous. On the upper terrace a blanket vein that surrounds the point of the spur is exposed by a cut from 10 to 50 feet wide and about 700 feet long (fig. 34). In most places near the rim the vein averages 5 or 6 inches in thickness, but a few feet back it is considerably thinner as a rule and in places pinches out entirely. Beyond the limits of this ore body the manganese horizon shows few workable veins, but in places the underlying sandstone contains unusually abundant streaks and nodules of ore. At one place an open cut shows them to form as much as 5 or 10 per cent of a layer 8 feet thick. A terrace about 50 feet below the upper terrace marks the position of two or more blanket veins, the largest of which is 5 inches thick and 200 feet long. Residual fragments form a small workable deposit on the slope below the lower terrace.

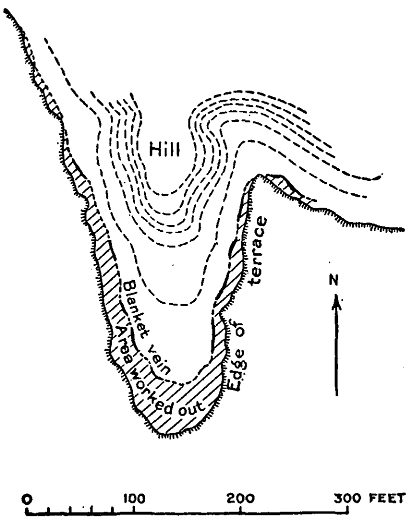


FIGURE 34.—Plan of Black Bear mine, Little Grande district, Utah.

The blanket vein exploited on the upper terrace is composed mainly of dense, finely crystalline pyrolusite, with which a little calcite and barite are intergrown. A sample said to represent 30 tons of ore carried 78.2 per cent of manganese dioxide, 51.3 per cent of metallic manganese, 4.2 per cent of silica, and 0.3 per cent of iron. The other ore bodies mentioned consist of pyrolusite, barite, and more or less unreplaced quartz sand. They are presumably of lower grade. A specimen from a body on the lower terrace contains a little of the undetermined flaky brown oxide mentioned in the description of the Seven Up group.

ADDITION AND MULTIPLY.

The Addition and Multiply claim, at the west of the Black Bear group, is said to have been developed in 1916, when about a carload of ore was produced. The workings expose a blanket vein 100 feet long, 15 or 20 feet wide, and 4 to 16 inches thick, which consists of limestone and manganese oxides mixed in various proportions. Most of the ore remaining is of low grade.

MINES AND PROSPECTS ON DUMA POINT.

Eastward beyond the Black Bear group along the sinuous line of the main escarpment no workable deposits are known for several miles, but the manganese horizon is said to be generally marked by stains of manganese oxides. On the long southward projection of the escarpment known as Duma Point the deposits reappear. Except in a few details the rock section is similar to that at the C. F. & I. mine, which is only 4 or 5 miles to the northwest. A terrace prominently developed at an elevation of about 4,400 feet marks the position of a bed of limestone that contains numerous blanket veins and is evidently to be correlated with the upper terrace at the mines previously described. A terrace about 50 feet lower, developed on a sandstone bed equivalent to stratum No. 7 in the section given on page 187, carries a few ore bodies here and there.

Several of the ore bodies were developed in 1915 by Elmer & McWilliams and in 1917 by the Burgess Minerals Co., a total production of 850 tons of ore that was largely of the dioxide grade being reported. A moderate amount of medium-grade ore is estimated in reserve. In the following pages the deposits are described in the order in which they are met in a trip around Duma Point from west to east.

SUEZ.

On the Suez claim, which is on the west side of Duma Point, about a mile north of its end, a blanket vein on the upper terrace surrounds a small spur. As developed by an open cut it ranges from 1 to 6 or 8 inches in thickness and is at least 50 feet long and 20 feet wide. It consists chiefly of dense, fine-grained pyrolusite, with a little calcite and an undetermined flaky brown oxide of manganese that occurs in small vugs. In places aggregates of the brown flakes preserve the outward crystal form of pyrolusite or manganite, of which they appear to be an alteration product. Commonly also the flakes are inclosed by free calcite crystals. The ore produced from this vein is said to have contained 75 per cent of manganese dioxide, 9.6 per cent of silica, 0.033 per cent of phosphorus, and 0.41 per cent of copper. A few small, irregular streaks of ore occur in the sandstone below the vein.

U. S. GERMAN.

The U. S. German group of claims is developed by several shallow cuts along the upper terrace that range from 10 to 50 feet in width and have a total length of about 1,000 feet. They expose several blanket veins formed in the lower of two layers that compose a thin limestone bed. The veins range from 1 to 4 inches in thickness and consist of dense, fine pyrolusite with a little barite and an undetermined brown flaky oxide. A carload of ore mined by the Burgess Mineral Co. is said to have contained 84.5 per cent of manganese dioxide, 53.4 per cent of metallic manganese, 0.336 per cent of iron, 0.851 per cent of copper, and 0.382 per cent of sulphur. In most places the limestone adjoining the vein has been partly replaced by manganese oxides and thus converted into a mixed ore estimated to carry from 20 to 35 per cent of manganese.

AMY.

The Amy claim is said to contain a blanket vein at the upper terrace level that ranges from 3 inches to 3 feet in thickness and is 50 feet long. It is filled with manganese oxides and in general is similar to the veins previously described.

DUMA.

The Duma group of claims covers the end of Duma Point, around which a vein has been mined on the upper terrace (fig. 35). The vein is about 300 feet long and 10 to 40 feet wide and lies next to the rim, back from which it pinches out. Several smaller veins occur farther north at the same level along the west side of the point. Most of them average 3 or 4 inches in thickness, and all become thinner back from the rim. The ore from these bodies consists mainly of dense, fine pyrolusite, with a little calcite and barite.

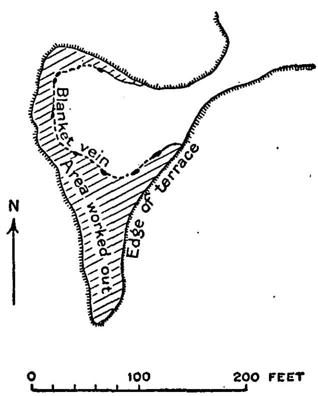


FIGURE 35.—Plan of Duma No. 1 mine, Little Grande district, Utah.

At a level about 500 feet lower a terrace is developed on a thin but persistent layer of hard sandstone, the equivalent of stratum No. 7 in the C. F. & I. section given on page 187. At one place on the east side of Duma Point a deposit of manganese oxide lies on this terrace. It is made up of rough, flattened nodules that range from some the size of a man's hand to masses 5 or 6 inches thick and a foot long and are so distributed as to form in the aggregate a blanket vein 100 feet or more in length. The body has replaced sandstone and yields a rather siliceous ore.

A short distance north of this body, at a level about 40 feet lower, a sandstone layer 5 or 6 feet thick shows noteworthy amounts of iron and manganese oxides. Qualitative tests of a sample representing a body 2 feet thick indicate that it may contain as much as 30 per cent of iron and manganese together, the iron preponderating.

In a few small areas in these claims residual fragments are plentiful enough to form workable deposits.

WEST POINT.

The West Point group of claims cover a small flat spur that projects southwestward from Duma Point at the level of the lower terrace. Small blanket veins are said to be found along the rim of the terrace for a distance of 2,000 feet. Small quantities of ore are reported as mined and in reserve.

MONDAY.

On the Monday claim, along the east side of Duma Point, small ore bodies found on the lower terrace have yielded a little ore.

RED ROCK.

Several carloads of manganese ore are said to have been produced from deposits at the upper terrace level on the Red Rock claim. The principal working is an open cut 10 feet in maximum depth, 15 or 20 feet wide, and 500 feet long. It exposes a limestone bed containing several blanket veins, the most productive of which has the form of an irregular lens about 15 feet in diameter and 2 or 3 feet thick in the middle. Most of the other ore bodies are of tabular form and not more than a few inches thick. One of them is followed under cover by a drift 30 feet long, at the end of which the following section is exposed:

Section in drift on Red Rock claim.

	Ft.	in.
Red clay.		
Limy sandstone partly replaced by ore		6
Sandstone with streaks and nodules of ore	1	
Ore		6
Sandstone with scattered nodules of ore	2	

The ore consists of fine-grained pyrolusite and more or less barite, calcite, and unreplaced sand grains.

FAIRPLAY.

On the Fairplay claim, north of the Red Rock, a thin blanket vein on the upper terrace is uncovered by a narrow cut 120 feet long. A little manganese ore is said to have been produced from this vein.

BLACK ROCK.

On the Black Rock claim an open cut uncovers a rather persistent blanket vein on the upper terrace, about 5 inches thick, 20 feet wide, and 120 feet long. This vein has replaced limestone and consists of dense, fine pyrolusite mixed with considerable calcite and a little barite. A short distance west of it a small cut exposes a vein that is locally 1 foot thick and is formed in the sandstone below the limestone. Loose fragments of ore are plentiful in an area of half an acre below the terrace, where they probably form a workable deposit.

BLACK QUEEN.

A blanket vein filled with manganese oxides is found on the Black Queen claim, at the upper terrace level. As exposed for 200 feet in an open cut the vein is 8 inches thick, has replaced limestone, and consists of pyrolusite, with more or less calcite and barite.

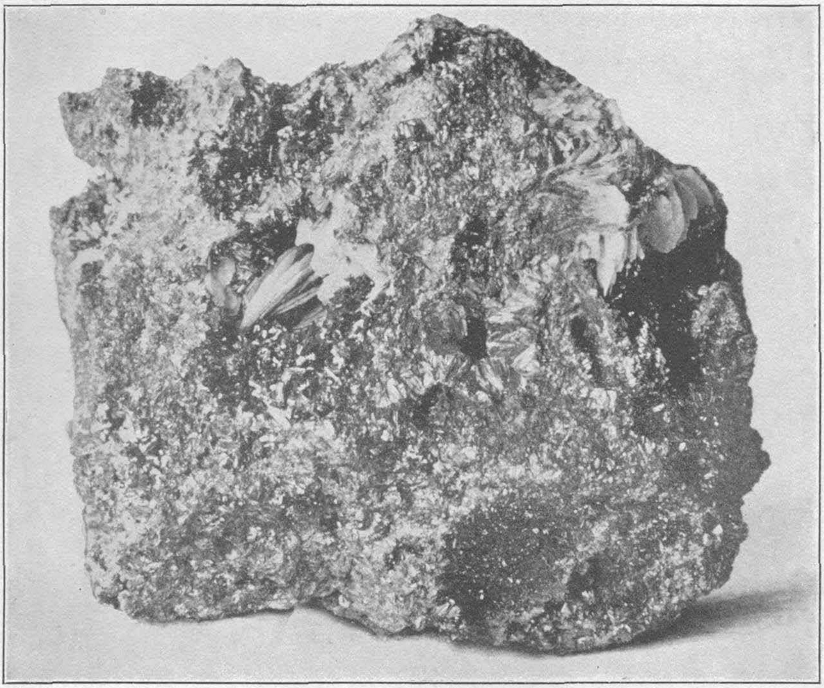
MINES AND PROSPECTS NEAR THE NEEDLES.

Several claims from which considerable manganese ore was produced in 1918 by the Needles Mining Co. lie east of Tenmile Wash, near some picturesque rocks known as The Needles and about 18 miles south of Crescent, on the Denver & Rio Grande Railroad. They cover part of the eastward continuation of the main escarpment, which is here of the same general form and features as elsewhere. As brought out by the following comparison, however, the middle part of the McElmo formation is much thinner:

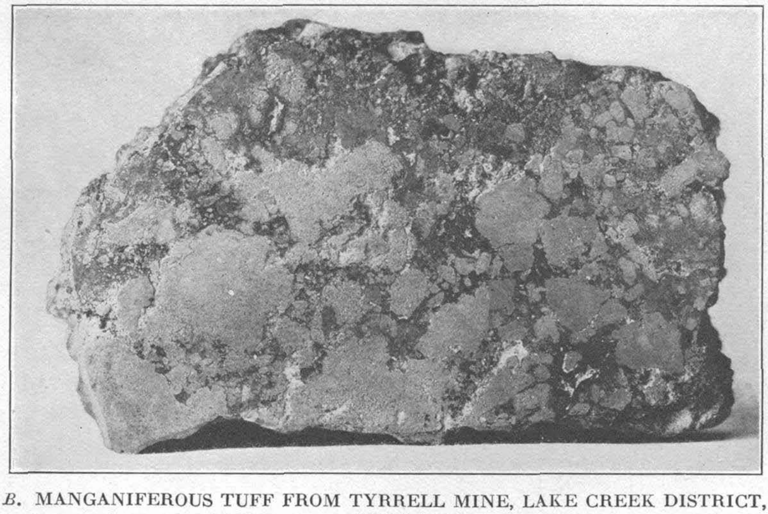
Comparison of sections at Gustavus claim and C. F. & I. mine.

Section at Gustavus claim.		Probable equivalent in C. F. & I. section (p. 187).		
		Bed No.	Thickness.	Member.
Top eroded.	Feet.		Feet.	
Gray cross-bedded pebbly sandstone....	....	1	....	Salt wash sandstone.
Thin-bedded red sandstone.............	50	2, 3, 4	110	Middle part of McElmo formation.
Limestone; sandy. Contains bodies of manganese ore........................	1-5	5	5-15	
Unconformity (?)........................	....	6, 7, 8, 9, 10	278	
Massive red and gray sandstone........	....	11	....	Lower part of McElmo formation.
Bottom not exposed.				

On the Gustavus claim irregular blanket veins crop out for 300 feet at the upper terrace level. Open cuts develop one body 60 feet long, 30 feet wide, and 5 feet thick; another 80 feet long, 20 feet wide, and 2 feet thick; and two smaller ones each about 1 foot thick. They consist chiefly of limestone, with manganese oxides and other minerals of a later generation. Perhaps one-third of the material they contain averages 35 per cent of manganese. In mining about one-sixth



A. MANGANESE OXIDE ORE FROM NEEDLES MINE, LITTLE GRANDE DISTRICT, UTAH.



B. MANGANIFEROUS TUFF FROM TYRRELL MINE, LAKE CREEK DISTRICT, OREG.

of the material broken is selected to carry 40 per cent or more of manganese. The selected ore consists chiefly of pyrolusite and manganite, with more or less barite, calcite, and manganocalcite. Locally a light-pink, coarsely crystalline rhodochrosite is present. The ore contains many vugs lined with free crystals of manganite and pyrolusite that look like so many little square-ended rods. They are gathered together in radial aggregates or small bundles. The barite forms platy crystals deposited at the same time as the manganese oxides. Calcite and manganocalcite are in part contemporaneous with the oxides and in part later. The rhodochrosite fills vugs and cracks and is evidently later than the bulk of the manganese oxides. (See Pl. X, *A*.)

On the Autotruck No. 2 claim, half a mile east of the Gustavus, the terrace that marks the manganese-bearing stratum gives place to a very gentle soil-covered slope. Here open cuts expose between 200 and 300 feet in total length of blanket veins that are irregular in plan, about a foot in average thickness, and of similar composition to those in the Gustavus claim, except that no rhodochrosite was observed in them. Streaks and nodules of manganese oxides are fairly abundant in a 2-foot bed of sandstone beneath the blanket veins.

On the Autotruck No. 1 claim, half a mile east of the Autotruck No. 2, the manganese horizon is marked by a narrow discontinuous terrace developed on a rather gentle slope. An area of 2 acres is partly explored by several pits that expose blanket veins ranging from 6 inches to 2 feet in thickness. These bodies are variable in composition, but parts of them are estimated to carry 40 per cent or more of manganese. The manganiferous stratum can be readily traced half a mile farther east, but it carries only a little ore in places.

Residual fragments of ore are scattered through the soil here and there but not in sufficient quantities to form many workable deposits. On the slope below the Gustavus ore body several boulders of ore that would weigh half a ton were found.

A large number of samples of mixed ore from the bodies described, reported by the Needles Mining Co., average a little more than 45 per cent of manganese. Several carry from 59 to 86 per cent of manganese dioxide, 6 to 9 per cent of silica, about 0.35 per cent of iron, 0.033 per cent of phosphorus, and 0.20 per cent of copper.

MINES AND PROSPECTS IN OUTLYING AREAS.

SALT WASH.

The Salt Wash mine comprises several claims along the base of the escarpment that forms the north wall of Salt Wash valley. It was worked in a small way at different times in 1916 and 1917 by McCarty & Tomlinson and Elmer Dahling. In 1918 work was continued by the Green River Mining Co., which produced a considerable amount of ore.

The escarpment north of Salt Wash valley consists of a vertical cliff from 40 to 100 feet high with terraced slopes above and below. Its course averages about N. 70° W. but is very irregular in detail. The rocks composing it are the equivalents of those in the upper part of the C. F. & I. section (p. 187). At the foot of the slope red sandstone is exposed. Above this is the manganiferous stratum, consisting of a discontinuous layer of limestone and more or less mixed gypsum and red clay. The cliff is chiefly gypsum and is probably also to be regarded as part of the same stratum. The gypsum is overlain by sandstones similar to beds Nos. 4, 3, and 2 in the C. F. & I. section, and above these is the type occurrence of the Salt Wash sandstone. The general inclination of the rocks is 3° or 4° N., but locally the dip changes as a result of faulting. Salt Wash valley is eroded along a fault zone that has caused the block north of it to be elevated relatively about 300 feet. Thus the manganiferous stratum that is carried by the general dip below the surface north of the C. F. & I. mine is here again brought to view. Apparently the escarpment, which is somewhat north of the fault, is inherited from the uplifted wall of that fracture, its present position and irregularities being due to erosion since the fault movements ceased.

The ore bodies consist of blanket veins and patches of residual fragments that are similar in character and occurrence to those at the C. F. & I. mine. They are distributed rather sparingly and irregularly for a distance of 6 or 7 miles along the slope at the base of the escarpment, where the manganese horizon is generally marked by a terrace. At the east, on the Wildcat and adjoining claims, where most of the mining has been done, the blanket veins are comparatively numerous, and the overburden is thin. Most of the veins are from 1 to 6 inches thick and less than 50 feet long or broad, and in places several are closely spaced, one above another. On the Albert claims, near the middle of the ore-bearing strip, several workable veins crop out, and a number of them are so closely spaced as to form an almost continuous body from 1 to 6 inches thick and 500 feet long. Another vein near by attains a maximum thickness of 3 feet. On the Black Bear and other claims west of the strip the veins are of comparatively small extent and from half an inch to 4 inches in thickness. Residual fragments are rather generally distributed along the slopes below the blanket veins in the different parts of the strip mentioned, but they do not form workable deposits of any great extent.

The blanket veins consist of manganese oxides, chiefly pyrolusite and manganite, with more or less gypsum and unreplaced limestone or sandstone. Many of them yield a fine-grained, dense ore similar in appearance to the dioxide ore of the C. F. & I. mine. Others contain an excess of snow-white gypsum that is intergrown with the manganese minerals and was evidently deposited by the same solutions.

In the middle and western parts of the strip reddish-brown jasper forms numerous bodies that are similar to the blanket veins in form and size. They lie at the manganiferous horizon in many of the stretches barren of ore and also in a plane just below that horizon where ore occurs. Their close association with ore suggests that they are in some way complementary to it, possibly representing some of the material removed by the solutions that deposited the ore.

SUNRISE.

The Sunrise group of claims, owned by Col. J. A. Shinn and Albert Hahnewald, is on the west bank of Green River about 16 miles below the town of Green River. The deposit is said to be of similar occurrence and character to those at the C. F. & I. and Salt Wash mines. A carload of mixed ore from blanket veins and residual deposits is said to have contained 43.72 per cent of manganese, 8.62 per cent of silica, 0.91 per cent of iron, and 0.07 per cent of phosphorus. A moderate amount of similar ore is estimated in reserve.

MONGOL.

About a carload of ore is reported to have been shipped in 1917 from the Mongol claim of W. F. Reeder, 5 or 6 miles southeast of the town of Green River. The mine is on the north side of Little Grande Wash valley, below an irregular east-west escarpment from 100 to 200 feet high. The rocks exposed are the Dakota sandstone and a considerable thickness of variegated shale that belongs to the upper part of the McElmo formation. The sandstone forms cliffs at the top of the escarpment above slopes composed of the shale. The beds exhibit a rather uniform dip of 2° or 3° N. except along the front of the escarpment, where they are bent steeply down on the south. The axial plane of this fold coincides with a fault that dips 50° N., on which the mass forming the hanging wall has dropped relatively. Both walls are well defined and marked with grooves.

As shown by an open cut 40 feet long and 20 feet deep, the manganese deposit is a tabular body or vein from 6 inches to 3 feet in thickness that, together with more or less crushed country rock, occupies the fault fracture. The outcrop is low and generally concealed by surface mantle, but small fragments and stains of manganese found here and there indicate the lode to persist several hundred feet east and west of the cut. At one end of the cut a shaft, now filled with waste, is said to have followed the ore shoot to a depth of 40 feet without showing any decrease in its thickness.

The ore consists of soft, compact, finely crystalline manganese oxides, regarded to be chiefly pyrolusite, in which fragments of partly replaced shale and sandstone are embedded. The ore shipped is said to have averaged 47 per cent of manganese and 15 per cent of silica.

COURT HOUSE.

Outcrops of manganiferous material are reported at a locality known as Court House, south of Thompson on the road between Thompson and Moab. According to J. B. Fonder, the manganese occurs in the upper part of the McElmo formation a short distance below the Dakota sandstone. The beds dip 25° N., and certain sandy layers are incompletely replaced by manganese oxides. One layer 18 inches thick shows manganese throughout but no ore. Large fragments broken from the manganiferous beds have rolled down the slopes below.

STOCKTON.

A manganese deposit is reported on the Stockton claims, on the north side of Salt Valley, about 18 miles southeast of Thompson, on the Denver & Rio Grande Railroad. According to H. Clark, of Thompson, manganese oxides are found in places along a southeast reef of sandstone 3 or 4 miles long. An 80-foot shaft is said to penetrate a flat-lying body of siliceous manganese ore 6 feet thick. No production is reported.

TINTIC DISTRICT.

GENERAL FEATURES.

The Tintic district is described in detail by Lindgren and Loughlin [36]. It is in the East Tintic Mountains, about 60 miles south of Salt Lake City, and is served by two railroads, the Denver & Rio Grande and the Los Angeles & Salt Lake. The rocks are Paleozoic quartzite and limestone that have been intruded by Tertiary granitoid rocks and largely overspread by Tertiary lavas.

The lodes, which are considered among the most valuable deposits of silver and other metals found in this country, commonly contain small amounts of manganese. So far, however, only one workable deposit of manganese ore has been found, namely, that in the Tip Top tunnel, in the eastern part of the district. This body is of moderate size, podlike form, and cavernous texture and consists of manganese oxides with quartz and other impurities. It

[36] Lindgren, Waldemar, and Loughlin, G. F., Geology and ore deposits of the Tintic mining district, Utah: U. S. Geol. Survey Prof. Paper 107, 1919.

was formed by the replacement of limestone, the parent manganese mineral presumably being a carbonate. Like the other lodes of the district it is probably related in origin to some deep-seated intrusive rock.

TIP TOP TUNNEL.

An adit level on a claim in the eastern part of the Tintic district belonging to the Chief Consolidated Mining Co. is known as the Tip Top tunnel. It was run prior to 1917 to develop a silver lode and incidentally disclosed a deposit of manganese. Mining of manganese ore was begun under a lease in October, 1917, by T. L. McCarty & Co., and continued in 1918 by Huish & Bean. The total production prior to the writer's visit (June 20, 1918) is estimated to be 1,200 tons.

The adit is driven 250 feet in the slope south of Homansville Canyon, at a level about 300 feet above the stream. Near the face a raise is made to the surface, 90 feet above. The ore is conveyed by a wire-rope tramway from the mouth of the adit to the foot of the slope, from where it is hauled a short distance to a siding on the Denver & Rio Grande Railroad.

The country rock is the Ordovician Opohonga limestone, described by Loughlin,[37] which occupies a small area along the south side of Homansville Canyon. On weathered surfaces it shows a striped or mottled appearance caused by alternating thin layers of clayey material and relatively pure carbonate. Fresh exposures are uniformly light gray. Small streaks and bunches of manganese oxides crop out here and there along the ridge above the adit, in a belt 10 to 40 feet wide and 500 feet or more long. As shown by the workings, some of these streaks are offshoots from the body that is being mined.

The deposit explored by the adit is an irregular pod or pipelike body at least 90 feet long and from 3 to 40 feet in diameter. It pitches about 45° S., and so far as the adit shows does not extend below the roof of the adit. It reaches the surface as one or more small veins that crop out near the middle of the manganiferous belt mentioned. The ore is cavernous, rather loose and friable in places, and made up chiefly of nodules and streaks of manganese oxides, with soft clayey material partly filling the spaces between. The oxides are intimately mixed, and so far as can be determined psilomelane is the most abundant. Commonly the smaller cavities are filled with wad or lined with free crystals of pyrolusite. The clayey material consists chiefly of kaolin and quartz, with small amounts of iron oxides.

In mining about two-thirds of the mass is selected as ore, of which most of the shipments averaged approximately 37 per cent of man-

[37] Op. cit., pp. 32–33.

ganese and 12 per cent of silica and contained from 0.25 to 0.45 per cent of phosphorus. However, one of the last car lots shipped, which had been more carefully selected in mining, carried 44.89 per cent of manganese and 0.253 per cent of phosphorus, the other constituents determined being silica 7.35 per cent and iron 0.55 per cent. Only a small ore reserve is developed, but additional amounts will probably be revealed by further exploration.

The general features of the deposit, particularly its form and structure, indicate that it was formed by replacement of the limestone along fractures and bedding planes. The parent manganese mineral was probably rhodochrosite or a mixed carbonate, the oxidation of which would be accompanied by a shrinkage in volume sufficient to produce the cavernous texture of the ore. Presumably the manganese, like the silver and other metals of the district, was brought to place by ascending solutions whose source was some deep-seated rock.

ERICKSON DISTRICT.

LOCATION AND GENERAL FEATURES.

Deposits of manganese ore are found at several places in the southern part of the Simpson Mountains, in the Erickson district, Juab and Tooele counties, Utah. Some of these in the vicinity of Camp Blaine, otherwise known as Fleiner's camp, were visited by the writer June 20 and 21, 1918. At that time the ore was being mined from a shaft on the Black Jack No. 4 claim, half a mile east of Camp Blaine, and hauled 28 miles south to Lucerne, on the Los Angeles & Salt Lake Railroad.

Camp Blaine is at a spring in the lower part of Blaine Canyon about 35 miles west of Eureka. Two miles farther west is Death Canyon. The geology is described by Loughlin.[38] In the vicinity of Blaine and Death canyons the rocks are Cambrian and pre-Cambrian quartzite and shale, with a few dikes of a later intrusive porphyry. The general strike is about northwest, and the dip about 45° NE.

MANGANIFEROUS DEPOSITS.

The manganiferous deposits are parts of silver-bearing quartz lodes and may be classified as the result of replacement by carbonate and silicate minerals, superficially oxidized. They have the form of irregular veins or tabular bodies and are found along fractures and bedding planes in the sedimentary rocks. Generally they are thin, but here and there one is swelled to a pod or pipelike body as

[38] Loughlin, G. F., U. S. Geol. Survey Prof. Paper 107, pp. 447–448, 1919.

much as 15 feet in diameter. The development workings, most of which were made in a search for silver, show that generally the bodies persist 100 feet or more in depth. The lower limit of oxidation is about 100 feet. Above this the bodies are cavernous and consist chiefly of quartz, altered country rock, and the manganese oxides psilomelane, pyrolusite, and wad. As selectively mined half or less of their mass is marketable ore. Below the limit of oxidation the bodies are dense instead of cavernous and the manganese occurs as the silicate rhodonite and the carbonate rhodochrosite. In addition, one or more of the minerals pyrite, zinc blende, galena, and chalcopyrite are present. Specimens of this material show replacement of the country rock by the manganese minerals and quartz. Furthermore, that replacement has been general is suggested by the podlike forms and other irregularities of the bodies. The cavernous texture of the oxidized material is a result of the net loss in volume that occurred when the silicate and carbonate of manganese were changed to oxides.

MINES AND PROSPECTS.

BLACK JACK.

The Black Jack group, owned by B. F. Fleiner and others, is in the foothills south of the Simpson Mountains, about half a mile east of Camp Blaine. At the time of the writer's visit (June 21, 1918) manganese ore was being mined on the Black Jack No. 4 claim by Wright & Williams, lessees. The production was reported to be about 150 tons, and the ore was hauled by teams 28 miles south to Lucerne, on the Los Angeles & Salt Lake Railroad.

The country rock is gray to brown weathering quartzite, with intercalated layers of gray to green micaceous shale or slate. A short distance to the east is a large dike of intrusive porphyry. The quartzite and shale strike northwest and dip about 45° NE.

On the Black Jack No. 4 a northward-trending lode about 6 feet wide composed of sheared country rock, vein quartz, and manganese oxides is exposed by shallow pits for 75 feet or more. At the south is a shaft 60 feet deep, with a drift at the bottom extending 40 feet north. This working shows 2 feet of ore on a smooth wall from the surface to a depth of about 20 feet. Below this the wall is not exposed, the shaft and the drift being entirely in rather low-grade manganiferous material. A stope above the drift 20 feet long, 15 feet wide, and 15 feet high does not show the limits of the body.

The deposit is somewhat loose, friable, and cavernous and consists of manganese oxides and clayey matter, mainly kaolin and quartz sand, that form bunches and streaks. The manganese oxides are chiefly psilomelane, with some pyrolusite and a little wad. The psilomelane forms nodules, concretions, and irregular streaks in which thin layers of pyrolusite are commonly inclosed. Free crystals of pyrolusite and films of sooty wad line some of the cavities. In mining about half the mass is selected for shipment. Samples of two cars yielded, respectively, 41.9 and 44.85 per cent of manganese, 8.34 and 9.6 per cent of silica, 3.3 and 3.0 per cent of iron, and 0.044 and 0.45 per cent of phosphorus.

On the Black Jack No. 2 a manganiferous body 30 feet long and 20 feet wide crops out. It consists of a light, somewhat leathery porous material, chiefly wad and decomposed country rock. Bunches of good-looking ore, chiefly pyrolusite, appear in places. The deposit is cut by an adit level at a depth of 70 feet and explored 40 feet deeper by a winze. In these workings it ranges from 6 inches to 6 feet in width and lies on a bedding plane in quartzite that strikes north and dips 45° E. Bunches of good ore are found in places, but most of the material is like that in the outcrop, which is said to average about 30 per cent of manganese. A small shipment of ore is reported.

On the Black Jack claim, about a quarter of a mile north of the Black Jack No. 4, a deposit of manganese oxides is exposed by an inclined shaft 100 feet deep. This body lies on a bedding plane in quartzite that strikes N. 35° W. and dips 45° NE. It is of tabular form, 2 feet thick at the surface, and rather uniformly 4 feet thick from a depth of 60 feet to the bottom. On one side of the shaft the deposit consists of light, porous leathery manganese oxide like that in the Black Jack No. 2. On the other side it is largely pyrolusite and apparently will yield ore of good grade. About 500 feet northwest of this working a 50-foot shaft exposes a few bunches of ore, presumably in the same lode. All the workings described are dry, and no unoxidized ore was seen.

BABY ELEPHANT.

The Baby Elephant group, known also as the Strang group, is in Death Canyon about 2 miles northwest of Camp Blaine. At the time of the writer's visit (June 21, 1918) the property was idle. Formerly some development work had been done in a search for silver.

On the Baby Elephant No. 1 a manganiferous quartz lode crops out for 200 feet or more in an easterly direction up the steeply sloping side of the canyon. Here and there it shows about 1 foot of ore consisting chiefly of psilomelane. The wall rock is conglomeratic quartzite that stands up in vertical ledges stained black with manganese oxides. An adit level driven 150 feet on the lode exposes a somewhat cavernous body 2 feet or more wide, made up of quartzite fragments, clayey matter, quartz, and manganese oxides. At the face, which is about 120 feet below the surface, the oxidized material changes rather abruptly into a dense body consisting of quartz, pink manganese, and a little pyrite. The manganese mineral is mostly rhodonite, with some rhodochrosite. The lode at this point was moist but not supersaturated; apparently it had discharged some water earlier in the season. A sample representing oxidized material, of which a moderate amount is estimated in reserve, is reported to have yielded 29.95 per cent of manganese, 25.2 per cent of silica, and 6.8 per cent of iron.

An eastward-trending lode from 1 to 6 feet wide crops out on the west side of Death Canyon on the Baby Elephant No. 3 claim. Here and there for a distance of 500 feet or more a little good-looking manganese oxide ore is exposed. An adit level with a drift 100 feet long explores the lode to a depth of 50 feet or more. This working exposes a body composed of mixed quartz, country rock, and manganese oxides from which it may be possible to sort a moderate amount of ore. A sample said to represent the body runs 28.11 per cent of manganese, 26 per cent of silica, and 5.4 per cent of iron.

On the Baby Elephant No. 2 a manganiferous body crops out in a cliff opposite the workings of the Baby Elephant No. 1. It is about 10 feet wide, dips 45° S., and is composed of sheared country rock, quartz, and manganese oxides. The deposit is evidently of low grade, but probably it could be selectively mined to yield ore.

UTONIA.

On the west side of Death Canyon, south of the Baby Elephant group, adits are made at altitudes of 6,400 and 6,800 feet on the Utonia claim. They explore a lode valuable for silver in which moderate amounts of manganese are found. Below the oxidized zone, which is 100 feet or more deep, the manganese occurs as rhodonite and rhodochrosite, with which pyrite, galena, and zinc blende are associated.

DEPOSITS IN OREGON.

PRODUCTION OF MANGANESE ORE.

Prior to 1917 manganese mining was not among the known industries of Oregon, and its development between that time and the later part of 1918, when the market failed, was not extensive. No large bodies of marketable ore were found, but should a war demand again arise the known deposits may be regarded as the source of considerable high-grade concentrate. The total production is less than 1,000 tons. About half of this was mined near Pleasant Valley, Baker County, in 1917, and most of the remainder in the Lake Creek district, Jackson County, in 1918. A total of about 500 tons was shipped to Tacoma, Wash., and the East for making ferroalloys, and the remainder was left in stock at the mines.

ORE DEPOSITS.

DISTRIBUTION.

The known deposits of manganese ore in Oregon are practically confined to the southwestern counties and a small area in Baker County, in the northeastern part of the State. (See fig. 36.) Else-

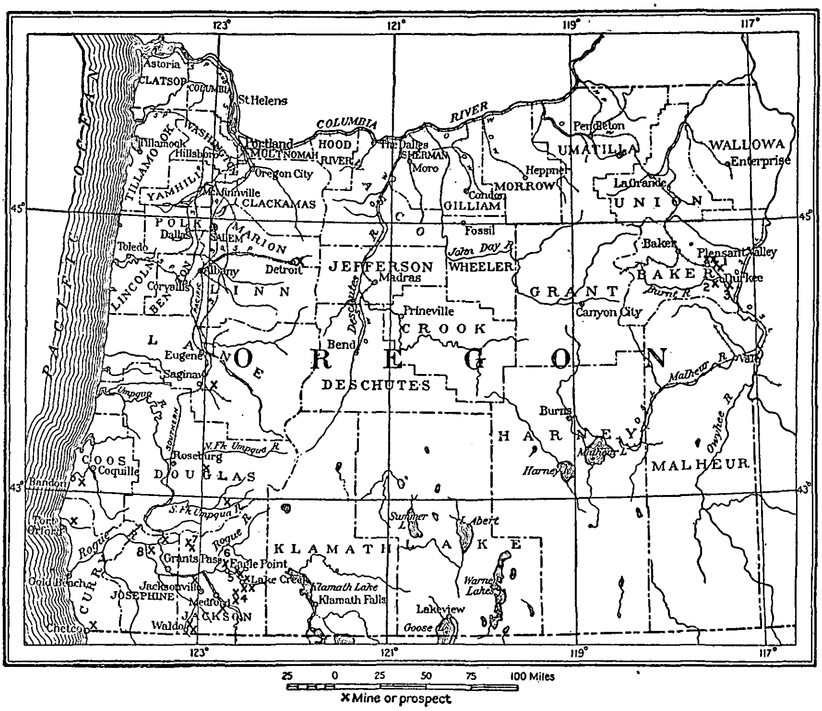


FIGURE 36.—Map showing location of manganese mines and prospects in Oregon. 1, Utah; 2, Sheep Mountain; 3, Corander; 4, Tyrrell; 5, Gus Nichols; 6, Vestal; 7, Capitol Hill; 8, Britton.

where only two deposits have been reported, one east of Saginaw, Lane County, and the other near Detroit, Marion County. The deposits described herein are in the Lake Creek and Gold Hill districts, in Jackson County; the Greenback district, in Josephine County; and small areas near Pleasant Valley and Durkee, in Baker County. Other deposits are reported in southwestern Oregon in the Ashland, Waldo, and Chetco districts, near Port Orford, Bandon, and Roseburg, and along the South Fork of Umpqua River. Presumably most of these are undeveloped prospects.

CLASSIFICATION AND GENERAL FEATURES.

Deposits of oxide minerals in open spaces.—The deposit at the Tyrrell mine and other deposits in the Lake Creek district consist of manganese oxides that fill cracks, pores, or other cavities in a Tertiary volcanic tuff. The manganese minerals are distributed over several hundred acres, but so far as known they do not extend more than a few feet below the surface. As a rule the mineralized tuff does not carry more than 1 or 2 per cent of manganese, but in a few places portions that contain from 10 to 20 per cent or more constitute bodies of considerable size.

Manganite is the principal ore mineral. Psilomelane and wad are moderately abundant, and there are small amounts of a soft brown greasy-lustered oxide that appears to be derived from the manganite by alteration in place. A superficial part of the ore-bearing layer generally contains most of the softer oxides and is relatively poor in manganese. Below this is a richer layer containing the harder oxides. Most of the ore is segregated in distinct streaks, grains, and nodules and is therefore easily separated by ordinary milling methods from the rather soft tuff.

The manganese was deposited by descending solutions, but its origin is obscure.

A small amount of concentrate has been made at the Tyrrell mine, where considerable material containing from 10 to 30 per cent of manganese has been developed. In the district a large amount of similar material is probably to be found.

Deposits formed by replacement.—Deposits near Pleasant Valley and Durkee, Baker County, are tentatively classified as resulting from replacement of the country rock by carbonate or silicate minerals that have become wholly or partly oxidized. They consist of irregular veins, lenses, and podlike bodies in siliceous argillite and limestone of Paleozoic age. Though their exposed parts contain oxide minerals, only their cavernous texture and some other features suggest that before oxidation they were dense bodies of carbonate and silicate minerals.

The most abundant manganese minerals seen are pyrolusite, psilomelane, and manganite. There is more or less soft pulverulent oxide, of which part appears to be wad and part is an unidentified greasy-lustered brown mineral. Fine-grained quartz is abundant, and kaolin is common. Iron oxides are abundant in one deposit but rather scarce generally. Several of the deposits are said to contain a little gold and silver, and some of those near Pleasant Valley contain a little tungsten.

The bodies under consideration are similar in many features and are therefore thought to be similar in origin to the metalliferous quartz lodes of the surrounding region, which are generally regarded as deposited by solutions ascending from some intrusive body. A shade of doubt is cast over this interpretation by the fact that many of the deposits are alined with the general strike of the rocks, as if they were confined to a certain stratum and might therefore be of sedimentary origin. However, no other evidence to support such a conclusion was found.

Practically no ore reserves are developed, but a rather large amount of highly siliceous manganiferous material that may be capable of beneficiation is in sight or in prospect.

Veins and lenslike bodies in the Gold Hill and Greenback districts and in other parts of southwestern Oregon outside of the Lake Creek district contain rhodonite, a silicate of manganese. Near the surface this mineral is changed to oxides. These bodies are not extensively developed and have yielded but little ore. They are tentatively classified with the group under consideration.

LAKE CREEK DISTRICT.

GENERAL FEATURES.

The Lake Creek district is an indefinitely bounded area in the east-central part of Jackson County that comprises a large part of the drainage basin of Little Butte Creek and some adjoining areas. Lake Creek post office, in the middle-western part of the district, is 15 miles northeast of Medford, with which it is connected by an automobile road 25 miles long. Eagle Point, on the Pacific & Eastern Railway 10 miles northwest of Lake Creek, is the most convenient shipping point.

A small amount of cinnabar is found a short distance northwest of Lake Creek post office, but manganese ore is the only mineral product of economic value so far developed in this area. Manganese was discovered in several places during 1917. In the fall of that year a deposit on the Tyrrell ranch was developed by the Manganese Metals Co., which made several open cuts and drill holes and later built a concentrating mill. In 1918 this company produced about 200 tons of concentrate from the Tyrrell deposit. During the summer of 1918 part of the Tyrrell deposit was prospected by Victor Rakowsky. Elsewhere in the district no production was reported, and only a very little development work was done.

FIELD WORK.

A reconnaissance of the district was made in the period July 7 to 15, 1918, by the writer in company with Henry M. Parks, director of the Oregon Bureau of Mines and Geology. To Mr. Parks the writer is indebted for much information about the district in general and the Tyrrell mine in particular, which Mr. Parks had examined previously.

GEOGRAPHY.

The manganiferous area is a short distance east of Rogue River valley and comprises part of the western slope of the Cascade Mountains. The surface is moderately rough, the relief ranges from 500 to 2,000 feet or more, and the general altitude increases from 2,000 feet at the northwest to 5,000 feet at the southeast, on a broad plateau that forms the summit of the mountains. Streams are numerous, though most of the smaller ones run dry in the summer. The climate is mild, and the year is made up of a wet and a dry season, corresponding to winter and summer. Below an altitude of 2,500 feet the surface generally is covered with madrona, manzanita, and chapparal brush and a few scattered scrubby oaks. At greater elevations pine and fir are abundant. The region supports a rather sparse population, engaged chiefly in farming.

GEOLOGY.

The rocks of the Lake Creek district belong to the Tertiary volcanic series that composes the middle and southern parts of the Cascade Mountains. The most noticeable features of the rocks and the probable order in which they occur are given in the following table:

Composite section of rocks in the Lake Creek district, Oreg.

	Thickness (feet).	Locality of exposures.
1. Basalt flow (top eroded), dense, black, and fresh looking; light gray on weathered surfaces.	0–100	Small areas along south fork of Little Butte Creek.
Erosional unconformity.		
2. Rhyolite tuff, light yellow to gray, speckled red with iron oxides, very porous; fragments are chiefly glass, with a little quartz and feldspar.	0–200	Cliffs along south fork of Little Butte Creek at boundary of Crater National Forest.
Erosional unconformity.		
3. Basalt flow, dark gray, dense to vesicular, commonly platy; shows numerous small feldspar crystals and a few grains of olivine.	100+	Tyrrell mine; vicinity of Newstrom claim; Gus Nichols claim, on slope north of Salt Creek.
4. Red tuff, chiefly a consolidated mass of pumiceous fragments the size of a coconut or smaller; under the microscope small laths of feldspar appear in a matrix clouded with iron oxides; at the Gus Nichols claim this rock is interbedded with fine-grained gray tuff and a flow of andesitic lava.	100–300	Tyrrell mine; Newstrom claim; spur west of Lost Creek; Gus Nichols claim; Star F claim.
Erosional unconformity.		
5. Basalt, dense and platy; plagioclase laths abundant in a glassy groundmass; specks of iron ore and grains of olivine.	500+	Tyrrell mine; Newstrom claim; Gus Nichols claim; Star F claim.
Bottom not exposed.		

At the Vestal claims, on Reese Creek, about 12 miles northwest of the area containing the exposures described, there are pink and red tuffs, purple and gray tuff breccias, and platy basaltic flows that are probably to be correlated with beds 3 and 4 of the table.

The layers show a general dip of 8° or 10° ENE. Faulting is suggested by certain scarplike slopes and notches and the reappearance of the beds at positions not accounted for by the prevailing dip. Thus the slope east of Lost Creek is cliff-like and much steeper than the slope opposite or the slope on the other side of the divide. It has a nearly straight course of about N. 30° W. and is probably due in part to a fault that has raised the block east of it relatively. A notch on the Newstrom ranch, on the ridge between the forks of Little Butte Creek, probably marks the position of another northerly fault that has elevated the rocks on the east. The positions of the red tuff on the slopes east and west of Lost Creek and on the Newstrom ranch indicate a vertical displacement of at least 100 feet along Lost Creek and several hundred feet between the Tyrrell mine and the Newstrom ranch.

The rocks described overlie a coal-bearing Eocene sandstone that crops out in the foothills east of Medford. They bear a general resemblance to the rocks of central and eastern Oregon and are probably to be correlated with some of the middle Tertiary rocks of the John Day Basin described by Merriam [39] and Collier.[40]

MANGANIFEROUS DEPOSITS.

DISTRIBUTION AND GENERAL FEATURES.

Manganese in greater amounts than are ordinarily found in igneous rocks is practically confined to the red tuff and the gray tuff associated with it, described as bed 4 in the table on page 215. Outcrops of the red tuff that are scattered throughout the district and aggregate several hundred acres show noticeable amounts of manganese oxides generally. In most places the material exposed at the surface is estimated to carry from 0.5 to 2 or 3 per cent of manganese. Locally, at least, there is a lower layer that is much richer. At the Tyrrell mine this layer is as much as 12 feet thick and carries from 10 to 20 per cent of manganese. The total thickness of manganiferous material ranges from a foot or two on the Vestal claims to 30 feet or more at the Tyrrell mine.

The manganese occurs as oxides that are deposited in cracks and cavities forming irregular streaks, veinlets, nodules, and grains. To a slight extent these bodies have made additional room for themselves by replacing the tuff. In the upper layer as a rule most of the oxides are soft and sooty, and in the lower layer they are rather

[39] Merriam, J. C., Contributions to the geology of the John Day Basin: California Univ. Dept. Geology Bull., vol. 2, pp. 269–314, 1901.

[40] Collier, A. J., The geology and mineral resources of the John Day region; Mineral Resources of Oregon, vol. 1, No. 3, 1914.

hard and compact. Owing to the comparative softness of the tuff it is very easily separated from the harder oxides by ordinary means. Tests made by both the Manganese Metals Co. and Victor Rakowsky with jigs and tables show that the production of a concentrate running as high as 55 per cent of manganese is practicable, and that under the conditions prevailing in the summer of 1918 crude material containing as little as 10 per cent of manganese could probably be worked at a profit.

MINERALOGY.

Most of the harder manganese oxides consist of a fine-grained substance with a fibrous or prismatic crystal habit and therefore regarded tentatively as manganite. It varies somewhat in hardness and the color of its streak and is doubtless mixed with pyrolusite or other oxides. A small part of the material consists of psilomelane. Soft but coherent wad of low specific gravity occurs in the Gus Nichols deposit, and powdery or sooty varieties of wad are found generally in cavities in the upper layer of the tuff. A soft brown oxide made up of bronzy-lustered scales is widely distributed in small amounts. Locally kaolin, gypsum, barite, and zeolites, one or more at a place, are associated with the manganese minerals, and about $2 a ton in gold is contained in the concentrate from the Tyrrell mine.

ORIGIN.

Psilomelane and the manganite commonly form alternate layers in the bodies that have filled cracks and vesicles. Many of these bodies themselves contain cavities at the center that are lined with free crystals of manganite on which a little wad is dusted. A few masses of soft bronze and black oxides that preserve outwardly the crystal form of manganite apparently have been derived from that mineral by alteration in place. Nothing was seen to suggest that the deposits came from below. On the other hand, their shallow depth and their relation to the surface indicate that they were formed by descending solutions. Presumably the manganese came from parts of the tuff or the overlying lavas that have been eroded away, but its source is obscure. That the deposits are, at least in part, migrating downward as the surface is lowered is suggested by the fact that many cavities in the upper and leaner part of the manganiferous layer that were apparently once filled with ore now contain only small residues of soft powdery oxide. In places, particularly on the Vestal claims, these partly emptied cavities are joined to filled cavities below by irregularly descending streaks of oxides that presumably mark the channels through which the material was transferred.

RESERVES.

Material containing less than 10 per cent of manganese would probably not be workable under any conditions likely to arise. In July, 1918, considerable ore carrying from 10 to 20 per cent of manganese had been developed at the Tyrrell mine, and a small amount of similar material was in sight on the Vestal claims. Elsewhere little or no workable material was seen. It is not unlikely, however, that further development work in the different areas of red tuff would disclose relatively large amounts of similar concentrating ore.

MINES AND PROSPECTS.

TYRRELL.

The Tyrrell mine is on the east side of Lost Creek about 15 miles in a straight line east northeast of Medford. The nearest post office is Lake Creek, 5 miles to the northwest, and the nearest shipping place is Eagle Point, on the Pacific & Eastern Railway, 12 miles farther away. The mine is conveniently reached from Medford by automobile over a road 30 miles long that passes through Eagle Point and Lake Creek. Development of the deposit by open cuts and drilling was begun in the fall of 1917 by the Manganese Metals Co., which later built a concentrating mill capable of treating about 20 tons of crude ore in 24 hours. Prior to July 15, 1918, the mill was operated intermittently and produced about 200 tons of concentrate. Late in the summer of 1918 Victor Rakowsky, of Joplin, Mo., prospected by drilling a part of the land controlled by the Manganese Metals Co., on which he had obtained an option.

The mine is about a mile above the junction of Lost Creek and South Fork of Little Butte Creek, on a northward-descending spur that separates the two streams. The altitude of Lost Creek is about 2,000 feet, and the summit above the mine rises from 400 to 600 feet higher.

The rocks are nearly horizontal basaltic flows and tuffs. A dense dark-gray basalt of a platy habit occupies the lower part of the slope east of Lost Creek. With the aid of a hand lens small laths of feldspar and grains of olivine are visible in it. Next above this is a layer at least 100 feet thick of soft, porous brick-red tuff, and above the tuff, forming the top of the spur, is a basalt generally similar to that on the lower part of the slope. At the south side of the mine the rocks mentioned are cut by a steeply pitching diabase dike 10 feet wide that strikes east.

The main working is an open cut 100 feet long and from 20 to 30 feet deep on the uphill side. It is made on the steep west slope of the spur east of Lost Creek, at a level about 300 feet above the stream.

At intervals for 1,000 feet or more northward to the turn or nose of the spur smaller cuts are made on the same level. On the summit, at the same or a slightly higher level, an area of 3 or 4 acres has been prospected by drilling. At a level about 40 feet lower an adit is run part way beneath the main cut.

The ore is found in the upper part of the red tuff as irregular veinlets and nodules. (See Pl. X, *B*.) The main cut exposes a layer of tuff 16 feet thick, the lower 10 feet of which is rather thickly crowded with these bodies. The other workings, including the drill holes, show that the ore-bearing layer is practically continuous northward for 1,000 feet and that, at least on the nose of the spur, it extends a considerable distance under the basalt. A minimum thickness of 6 feet is shown in places north of the main cut, and one of the drill holes is said to have passed through 30 feet of manganiferous material. South of the main cut the ore-bearing layer is cut by a diabase dike, beyond which for a short distance a little ore-bearing material is exposed here and there, but its extent in that direction is not determined.

The ore consists of manganese oxides, chiefly manganite, with a moderate amount of psilomelane and a little soft black and bronze oxides. These minerals have filled cracks and cavities, replacing the tuff very little if at all. The manganite is of fibrous to prismatic crystal habit, the aggregates commonly showing plumose forms. Sections of the ore bodies generally show an outer thin shell of psilomelane, succeeded by one or more concentric layers of manganite. In some nodules an unfilled space remains in the center. The soft oxides are practically confined to the upper or weathered parts of the manganiferous layer. Commonly they preserve the outward crystal forms of manganite. Locally a little gypsum occurs with the manganese minerals, and barite is reported in some of the ore. In the manganiferous layer, especially in the upper part, the tuff is more or less altered to a soft clayey material consisting largely of kaolin and iron oxides. A waxy pale greenish-yellow variety of kaolin is commonly associated with the softer manganese oxides.

The crude ore treated at the mill is reported to have averaged about 20 per cent of manganese. This material was selected from the lower 10 feet of the manganiferous layer, in which most of the harder oxides are found. A sample obtained by Mr. Parks, representing the lower 12 feet of the layer at one place in the main cut, contained 14.86 per cent of manganese. Other samples mostly representing the upper part of the layer as exposed in the smaller cuts contained less, the minimum reported by Mr. Parks being 2.13 per cent. Samples of two car lots of concentrate reported by the Manganese Metals Co. carried 47.5 and 48.5 per cent of manganese, other samples of concentrate contained from 46.5 to 52.8 per cent of manganese, 11.1 to 14.5 per cent of silica, 1.4 to 0.9 per cent of iron, 0.09 to 0.207 per cent of phosphorus, and 0.08 to 0.16 ounce of gold to the ton. According to Mr. Rakowsky, the concentrate from a sample treated at Joplin, Mo., showed still more manganese and less silica than the samples mentioned above.

It is reasonably certain that the Tyrrell mine contains a large body of material that carries from 2 or 3 to 15 per cent of manganese, the richer parts of which are probably workable under conditions approximating those of 1918. Most of the higher-grade material so far developed is within 150 feet north of the diabase dike, though that rock evidently was not the source of the manganese. Probably, however, it shattered somewhat the adjoining mass of tuff, which was thus made more favorable for mineral deposition.

NEWSTROM.

Manganese-bearing material is found about 2 miles north of the Tyrrell mine, on the Newstrom ranch. Here the red tuff underlies a strip 1,000 feet wide and a mile long that curves around the west and north slopes of the broad uneven ridge that separates the north and south forks of Little Butte Creek. The tuff is at least 200 feet thick, rests upon an uneven surface of dense platy basaltic lava, and at the top apparently grades into a dark-gray lava, the layers of which dip at a moderate angle to the northeast. The middle and lower parts of the tuff are fine textured and crowded with small cavities or vesicles. The top layer is rather dense and somewhat like a tuff-breccia. In a few places, the most noteworthy of which are on the north slope, the tuff crops out prominently, but generally it is concealed by a deep surface mantle. In all the exposures seen it is more or less decomposed, the freshest tuff observed being an opaque claylike material in which small feldspar laths are embedded.

Manganiferous material is shown in several open cuts and natural exposures distributed through an area of 40 acres or more and at different levels from top to bottom of the tuff layer. The largest working, a cut 30 feet long and 12 feet deep, at an altitude of 2,500 feet, exposes the lower part of the tuff bed. Here the material in general is very poor in manganese, but small portions of it contain as much as 10 or 15 per cent. Similar materials are shown here and there in other cuts, and the richer portions are generally found at a depth of a few feet. The ore consists of manganite and one or more unidentified soft brown to black oxides derived from it by alteration in place. Most of it is in pores or vesicles, the soft oxides as a rule in that part of the tuff just below the surface and practically all the manganite in the next deeper part. Generally manganite unmixed with other material forms compact bodies from the size of a wheat grain to that of a walnut. A sample of these bodies is reported to contain approximately 58 per cent of manganese, 5 per cent of silica, 2 per cent of iron, and but very little phosporus. Many of the vesicles are empty, and others contain calcite, gypsum, or zeolites. No considerable amount of material rich enough to be classified as ore is developed.

STAR F.

On the Star F ranch of C. L. Farrar, 5 miles north of the Tyrrell mine and 3 miles northeast of Lake Creek, red tuff forms a rounded hill 100 feet high and 30 or 40 acres in area. The surrounding land is rather flat and underlain by platy basalt, upon which the tuff rests. Near the top of the hill a shallow pit exposes small irregular streaks and nodules of manganese oxides, associated with a fibrous satiny-lustered white zeolite. The material exposed is evidently very low in manganese. Other masses of similar tuff are reported at short distances to the north and east.

GUS NICHOLS.

The manganese prospect of Gus Nichols is about 5 miles north of Lake Creek post office, at an altitude of 2,500 feet on the slope north of Salt Creek. Beginning at the foot of the slope, basalt, red and gray tuff, andesitic lava that shows hornblende crystals, gray tuff, and dark-gray basalt crop out one above another. These rocks are nearly horizontal and at least 500 feet thick in the aggregate. The topmost basalt layer evidently flowed as a molten lava over the tuff next below, for it is glassy, vesicular, and shattered at the bottom.

The manganese is found in a layer from 2 to 10 feet thick made up chiefly of the lower part of the basalt described, with a little of the underlying tuff. As shown by a few shallow pits made at intervals for a distance of 1,000 feet, some of the cracks and vesicles are filled with a soft black noncrystalline manganese oxide regarded as wad. These bodies of wad range in size from specks and grains to pockets a foot in diameter, but so far as the development work shows no considerable part of the layer contains enough of them to make it workable.

HOMESTAKE.

The Homestake claim of I. C. Daly is about a mile west of the Nichols prospect, on a gentle south slope at an altitude of about 2,200 feet. It is underlain by a red tuff much like that at the Tyrrell mine, and in two places pits show soft manganese oxides in small cracks and cavities. No ore is developed.

VESTAL.

Several claims belonging to J. S. Vestal and others are in the basin of Reese Creek, about 6 miles north of Eagle Point and 20 miles northwest of the Tyrrell mine. A broad, flat spur at an altitude of 1,800 feet between two headwater branches of Reese Creek is underlain by purplish-gray to pink andesitic tuffs and flows that dip about 6° E. On the Governor claim small pits show soft vesicular pink tuff containing irregular streaks of manganese oxides, the largest of which are an inch wide. Some of the vesicles are lined with free crystals of manganese oxides; others contain zeolites. The ore is chiefly a mixture of pyrolusite and manganite, with some psilomelane and a soft pulverulent oxide that were apparently derived from the other two by alteration in place. The body exposed in the cuts is estimated to carry about 10 per cent of manganese.

Farther east, on the Blackrock claim, a cut exposes a layer of pink tuff 18 inches thick that rests upon gray and green tuff and is covered by a few inches of soil. The pink tuff is crowded with vesicles about the size of an ordinary white bean, most of which are filled with compact, finely crystalline manganite. Vesicles in the upper 6 inches of the tuff contain soft oxides that appear to have been derived from the manganite by alteration in place. Plumose streaks of manganese oxides descend from the vesicles in the upper part of the tuff to those in the lower. A layer of the tuff 1 foot thick probably contains 25 per cent or more of manganese. No manganese is visible in the underlying tuff, the green color of which is caused by chlorite.

A bed of similar manganese amygdaloid is exposed in a pit on the Butte claim, east of the Blackrock. Probably the manganiferous layer underlies a total area of several acres and contains a moderately large amount of material carrying 10 per cent or more of manganese.

On the Banner claim, along Reese Creek south of the deposits described, a rather hard red tuff is exposed beneath a dense platy basaltic lava. Locally this tuff shows a few streaks and nodules of manganese oxides similar to those in the red tuffs at the other places described.

SIERRA METALS CO.

Several claims belonging to the Sierra Metals Co. are on the wide flat ridge between Lake Creek and Lost Creek, about 3 miles southwest of the Tyrrell mine. They include an area of red tuff that crops out at altitudes ranging from 2,500 to 2,700 feet. A few shallow pits show a little soft manganese oxides here and there in the pores or cavities of the tuff. In places the red tuff is overlain by remnants of a bed of gray tuff, and in places large boulders of a brown jaspery quartz containing seams of manganite are scattered over the surface. No ore is developed.

GEMMELL.

A considerable area of red tuff south of the Sierra Metals Co.'s ground is covered by the Gemmell claims. According to Mr. Parks, the outcrops show about the same amount of manganese as elsewhere.

GOLD HILL AND GREENBACK DISTRICTS.

CHARACTER OF DEPOSITS.

Deposits in the Gold Hill and Greenback districts, in Jackson and Josephine counties, respectively, were visited by E. S. Larsen, jr., of the United States Geological Survey, in October, 1917. They are tabular and lenslike bodies that consist chiefly of quartz and rhodonite and are found along bedding or cleavage planes in slaty-appearing rocks of pre-Tertiary age. The superficial portions are oxidized and contain a little ore. Presumably most of the deposits reported elsewhere in southwestern Oregon outside of the Lake Creek district are of the same type. Most probably these bodies were formed by replacement of the country rock, ascending solutions having brought in the manganese.

MINES AND PROSPECTS.

CAPITOL HILL.

The Capitol Hill prospect is on the homestead of J. W. Neathamer, along Evans Creek, about 12 miles by road northeast of Rogue River station on the Southern Pacific Railroad. The deposits are tabular or thin lenslike bodies 5 feet in maximum thickness. One is exposed for a length of 20 feet and a depth of 10 feet, and another for a length of 100 feet. They occur along the bedding of steeply tilted pre-Tertiary slaty rocks and consist chiefly of quartz and rhodonite. Near the surface more or less of the rhodonite is changed to oxides, and the superficial parts of the deposit contain a small amount of ore.

BRITTON.

The claims of G. W. Britton and others are on Shaw Creek 4 miles east of Rogue River and about 15 miles northwest of Grants Pass. They include several lenslike bodies of rhodonite and cherty-appearing quartz lying along bedding planes in steeply tilted slaty rocks of pre-Tertiary age. The largest body exposed is 18 feet long and 6 feet wide. Near the surface it is oxidized and contains a little ore.

CHISHOLM.

The claim belonging to Dr. W. P. Chisholm and others, in the basin of Evans Creek about 17 miles northeast of Gold Hill, contains several small veins of rhodonite and quartz. No considerable amount of ore was seen.

OREGON MANGANESE CO.

The claims of the Oregon Manganese Co., on Coyote Creek about 6 miles east and southeast of Wolf Creek station on the Southern Pacific Railroad, include a crushed zone in pre-Tertiary slate that shows in places films of manganese oxides. No ore was developed when the workings were examined in October, 1917.

PLEASANT VALLEY.

LOCATION AND ACCESSIBILITY.

Manganiferous deposits are found at several places near Pleasant Valley station on the Oregon-Washington Railroad & Navigation Co.'s line, in an area that lies from 12 to 20 miles southeast of Baker and can be easily reached from that place by automobile. From Pleasant Valley the Stephens and Capitola groups of claims are respectively 2 miles and 3 miles north, the Black Prince group and the Black Nigger claims, respectively, 2 miles and 5 miles northeast and other claims from 4 to 7 miles east. The Stephens and Black Prince groups and several of the other claims are distributed along a belt that trends about N. 60° W. This belt is approximately parallel to the valley of Alder Creek, through which the railroad goes, and from 1 to 2 miles northeast of it.

PRODUCTION.

Most of the claims were located prior to 1917 for gold and silver, though very little development work was done on them. In 1917, according to reports, 450 tons of manganiferous material was produced from the Utah claim of the Stephens group. Most of this material was shipped to Tacoma and after being reassorted yielded about 300 tons of 40 per cent manganese ore that was used in making ferro-alloys. The Utah and other claims in the Stephens group were idle when visited by the writer, September 4, 1917. Development workings on the Utah had reached a depth of 45 feet; elsewhere they consisted of shallow pits. No production was reported in 1918.

OCCURRENCE OF TUNGSTEN.

One feature of the Pleasant Valley deposits of more than ordinary interest is the association of tungsten with manganese, as reported by Emil Melzer, of Baker, Oreg., who acquired control of the claims late in 1917. According to Mr. Melzer, a sample composed of material from four different bodies was tested for concentration by the

Hendrie-Bolthoff Co., of Denver, Colo., the assays being made by E. E. Burlingame & Co. Of several different concentrates produced, one that represented the final product and amounted to 3.69 per cent of the composite sample carried 23.62 per cent of tungstic acid (WO_3). This is equivalent to about 0.75 per cent of tungstic acid in the crude ore. Whether the tungsten came from one or all of the four different deposits represented by the sample or in what proportion from each was not determined, and the tungsten-bearing mineral was not identified.

SURFACE FEATURES.

The area through which the deposits are scattered has a general southwesterly slope toward Alder Creek and is crowded with ravines and small narrow valleys that range from 200 to 600 feet in depth. The sides of the valleys are rather steep, and the intervening summit areas flat or gently sloping. The altitude of Pleasant Valley is about 3,800 feet, and summits to the east are from 500 to 1,000 feet higher. Locally water is scarce, timber is absent, and the dominant vegetation is of the sagebrush type.

ROCK FORMATIONS.

The prevailing rocks are thin-bedded gray argillite and cherty-appearing shale, with isolated lenses or blocks of crystalline limestone here and there. The whole forms part of a group of rocks that are extensively developed in the surrounding region and are probably of Carboniferous age. They have undergone extreme deformation, as shown by the steeply inclined attitude of the beds, the multitude of small compressed folds, the erratic distribution of the limestone blocks, and the alteration of what were originally shale and limestone to argillite and marble. The general trend of the folds is about N. 60° W. In places, especially on the flat summits, these rocks are deeply weathered to a mantle of fine clayey soil that contains numerous fragments of the more resistant cherty or siliceous layers. Here and there the rocks and their residual mantle are overlain by gently inclined beds of lava and fresh-water sediments of Tertiary age.

ORE BODIES.

The ore bodies are of moderate to small size and irregular form. Most of them are found near the surface along bedding planes or joints in the argillite and are associated with tabular or lenslike masses of fine-grained quartz. Ore obtained from them, even by careful mining, runs high in silica. The sample of crude ore reported by Mr. Melzer assayed 36.06 per cent of manganese, and the concentrate produced by reducing it about one-half contained 48.28 per cent of manganese, 13.40 per cent of silica, and 0.124 per cent of phosphorus. The largest body found on the Utah claim is in general terms a flat lens 20 feet wide (stope length), 30 feet long (pitch length), and 5 feet thick in the middle. It extends from a point near the surface downward along a wavy gouge-lined bedding plane or seam that has an average dip of 20° E. Several smaller lenses are found below it to a depth of 60 feet on the slope, which is the limit of exploratory work. The ore is rather soft and cavernous and is composed chiefly of manganese oxides, clay, and quartz. The oxides are apparently an intimate mixture of pyrolusite, psilomelane, and wad.

About 200 feet east of the deposit just described other bodies are developed by a 25-foot shaft, from which a drift runs east 63 feet and ends in a winze inclined southwestward 30 feet deep. Water stands in the bottom of the winze, at a level estimated to be about 45 feet below the surface. The shaft penetrates an irregular cylindrical body about 10 feet in diameter and 15 feet long, composed chiefly of quartzose or silicified argillite. A small part of it is made up of indistinct veinlets and bunches of manganese oxides, among which pyrolusite and manganite were identified. The body is cut by a few stringers of a coarser-textured quartz with manganese oxides, and from its lower end several seams filled with manganese oxides and clay lead off along bedding planes. The drift follows a seam that is normally 2 or 3 inches wide but swells here and there into bunches or pockets, the largest of which is 5 feet in diameter. Another seam with several small pockets is developed by the winze. Ore from these pockets is said to carry from 35 to 45 per cent of manganese and 20 to 30 per cent of silica and to be practically free from iron. A shallow cut 20 feet west of the shaft exposes an 18-inch vein of flinty-textured quartz and manganese oxides that dips 50° NE.

On the Black Joe claim, about half a mile southeast of the Utah, a body of flinty-textured quartz with manganese oxides is exposed by shallow workings for a distance of 50 feet. This deposit is of tabular or vein form, is 4 feet wide, and strikes about east. Seams and small cavities in it are filled with the softer manganese oxides.

Outcrops of many bodies similar to those in the Utah and Black Joe are reported in an area that extends from the vicinity of these claims southeastward for 6 or 8 miles. None are extensively developed. Several in the Capitola group of claims are said to occur in the limestone and to be high in iron. A body of manganiferous quartz 10 feet wide is said to form a prominent outcrop on the Black Prince claim.

The manganese oxides were probably derived from rhodonite and rhodochrosite. Oxidation of the rhodochrosite was accompanied by shrinkage that gave the ore its cavernous texture. The distribution of the siliceous manganiferous bodies for several miles along a course that coincides with the general strike of the bedded rocks suggests that they are of sedimentary origin. On the other hand, the presence of vein quartz and the reported occurrence of small amounts of gold, silver, and tungsten indicate that they are similar in origin to the metalliferous quartz lodes of the surrounding region, which are believed to have been deposited by solutions ascending from some deep-seated intrusive rock.

No good basis exists for making an estimate of ore in reserve. Probably, however, small amounts that contain 35 per cent or more of manganese are to be found, together with a comparatively large amount of highly siliceous material which is rather poor in manganese but which may possibly be capable of beneficiation.

SHEEP MOUNTAIN.

An undeveloped lode showing considerable manganese at the surface crops out in the claims located by John Arthur and others near the summit of Sheep Mountain, 7 miles west of Durkee. Sheep Mountain is a massive rounded knob on the ridge south of Burnt River that reaches an altitude of 5,325 feet, or about 2,300 feet above the stream. The prevailing rock is schistose argillite, presumably to be correlated with the argillite at Pleasant Valley, described on page 225. The outcrop, which is not conspicuous, ranges from 2 to 10 feet in width and extends from a point near the summit S. 50° W. at least 4,000 feet down the slope. It consists chiefly of siliceous argillite traversed by small quartz veins, the whole fractured and partly replaced by manganese oxides. Irregular masses of manganiferous material as much as 3 feet wide and 6 feet long appear here and there. These are composed of streaks, nodules, and irregular bodies of psilomelane, pyrolusite, manganite, and wad bound together with a lattice of quartz seams. The body is cavernous, and the quartzose portions show some flattened cavities whose forms suggest they were molded around crystals of a carbonate such as calcite or rhodochrosite. An average sample of the material selected in mining is reported to carry 27.62 per cent of manganese and 42.48 per cent of silica. Possibly it can be beneficiated by ordinary methods of concentration. According to Mr. Arthur, a panning test yielded a concentrate containing 39.68 per cent of manganese, 24.60 per cent of silica, and 0.052 per cent of phosphorus. A small amount of ore is found that runs as much as 48 per cent of manganese, with 8 per cent or less of silica.

The general features of this deposit suggest that it is to be classified with the metalliferous quartz lodes that are abundant in the surrounding region and like them was probably formed by solutions ascending from some cooling, deeply buried igneous rock.

DURKEE.

Manganiferous iron ore is found in the Corander mine, on the steep slope east of Burnt River about 4 miles below Durkee. The Oregon-Washington Railroad & Navigation Co.'s main line, which follows the valley of Burnt River, passes within a few rods of the mine. The development workings consist of adits from 100 to 240 feet in length at levels 300, 420, and 620 feet above the river, made several years ago in a search for gold. In June, 1918, they were being cleaned out and repaired by J. H. Prescott, the operator, preparatory to mining manganiferous ore.

The rocks are limestone and soft gray argillite that belong to the same group of Carboniferous sediments as the rocks at Pleasant Valley, described on page 225. The strike is about N. 70° W. and the dip 45° N. The argillite is subdued in surface expression, but the limestone shows cliff-like exposures from the river to the top of the slope. The lode crops out on the upper part of the slope and on the summit, about 1,000 feet above the river, where it is a conspicuous ledge 8 or 10 feet high stained black with manganese oxides. It lies between the limestone and the argillite, is 5 to 10 feet wide, and consists mainly of silicified argillite with more or less iron and manganese oxides. This material is sharply separated from the limestone, which forms the footwall, but it grades indefinitely into the argillite of the hanging wall. The ore bodies range from small streaks to irregular pockets or lenses 3 or 4 feet thick and 50 feet or more in length and are most abundant in that part of the lode next to the limestone.

The ore is a rather soft cavernous material that commonly shows mammillated and stalactitic forms and consists chiefly of iron and manganese oxides, with more or less quartz and clay. Limonite and wad are the most abundant ore minerals. Cavities are lined with a soft manganese oxide that is made up of very fine brownish-black scales and in the mass has about the luster and color of stove polish. Small bodies of white earthy kaolin or halloysite are found in places adjacent to the ore. No analyses of the ore are available. To judge by its appearance, most of it carries more iron than manganese and is rather high in silica.

A deposit on the opposite or west side of the river is reported to be developed by shallow workings, in which a considerable amount of iron ore and some manganese ore is exposed.

DEPOSITS IN WASHINGTON.

INTRODUCTION.

In 1915 and 1916, when general attention was first turning toward western sources of manganese, several deposits in the State of Washington were developed and a small amount of ore was produced. (See fig. 37.) Some of these deposits had been discovered at an earlier date, and a few—in particular the Black and White mine, along the North Fork of Skokomish River above Lake Cushman, and the Tubal Cain, west of Quilcene—were partly developed in a search for copper and other minerals. In 1917 and 1918 deposits

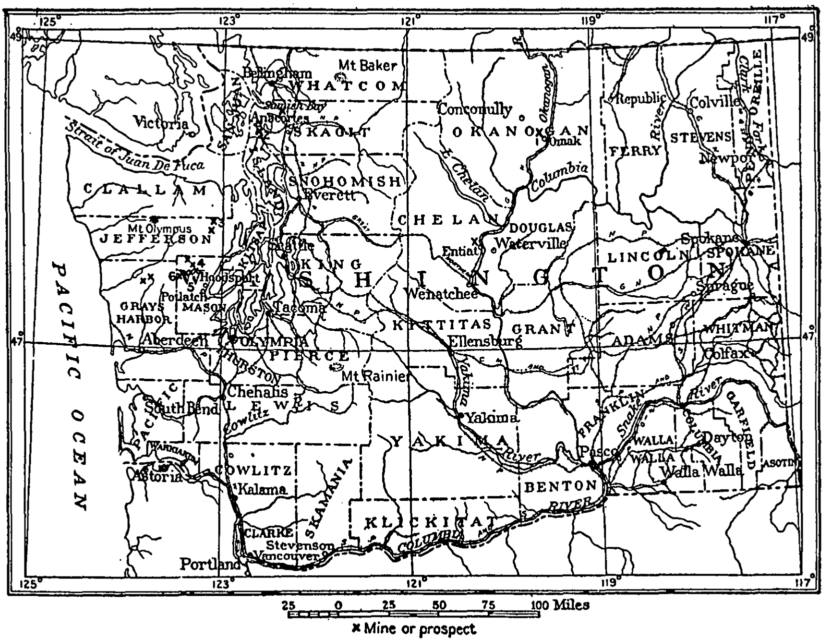


FIGURE 37.—Map showing location of manganese mines and prospects in Washington. 1, Three Buttes; 2, Mountain Home; 3, Tubal Cain; 4, Black and White; 5, Triple Trip; 6, Apex.

along the North Fork of Skokomish River were developed to a moderate extent for manganese, but no shipments were reported. From the Black and White mine, however, 100 tons or more of manganiferous material that contained noteworthy amounts of native copper was shipped as copper ore. The total reported production of manganese ore in Washington is less than 500 tons, most of which was used by the Bilrowe Alloys Co. at Tacoma for making ferromanganese. Despite their small production, however, most of the Washington deposits are decidedly interesting and not without future possibilities as profitable sources of considerable manganese. Except the deposit at the Three Buttes mine, a rather small body in the Okanogan Valley near Omak, the deposits are of an unusual type. They consist chiefly of bementite, a mineral which is practically unknown elsewhere and which, although it carries a rather large percentage of manganese, is too high in silica to be used for making ferroalloys by ordinary metallurgic methods. In places, however, manganese oxides are associated with the bementite, the mixture forming an ore suitable for reduction in the electric furnace. On account of the general lack of development work the amount of ore of this kind available is difficult to estimate, but it is believed to be large. As shown by the natural exposures the quantity of bementite available is to be measured by tens if not hundreds of thousands of tons. Whether this material unmixed will ever be a profitable source of manganese depends on future advances in metallurgy.

In September, 1917, deposits at Omak, in the Okanogan Valley; near Anacortes, on Fidalgo Island; and along the North Fork of Skokomish River were examined by the writer. In August, 1918, he made a brief examination of some deposits along the South Fork of Skokomish River, and, in company with Prof. Henry Landes, revisited some of the deposits along the North Fork. Earlier in 1918 the Tubal Cain mine was examined by Prof. Landes, to whom the writer is indebted for information concerning it.

MANGANIFEROUS DEPOSITS.

The known manganiferous deposits in Washington may be grouped as deposits formed by the replacement of country rock by carbonate and silicate minerals that have become superficially oxidized and as silicate and carbonate lenses in metamorphic rocks. The first group comprises the Three Buttes mine, near Omak, and probably an undeveloped deposit reported near Entiat; the second group comprises the deposits characterized by bementite, all of which, so far as known, are found in the Olympic Mountains and the northern part of the Puget Sound region.

OLYMPIC MOUNTAINS.

GEOGRAPHY.

Manganiferous deposits are found in a belt 2 or 3 miles wide that lies on the east and south slopes of the Olympic Mountains and extends from a point south of Lake Quinault to the basin of Dungeness River, a distance of 50 miles or more. Deposits that are similar to those in the Olympic Mountains are found also about 60 and 75 miles farther northeast, respectively, on Fidalgo Island, south of Anacortes, and on the mainland east of Samish Bay.

The Olympic Mountains are a group of closely spaced, extremely steep, narrow serrate ridges from 3,000 to 6,000 feet in height. Several peaks rise above 7,000 feet, and the altitude of Mount Olympus, the highest, is 8,200 feet. The valleys are correspondingly deep and narrow, and their sides commonly show slope angles that range from 35° to 50°. In the manganiferous belt the local relief ranges from 2,000 to 4,000 feet.

The annual precipitation is very heavy, and in the winter snow accumulates in areas above altitudes of 4,000 feet to so great a depth that much of it remains throughout the summer in the form of drifts, avalanche heaps, and small but active glaciers. Lakes and ponds are numerous in cirques distributed along the main ridges, and swift rivers and cascading brooks are met on every hand.

Perhaps the largest and most valuable forest of Douglas fir, spruce, and other conifers remaining in the United States covers the flanks of the Olympic Mountains, including the manganiferous belt. The close spacing and huge size of the trees and the rank undergrowth of ferns are features equaled in few other places. It is a somewhat remarkable fact that thick stands of large trees cling to slopes as steep as 42°.

From Lake Cushman the deposits along the North Fork of Skokomish River are reached by a road and trails. Lake Cushman is connected with Potlatch, on Hoods Canal, by a logging railway and with Hoodsport and the Olympic Highway by an automobile road. Deposits in other parts of the manganiferous belt are reached by trails only. Most of the belt lies within 20 miles of Hoods Canal, from which roads suitable for motor trucks could be built without undue expense up most of the valleys to points within a mile or two of the deposits. As most of the deposits are on steep slopes high above the valleys, ore and supplies would probably have to be transferred between them and the roads by tramways.

GEOLOGY.

STRATIGRAPHY.

Throughout the manganiferous belt the rocks consist of greenstone, sandstone, argillite, and limestone, named in descending order of abundance. The greenstone forms thick beds that crop out as prominent knobs and cliffs. A short distance above the locality known as Staircase huge blocks of this rock from adjacent cliffs obstruct the North Fork of Skokomish River, causing picturesque cascades. In some places the rock shows a fragmentary texture. Elsewhere it is massive or amygdaloidal and plainly is an altered basic extrusive rock such as basalt. A representative specimen from the cascades of the North Fork is a dense, fine-grained dark-green rock showing small irregular light spots. The microscope shows it to be an altered basalt or a diabase, the green color of which is due to secondary chlorite. The groundmass, which is clouded by decomposition products, incloses partly altered laths of plagioclase and patches of pyroxene or amphibole. The light spots are bodies of calcite and chalcedonic quartz that have filled vesicles. The sandstone shows no plainly marked bedding but is broken by fracture or shear planes into large masses, the angular forms of which are characteristic in the outcrops. It is gray, fine grained, and strongly indurated and is made up of rather sharp clastic grains of quartz, partly decomposed feldspar, and flakes of mica. The argillite is mostly lead-gray and extremely fine grained and exhibits a rather distinct slaty cleavage that probably coincides with the bedding. A decidedly schistose black variety of argillite forms the walls of the Black and White lode. The limestone occurs as lenslike, nonpersistent beds that are generally less than 100 feet in greatest thickness. It is a very fine, dense deep maroon or chocolate-colored rock with a splintery or conchoidal fracture. Commonly it is traversed by irregular veins of white calcite, and the weathered surface is coated with a soft brownish-red powder, composed chiefly of iron oxide, with some manganese and alumina. Qualitative chemical tests show that the fresh rock is composed chiefly of calcium carbonate, iron oxides, and silica, with a small but appreciable amount of manganese. Under the microscope the groundmass appears clouded, a little specularite can be seen, and a few flakes of manganese-bearing mica are observed associated with the calcite veinlets. Thin sections show numerous minute rounded shell-like bodies of calcite that represent fossil Foraminifera.

STRUCTURE.

Locally the rocks are strongly sheared, but no well-defined bedding planes and few good exposures of the contacts between the different kinds of rock were seen. However, the distribution of the rocks strongly suggests that the general strike is north-northeast, and the frequency with which the different rocks appear and reappear in a traverse at right angles to the strike indicates that the beds are steeply tilted and closely folded or extensively faulted.

AGE OF THE ROCKS.

The general characteristics of the rock group described are not unlike those of rocks in adjacent regions that are generally assigned to the Jurassic. The fossil Foraminifera shown by the limestone are rather poorly preserved. They were determined by T. W. Stanton as most probably belonging to the genus *Globigerina*, which may indicate that the rock is Mesozoic or younger. The field relations show only that the rock group is older than the recognized Tertiary of the region.

PHYSIOGRAPHY AND GLACIATION.

The Olympic Mountains were carved by streams and glaciers from a broadly arched or domelike upland, whose main axis trends northwest. Few remnants of the upland surface remain, as its dissection has progressed to maturity. The main ridges, however, show a general accordance in height and are presumably not far below the original upland level. In the manganiferous belt the general summit altitude ranges from 3,000 to 5,000 feet. Here and there peaks rise to greater heights. This old surface cuts across the rocks without regard to their attitude or differences in composition and was formed by erosion at a level probably not far above the sea. The narrowness of the valleys and the unusual steepness of their sides are due to a recent and rapid dissection of this upland and suggest that the uplift of the old surface was a comparatively recent event.

In late Pleistocene time large ice streams descended the main valleys, making them U-shaped along their upper courses. On the main divides glaciated rock surfaces, cirques, benches, and ponds are common, and the glaciation appears to have been general a short distance back from the mountain front. Many of the glaciated surfaces look as fresh as if the ice had lingered until a very recent date. In fact, glaciers still persist on most of the peaks and ridges that reach altitudes of 7,000 feet or more.

Lake Cushman is held back by a drift dam deposited across the Skokomish River valley by a great glacier that comes into the Puget Sound valley from the north. The relation of this glacier to local ice streams from the Olympic Mountains is discussed by Bretz.[41] Apparently it was large enough to hold back the rather large glaciers that came down the Skokomish and other mountain valleys.

MANGANIFEROUS DEPOSITS.

OCCURRENCE AND CHARACTERISTICS.

The manganiferous deposits are found either within the limestone or closely associated with that rock. They are tabular and lenslike bodies, commonly from 5 to 20 or 30 feet in thickness and from 50 to several hundred feet in their other dimensions. They stand at high angles and are parallel to the main sheared zones and also to the bedding. Some of them project as small knobs or reefs, but in general they do not rise above or sink below the adjacent surface. Where free of moss or other concealing vegetation, their blackness distinguishes them from the lighter-colored though decidedly somber country rock. Generally the lodes are bounded by shear or fault planes that separate them distinctly from the country rock,

[41] Bretz, J. H., Glaciation of Puget Sound region; Washington Geol. Survey Bull. 8, pp. 32, 34, 221–222, 1913.

though in places they grade indefinitely into the walls. The manganiferous bodies are dense and structureless except that they show an indistinct banding parallel to the walls. They are generally broken by sets of seams into rather small rhomboidal fragments. Oxidation has taken place along the seams to depths of as much as 40 feet, but it has generally affected the unbroken rock masses no further than to produce a thin film or slight surface discoloration. Parts of the lodes exposed to the weather rarely show complete oxidation to a depth of more than a few inches. The small progress made by oxidation is due partly to the dense texture of the material and partly to the shortness of the time since fresh material was exposed by glaciation.

MINERALOGY.

The lodes are generally made up of two distinct parts, one of which is a bright-red jaspery material that is composed of very fine-grained quartz and hematite mixed in varying proportions; the other, and commonly the larger part, is a dense, fine-grained material that consists chiefly of bementite, a silicate of manganese.

Fresh specimens of the bementite rock range from light grayish or yellowish brown to medium dark brown in color and from dull to vitreous in luster. With exposure to the weather the material darkens and finally becomes black. Its hardness is about 6, and its specific gravity about 3.1. It is translucent in thin chips, has a somewhat splintery fracture, is soluble in hot acids, fuses to a black glass, and gives reactions for manganese.

Locally the bementite rock is cut by veinlets, visible to the unaided eye, that contain one or more of the minerals quartz, calcite, manganocalcite, rhodonite (pink silicate of manganese), rhodochrosite (manganese carbonate), and manganophyllite (manganese mica). Under the microscope the bementite is seen to be in very fine felted aggregates of fibers or plates. Quartz, rhodonite, and manganocalcite are intergrown with it and also deposited in veinlets that cut it.

At the Apex mine a dense, hard, fine-grained dark-green to black material composed chiefly of manganese oxides forms numerous irregular streaks and bunches that are inclosed by the bementite rock. Under the microscope thin sections of this material show an irregular framework or skeleton of transparent bementite rock embedded in the opaque oxides. The boundaries between the silicate and the oxides are sharp, and the two appear to be of contemporaneous origin. The mineral species of the oxides have not been determined. Similar material occurs at several other places.

Specimens from the Black and White and some other deposits contain veinlets of neotocite, a dark-brown to black mineral having a resinous luster like that of some varieties of coal. Neotocite is a silicate of manganese closely related to bementite, as shown by the analyses given below.

A rather striking feature of the bementite rock is its local association with native copper. At the Black and White mine this metal is disseminated as fine specks and flakes through a considerable body of the bementite rock, to which it imparts a noticeable red color. Similar though less abundant occurrences of copper were observed at several other places. Very small amounts of chalcocite (copper sulphide) were observed in specimens from the Black and White and other deposits in that neighborhood.

The principal weathering product of the ordinary bementite rock is a soft, dull-black amorphous substance that consists chiefly of manganese dioxide. A little green copper stain is common, and in addition specimens from the Black and White mine contain bright-red coatings composed of felted aggregates of fine prisms of the copper oxides cuprite and chalcotrichite.

In some specimens veinlets of rhodonite cut the bementite. In others crystals of rhodonite are embedded in bementite, and the relations of the two suggest that rhodonite is the later and probably was derived from the bementite. Much of the quartz is clearly later than the bementite, as are also some of the calcite and manganocalcite and all the copper.

COMPOSITION.

The physical and chemical properties of bementite were studied by E. S. Larsen, jr., and George Steiger, of the United States Geological Survey, and the complete results of their work are published elsewhere.[42] The following table shows the composition of a representative sample of partly weathered bementite rock from the Black and White mine and of bementite and nectocite that were separated from it by heavy solutions:

Analyses of bementite rock, bementite, and neotocite from Black and White mine.

[George Steiger, analyst.]

	Bementite rock.	Bementite.	Neotocite.
Silica (SiO_2)	23.68	39.92	37.15
Alumina (Al_2O_3)	3.48	1.32	2.58 (Alumina and ferrous oxide together)
Ferrous oxide (FeO)	....	4.15	
Ferric oxide (Fe_2O_3)	3.52	....	....
Manganese monoxide (MnO)	46.57	41.58	37.0
Manganese dioxide (MnO_2)	....	....	2.03
Magnesia (MgO)	1.31	4.46	2.82
Lime (CaO)	1.56	.40	2.86
Carbon dioxide (CO_2)	....	....	2.10
Water above 100° C.	....	7.90	14.07 (water above and below 100° C. together)
Water below 100° C.	....	.49	
Loss on ignition	18.32	....	....
	98.44	100.22	100.61
Manganese (Mn)	36.08	....	....

[42] Washington Acad. Sci. Jour., vol. 11, pp. 25–32, 1921.

ORIGIN.

The character and the associations of the bementite deposits suggest that in their present form they are products of regional metamorphism. The alteration of the country rocks is uniform and widespread and is typical of that generally caused by dynamic forces. No bodies of intrusive rock are shown in the manganiferous belt or its neighborhood, nor were any evidences of contact metamorphism seen. There is nothing to suggest that the deposits are related to intrusive masses, such as are generally thought to be the source of metalliferous lodes in the surrounding regions. The bementite rock may have been deposited by descending solutions during the erosion of the old surface described on page 233, but no clear evidence in support of this supposition was found. The deposits are thought most likely to be manganiferous marine sediments, greatly altered by regional metamorphism. This idea is supported by the fact that they are confined to certain sedimentary horizons. Primary manganiferous sediments in Newfoundland described by Dale[43] resemble the bementite rock of Washington rather closely in composition except that they contain noteworthy amounts of phosphorus and barium. With that exception the composition of the Newfoundland deposits indicates that their metamorphism might be expected to produce material like the bementite rock. The Newfoundland deposits have not been severely metamorphosed, and their sedimentary origin is apparent. The manganese they contain is present chiefly as carbonate and oxides. The characteristics of the bementite rock suggest that it was formed within a zone of moderate rather than great depth, and its appearance in some thin sections suggests that the bementite was derived from a granular mineral, possibly tephroite. If these deposits are the result of the metamorphism of sediments originally containing carbonates and oxides, it is likely that the oxides of certain ore bodies such as that in the Apex mine (pp. 237–238) are primary minerals and therefore may extend in depth without regard to the present zone of weathering.

MINES AND PROSPECTS.

TRIPLE TRIP.

The Triple Trip mine is a quarter of a mile up Boulder Creek, a small affluent of the North Fork of Skokomish River from the south at a point about 4 miles above Lake Cushman. It is reached by automobile from Hoodsport to Lake Cushman, thence by horseback or on foot. In August, 1918, an autotruck road was being

[43] Dale, N. T., The Cambrian manganese deposits of Conception and Trinity bays: Am. Philos. Soc. Proc., vol. 54, pp. 271–456, 1915.

built along the upper part of the route. A quantity of ore shipped in 1916 was transported to the lake by pack animals.

The country rocks are sheared and crushed greenstone, gray slaty argillite, and an impure dark-red limestone, in which the shear planes and cleavage planes strike approximately northeast and dip 60°–70° NW. The workings consist of open cuts and two adit levels, one a few feet above the other, that aggregate about 150 feet in length. The adits partly explore a tabular body of bementite rock that ranges from 1 to 4 feet in width, is 50 feet or more in length and lies between the limestone and the greenstone. It is moderately crushed and bounded by rather definite walls that trend in the same direction as the shear planes. Slight oxidation along seams is shown at a depth of 40 feet. At the surface the lode is exposed by an open cut 50 feet long, from which a quantity of ore was removed. Here the bementite rock is weathered to a depth of a few feet, but as a rule complete oxidation does not extend more than a few inches. Here and there for a quarter of a mile or more up Boulder Creek similar lode material is exposed by small pits and trenches, from one of which a carload of ore is said to have been dug. Apparently these bodies are thin lenses that may be regarded as parts of a single lode or zone that coincides with the layer of limestone. The ore shipped is said to have carried 35 to 45 per cent of manganese and 17 to 30 per cent of silica. The richest ore is a dense, hard, fine-grained black rock that is an intimate mixture of bementite and manganese oxides, and that forms a streak at least 1 foot wide in places and more than 20 feet long. It does not appear to be a product of superficial weathering, its texture as shown by the microscope suggesting that the oxides were formed at the same time as the bementite and are not derived from it. This being true, the depth limit of such material need not be the same as that of weathering.

The analyses of six samples said to represent the lode where it is penetrated by the adits show from 6 to 25 per cent of manganese, 8 to 21 per cent of iron, 11 to 37 per cent of silica, and 4 to 36 per cent of lime. One sample was tested for phosphorus and sulphur, of which only traces were found.

In places a foot or two of red jaspery quartz that shows an occasional speck of native copper or a stain of copper carbonate accompanies the lode. Locally this material grades into almost unmixed hematite.

APEX.

The Apex mine is about half a mile up Boulder Creek from the Triple Trip, at an altitude about 1,200 feet higher. The trail is a rather difficult one that follows the stream bed most of the way, but it is proposed to build a tramway for the transfer of ore and supplies between the mine and the road along Skokomish River. The lode crops out in the bed of Boulder Creek and rises as small cliffs on either side. It appears to lie in a continuation of the same zone of sheared limestone and greenstone as the Triple Trip. The natural exposures show it to be at least 30 feet wide in one place and to have a minimum length and depth of 50 feet. It appears to strike northwest and lies between nearly vertical beds of greenstone and red limestone.

This body is made up of two rather distinct layers, one of which is chiefly red jaspery quartz and the other bementite rock. The jaspery layer ranges from 10 to 20 feet in width and forms rather more than half of the mass. It consists of very fine grained quartz, with which specks and flakes of specularite and bright-red hematite are intergrown. As a rule quartz forms the bulk of the rock, but locally hematite is the most abundant mineral, even displacing the quartz almost entirely. The bementite layer, as shown by an open cut made in 1918, is at least 10 feet wide. It consists chiefly of bementite, with irregular streaks and masses of very dense, fine-grained dark-green to black oxides. Specimens of what appears to be unmixed oxide have a hardness of about 6. Under the microscope, however, the oxides are seen to be inclosed by a fine network of bementite, no gradations appearing between the two minerals. Their relations suggest they were formed at the same time and therefore that the oxides are primary minerals and not the result of recent weathering. In fact, oxidation due to recent exposure of the lodes does not seem to extend in general more than a few inches below the surface. It has partly transformed a thin shell of bementite to soft dull-black oxides.

A sample taken in September, 1917, across the outcrop for a distance of 6 feet and analyzed by Benedict Salkover in the laboratory of the Geological Survey contained 43.10 per cent of manganese oxide, equivalent to 33.39 per cent of metallic manganese; 12.65 per cent of iron oxide, equivalent to 8.85 per cent of metallic iron; 3.87 per cent of lime; and 19.81 per cent of silica. Selection of material showing a relatively large proportion of the primary oxides mentioned would undoubtedly produce an ore of better grade.

The open cut and natural exposures show the presence of several thousand tons of bementite rock, an undetermined part of which may be regarded as a siliceous manganese ore suitable for reduction in the electric furnace. It is probable that the deposit is much more extensive than the outcrop described. Not far below the Apex mine an open cut shows 6 feet of bementite rock, and outcrops of similar material are reported elsewhere along the strike of the manganiferous zone.

BLACK AND WHITE.

The Black and White mine is on the divide east of the North Fork of Skokomish River, 6 miles north of the Triple Trip mine, from which it is reached by a trail 10 miles long. At times for five or six years prior to 1917 development work was done, supplies and ore being transported to and from the mine by pack animals. Although regarded by its locators as a copper deposit, the Black and White is a body of bementite rock essentially similar to the other bodies of the manganiferous belt.

No production of manganese ore is reported, but about 100 tons of rather low-grade copper ore was shipped to the Bilrowe Alloys Co., at Tacoma. The mine is in a small cirque at an altitude of 4,400 feet. Bare glaciated surfaces of the rocks that compose the lode and the country rock alternate with patches of drift and small ponds. Except the floor of the cirque, which is made up of rather level benches rising one above another, the surface is rough, and the descent to the North Fork of Skokomish River, at an altitude of about 1,100 feet, is steep. In the area surrounding the mine the rocks consist of alternate beds of greenstone, argillite or shale, and sandstone. The lode is inclosed by dark-gray schistose argillite. The development workings consist of a tunnel 200 feet long at an altitude of 4,300 feet, a shaft 40 feet deep situated above the tunnel but not connecting with it, and several pits and open cuts distributed along a distance of 300 feet.

The Black and White deposit is composed chiefly of the typical bementite rock described on page 234. Only a small amount of jaspery material was observed. The most interesting of the associated minerals is native copper, which is abundant enough in places to form a low-grade ore. The copper occurs as specks and ragged flakes that together with a little quartz appear to have replaced the bementite. The copper particles range in size from microscopic specks to ragged flakes and masses as much as a quarter of an inch in length. Most of them are extremely fine, and they color the bementite rock various hues of red, according to their distribution. The weathered copper-bearing rock shows strongly contrasting colors, chiefly black and red, one of which is due to oxides of manganese, the other to the copper oxide, cuprite, and a variety of that mineral, chalcotrichite, which forms velvety coatings composed of finely fibrous crystals. Blue and green stains, most of which represent carbonates and silicate of copper, are not plentiful, Specimens of bementite rock from the adit level and from the bottom of the main cut are traversed by veinlets containing one or more of the minerals rhodonite, rhodochrosite, manganocalcite, and manganophyllite. Small grains of chalcocite are sparingly scattered through both the veinlets and the groundmass, but this mineral appears everywhere to be later than the bementite. The rhodochrosite and the rhodonite show rather bright tints of pink. The manganocalcite is milk-white and shows curved cleavage faces, and the manganophyllite is very soft, is bronze-brown in color, and has a waxy luster. Locally the bementite rock is cut by veinlets of a glossy-black amorphous mineral that proved on examination to be neotocite, an uncommon silicate of manganese closely related in composition to bementite. The bementite of the groundmass is a finely fibrous aggregate that shows faint outlines of some granular mineral from which it may have been derived. An average sample across 8 feet of the lode at one end of the main cut, analyzed by Benedict Salkover in the laboratory of the Geological Survey, contained 29.63 per cent of manganese oxide, equivalent to 22.81 per cent of metallic manganese; 12.38 per cent of iron oxide, equivalent to 8.66 per cent of metallic iron; 0.706 per cent of lime; and 24.35 per cent of silica. Other samples reported by the operators show from 16 to 38 per cent of manganese, 2 to 11 per cent of iron, 17 to 38 per cent of silica, and a trace to 3 per cent of lime. Evidently a rather large amount of bementite rock is available, but most of the material so far developed is of too low grade to be valuable for manganese.

DEPOSITS NEAR THE BLACK AND WHITE.

Several lodes reported on the slope east of the North Fork of Skokomish River within short distances of the Black and White mine are described as similar to that deposit. Specimens said to be from the Black Trail prospect, 2 miles north of the Black and White, show veinlets of chalcopyrite and calcite. A fragment of ore from the Arkansaw Traveler claim, southwest of the Black and White, shows copper sulphides and carbonates, and a sample from Smith Keller's claim, 7 miles above the camp on the North Fork of Skokomish River known as Devils Staircase, contains bementite. No information is available as to several other undeveloped deposits reported to occur in the neighborhood except that their outcrops are similar to those of the bementite bodies described. The analysis of a sample said to be from the Black Hump claim, 1 mile north of Devils Staircase, shows in round figures 28 per cent of manganese, 17 per cent of iron, and 25 per cent of silica. In August, 1918, a quantity of bementite rock from the Black Hump claim, similar in general to that from the other deposits of this region, was piled at the boat landing at the foot of Lake Cushman.

STEELE CREEK GROUP.

Several claims known collectively as the Steele Creek group are on the slope east of the South Fork of Skokomish River, about 5 miles due west of the Triple Trip mine. Two of these claims, the Bosnia and the India, were visited by the writer in August, 1918. A trail 24 miles long up the South Fork of Skokomish River leads to the claims, which lie on a steep west slope at altitudes ranging from 2,000 to 3,500 feet above the sea, or 1,000 to 2,500 feet above the river. Except a few small open cuts, no development work has been done, and no ore has been shipped. The outcrops are similar to those of the bementite bodies along the North Fork of Skokomish River. On the Bosnia claim, a short distance above the Steele Creek cabin, there is an outcrop of bementite rock similar in appearance to the outcrops of the Triple Trip and Apex. It is 8 or 10 feet wide, at least 200 feet long, 100 feet in vertical extent, strikes about N. 75° E., dips 75° S., and is inclosed by red limestone. In a gully 200 feet to the east is another exposure 10 feet wide, of which 6 feet is red jaspery quartz and the remainder bementite rock. Half a mile farther on, within the limits of the India claim, is a prominent outcrop of bementite rock 15 feet wide and 50 feet long. It is associated with red jasper and red limestone and is otherwise similar to the bementite bodies in general. Several other outcrops of comparable size are reported to occur within a mile or so farther east. Abundant float fragments of bementite rock were observed in gulches leading from this area down to the South Fork, and cobbles of bementite rock easily recognized by their black color and weight—they are heavier than the same-sized cobbles of ordinary rocks—are common along the main stream.

The average of several analyses reported by the owners to represent the bementite bodies described is manganese 24 per cent, iron 10.5 per cent, silica 30 per cent.

The exposures indicate that the bementite bodies are extensive. Some specimens obtained contain primary oxides like those occurring in the bodies on the North Fork, and the development of the South Fork deposits may be expected to disclose more or less mixed bementite oxide ore capable of being reduced in an electric furnace.

TUBAL CAIN.

The Tubal Cain mine is about 5 miles north of Mount Constance and therefore about 25 miles north-northeast of the deposits on the North Fork of Skokomish River. It is on Copper Creek, a small affluent of Dungeness River, and is reached from Quilcene by a trail about 25 miles long. The Tubal Cain mine is regarded as valuable for copper by its owners, who have driven a long crosscut adit but have not yet found an ore body. Prof. Henry Landes, who visited the deposit in July, 1918, describes it as being similar in general to the bementite bodies in the Skokomish basin. It consists of bands and lenses of bementite rock that are inclosed in a red limestone and form a practically continuous lode at least 1,500 feet long. The outcrop attains an altitude of 6,200 feet, and most of it lies above timber line, so that natural exposures are exceptionally good. The bementite layers aggregate about 6 feet in width, and natural cross sections made by ravines show that the lode persists to a depth of at least 500 feet; therefore its volume seems to be large. The weathered layer is thin, commonly forming but a mere shell an inch or two thick. The analyses of ore selected from the upper part of the deposit, reported by the owners, average about 37 per cent of manganese, 5 per cent of iron, 3.5 per cent of lime, and 35.5 per cent of silica.

DEPOSITS BETWEEN SKOKOMISH AND DUNGENESS RIVERS.

Manganiferous deposits are reported to occur in places between the Skokomish basin and the Tubal Cain mine, including one on Constance Creek, a tributary of Dosewallips River, but no other definite information concerning them is available.

OTHER DEPOSITS.

FIDALGO ISLAND.

The Mountain Home claim, belonging to A. V. Ginnett and others, is on Fidalgo Island, a few miles south of Anacortes and about 75 miles north-northeast of the Tubal Cain. This area shows evidences of severe Pleistocene glacial erosion and is underlain chiefly by greenstone with some argillite. A pit 15 feet deep exposes a body of bementite rock 10 feet wide that trends N. 65° W., is inclosed by greenstone, and contains scattered specks and flakes of native copper. A part of this body is moderately rich in hard, black oxide material similar to that in some of the deposits of the Skokomish area.

SAMISH BAY.

A manganiferous deposit, presumably of the bementite type, is reported to occur on the mainland east of Samish Bay, near the point where the State highway crosses Oyster Creek.

LAKE QUINAULT.

Several deposits of the bementite type are reported to occur south of Lake Quinault and in the neighborhood of Humptulips. It is said that in 1916, from a deposit on the Lizard claim, near Quinault Burn, about 6 miles south of the lake, a small amount of ore was mined that contained 36 per cent of manganese, 18 per cent of iron, and 5.5 per cent of silica.

OKANOGAN VALLEY.

Manganese oxide ore was mined in 1916 from a deposit at the Three Buttes mine, in the Okanogan Valley 3 miles northwest of Omak. At this point several low, irregular hills composed of bare granite and gneiss project through the gravel of the alluvial plain known as Pogue Flat. At the north end of the northernmost hill a quartz lode crops out prominently for a distance of 100 feet or more. It stands nearly vertical and trends south, but is somewhat discontinuous, being cut and displaced a few feet on each of two or more cross faults. The quartz has replaced granite more or less completely, and at the north the lode contains a rudely cylindrical body of manganiferous material from 12 to 20 feet in diameter. This body pitches 45° S., and at a depth of 50 feet it has narrowed considerably. It consists of manganese oxides, chiefly pyrolusite, with more or less quartz and partly decomposed altered granite. Apparently half or more of the material removed in mining was rejected in selecting the ore for shipment. The body is cavernous, a fact which suggests that the parent manganese mineral was rhodochrosite. The lode is similar in general to the metalliferous quartz lodes of the Northwest that are thought to have been deposited by ascending solutions. In August, 1917, no ore reserve had been developed.