MANGANIFEROUS IRON ORES.

By E. C. Harder.

INTRODUCTION.

The dependence of the United States on imported high-grade manganese ore and ferromanganese is well known to steel makers and other users of manganese. Normally the high-grade manganese ore produced in this country constitutes less than 2 per cent of the total amount of manganese ore consumed, not including the ore represented by the manganese imported in the form of the alloys ferromanganese and spiegeleisen. During 1916 the domestic production was about three times that of 1915, largely on account of the high prices paid for ore. The exploration for new deposits has also been stimulated, and many discoveries of manganese ore are being reported. Even with this outlook for increased production, however, it is not unduly pessimistic to say that the deposits of high-grade manganese ore in the United States will probably never be able to supply the manganese consumed in domestic industries. If, therefore, the importation of high-grade manganese ore were discontinued, numerous industries would be vitally affected. Of these the steel industry consumes by far the largest quantity of manganese.

Various ways have been suggested in which this situation may be alleviated in time of need. Some investigators propose the use of substitutes for manganese in steel making. Willcox [1] has recently suggested that aluminum, silicon, and titanium could be successfully used as deoxidizers in steel making to replace a large part of the ferromanganese. Willcox suggests also that by increased importation a reserve of high-grade manganese ore might be accumulated in this country sufficient to keep the steel industry in operation for perhaps a year should imports be stopped. The capital that would be tied up in such a reserve, however, is very large, and other remedies may be considered more feasible.

[1] Willcox, F. H., The significance of manganese in American steel metallurgy: Am. Inst. Min. Eng. Bull., February, 1917, pp. 199–207.

Newton,[1] who is at present engaged in a study of metallurgic problems concerning the use of manganese in the steel industry, proposes a modification of the basic open-hearth practice which would allow the extensive utilization of low-grade manganiferous iron ores. He suggests that instead of adding large quantities of ferromanganese or spiegeleisen to steel for deoxidizing at the end of the heat, a manganiferous pig iron containing about 3 or 4 per cent of manganese be used in the bath so that the deoxidation necessary at the end of a heat may be reduced to a minimum. It is believed that the presence of manganese in the bath throughout the heat will tend to prevent oxidation or the formation of ferrous oxide, and thus the addition of high-grade manganese alloys at the end of the heat would be economized. Various low-grade manganiferous ores could be used in the production of such high-manganese pig iron and the quantity of high-grade manganese ore required in the steel industry would be decreased. Newton suggests also that modifications might be made in steel-making practice which would permit the greater use of iron-manganese alloys containing manganese between the 20 per cent in spiegeleisen and the 80 per cent in ferromanganese, which are now considered essential.[2] These alloys also could be produced from manganiferous ores with the addition of varying amounts of high-grade manganese ore for the higher alloys.

With such possibilities in view it is very important that the attention of mining men should be directed toward the development of the reserves of both low-grade and high-grade manganiferous ore, especially the large reserves of manganiferous iron ore in the Cuyuna district of Minnesota.

Manganiferous ores of various kinds and grades are found in several parts of the United States. The Lake Superior iron-ore region contains extensive deposits of manganiferous iron ore, and in many mining districts of the West manganiferous silver ore is found in the upper oxidized portions of ore deposits containing precious and semiprecious metals. In the Lake Superior region the principal districts producing manganiferous iron ore are the Cuyuna, Penokee-Gogebic, and Iron River; the Cuyuna is by far the most productive. In the Western States manganiferous silver ore is being mined at Leadville, Colo., Pioche, Nev., Tombstone, Ariz., Silver City, N. Mex., and Philipsburg, Mont. Manganiferous silver ore is found also in other western mining regions, such as Butte and Neihart, Mont., and Lake Valley, N. Mex.; and manganiferous iron ore is more or less closely associated with the manganese ore of northern Arkansas

[1] Willcox, F. H., op. cit.; discussion of paper by Edmund Newton: Am. Inst. Min. Eng. Bull., June 1917, pp. 995–996.

[2] Newton, Edmund, personal communication.

and the Appalachian region. The manganiferous zinc residuum formed as a by-product in the smelting of New Jersey manganiferous and ferruginous zinc ores is also an important source of manganese.

The principal use for manganiferous ores in the West has been for flux in lead smelting. In some of the districts, however, such as Leadville, Colo., Philipsburg, Mont., and Tombstone, Ariz., some high-grade ore has been mined for the production of iron-manganese alloys. Much of the manganiferous iron ore of the Cuyuna range has likewise been used in the manufacture of iron-manganese alloys, the ore usually being mixed with foreign high-grade manganese ore. The Cuyuna ore is generally either too high in phosphorus or too high in silica to be used in making spiegeleisen without the admixture of other ores. A small tonnage, however, could probably be so used.

CUYUNA DISTRICT, MINN.

The Cuyuna district is in central Minnesota, about 90 miles west of Duluth. The productive area lies south of Mississippi River in Crow Wing County, but the ore-bearing formations are known to extend northeastward as far as the central part of Aitkin County and southwestward in Morrison and Todd counties.

Most of the ore deposits in the district consist of iron ore, the manganiferous iron ore bodies being confined mainly to the so-called north range, which forms the northern portion of the district, in Crow Wing County. A number of ore-bearing belts trend in a northeasterly direction through the north range, and bodies of iron ore and manganiferous iron ore are found at intervals along them, the former more abundantly in the southern part and the latter in the northern part. Iron ores and manganiferous iron ores are more or less closely associated, however, and may occur together in a single ore body. The ore-bearing belts are separated by areas of barren rock such as schist and slate.

The ore-bearing rocks consist of ferruginous chert and ferruginous slate near the surface and of cherty and slaty iron carbonate rock at a greater depth. Locally all these rocks carry manganese. The iron-ore deposits are inclosed in ferruginous chert and ferruginous slate near the bedrock surface and extend to depths depending upon the extent to which the rocks have been decomposed. They are generally very irregular in outline and grade into the inclosing rocks. Relatively barren masses of the associated rocks are common in the ore bodies. The deposits of manganiferous iron ore are similar in occurrence to the iron-ore deposits, but they are generally smaller and more irregular and do not extend as deep. The deepest manganiferous iron ore mine in the district has a depth of about 175 feet below the base of the glacial drift, and it will probably be found that most of the ore of these deposits is concentrated above this depth.

The productive deposits contain on an average between 200,000 and 500,000 tons each, though some contain considerably over 1,000,000 tons. The lower limit of workability of the ore bodies depends on a number of factors, such as grade and character of the ore, shape of the ore bodies, presence of included rock masses, depth of overburden, and amount of water. Some ore bodies containing less than 200,000 tons of ore can under favorable conditions be worked.

The character and mode of occurrence of the manganiferous iron ore depend upon the nature of the rocks with which it is associated. In deposits associated with ferruginous chert the ore is generally found along definite but locally rather thin layers, but in those occurring in slate the ore is scattered through wide zones. In many places the ore associated with ferruginous chert is finely crystalline and locally shows pure manganese minerals such as pyrolusite, psilomelane, and manganite in drusy cavities and veins, whereas that in ferruginous slate is commonly amorphous, although locally veins of manganese minerals are found. In deposits in ferruginous chert the entire beds are usually more or less impregnated with manganese and iron, although the metallic content shows a wide range from place to place. The ore in ferruginous slate, on the other hand, occurs in scattered nodules and irregular masses separated by ferruginous slate or its decomposition product, ferruginous clay.

There are two principal classes of manganiferous iron ore in the Cuyuna district—(1) low-phosphorus ores, which are usually high in silica, and (2) high-phosphorus ores, which are as a rule moderately low in silica. Low-phosphorus ores are commonly associated with cherty iron-bearing rocks and high-phosphorus ores with slaty iron-bearing rocks. This association, however, is not universal, and in some places high and low phosphorus ores occur together in the same series of rocks or even in the same deposit. Thus some mines produce only one class of ore, and in other mines ore bodies of both classes are closely associated. The ores of both classes show a great range in iron and manganese content, not only in different deposits but within short distances in the same deposit, especially across the strike of the formation. Layers low in manganese and high in iron may alternate with layers or lenses very high in manganese and low in iron. There are also variations along the strike of the beds, however, resulting locally in changes along the same bed from high-grade manganiferous iron ore to low-grade manganiferous iron ore or even to iron ore containing little or no manganese. In many deposits irregular masses of iron ore or of lean iron and manganese bearing rock are inclosed within manganiferous iron ore. These irregularities show that the grade of the ore varies from place to place and that it is difficult to maintain a uniform product from the mines. This difficulty is overcome in part by mixing ores from different parts of an ore body and in part by marketing several distinct grades of ore. Some mines offer as many as four grades of manganiferous iron ore.

The principal constituents of the ore are iron and manganese oxides, together with silica, which is found in the form of chert or quartz, and alumina, which occurs in clay and in several silicates. Iron and manganese carbonate are found locally in the ore, and iron silicates are common. Lime and magnesia occur in some ores and are probably present largely as carbonates or silicates. The principal gangue material is the country rock, such as ferruginous chert, ferruginous slate, or clay. Quartz veins occur in many of the ore bodies. With increasing depth ore bodies and associated rock grade into unaltered iron-bearing formation.

The content of manganese in the manganiferous iron ores ranges from 1 to 30 or 35 per cent, and the iron from 20 to 50 per cent or more. The silica usually ranges between 8 and 16 per cent in the low-phosphorus ores but is lower in the high-phosphorus ores. Phosphorus ranges generally from 0.06 to 0.10 per cent in the low-phosphorus ores and 0.15 to 0.25 per cent in the high-phosphorus ores. Water of hydration ranges from 6 to 12 per cent.

Below are given average cargo analyses of manganiferous iron ore from certain mines in the Cuyuna district:[1]

Average cargo analyses of manganiferous iron ore, dried at 212° F., from the mines of the Cuyuna district, Minn.

Mine.	Fe.	Mn.	P.	SiO_2.	Al_2O_3.	CaO.	MgO.	S.	Loss by ignition.
Armour No. 2	49.30	5.28	0.215	8.90	3.43	....	....	....	....
Cuyuna-Mille Lacs	37.71	21.22	.091	11.46	.95	0.82	0.47	Trace.	....
Do	39.02	17.06	.096	13.20	.42	.84	.67	Trace.	....
Do	37.39	12.91	.079	19.50	.22	.67	.63	Trace.	....
Do	40.02	8.96	.051	22.00	.18	.68	.60	Trace.	....
Ferro	29.29	22.29	.075	17.56	1.47	....	....	....	....
Hillcrest	43.811	9.880	.230	6.110	....	....	....	....	....
Algoma (Hoch)	32.26	19.50	.090	16.47	2.43	....	....	....	....
Mahnomen	40.00	14.00	.15	10.00	3.80	.22	.31	0.015	7.84
Do	46.00	8.00	.20	7.55	3.80	.22	.31	.015	9.84
Do	51.00	4.50	.19	6.10	3.70	.75	1.24	.029	9.90
Mangan No. 1	35.91	13.51	.099	22.29	2.99	.26	.37	.010	....
Meacham	46.58	4.42	.308	6.52	4.22	2.08	.55	....	12.02
Sultana	39.302	13.426	.170	8.536	3.50	.75	.50	.015	10.00
Do	37.74	14.68	.062	16.44	....	....	....	....	....

A total quantity of 363,334 gross tons of manganiferous iron ore, containing more than 5 per cent of manganese, has been shipped from the Cuyuna district to the end of 1916. The following table shows the annual shipments from the different mines:

[1] Analyses of Lake Superior iron ores, season 1916, pp. 8-11, Lake Superior Iron Ore Association, 1917.

Manganiferous iron ores shipped from the Cuyuna district, Minn., 1913 to 1916, inclusive, by mines, in gross tons.

Mine.	Ore containing 15 to 40 per cent manganese.				Ore containing 5 to 15 per cent manganese.				Total.
	1913	1914	1915	1916	1913	1914	1915	1916	
Cuyuna Mille Lacs	[a]26,200	55,000	35,221					90,000	206,421
Ferro				14,710					14,710
Hillcrest								[a] 2,712	2,712
Algoma (Hoch)		192	3,036	23,000			4,564		30,792
Mahnomen								43,000	43,000
Mangan, Nos. 1 and 2								30,329	30,329
Sultana			152					35,218	35,370
	26,200	55,192	38,409	37,710			4,564	201,259	363,334

[a] Percentage of manganese not stated.

As shown by the above table the production is rapidly increasing. In 1917 probably 14 or 15 mines will produce manganiferous iron ore.

The amount of manganiferous iron ore available in the district is only very imperfectly known. The following table shows estimated reserves of several grades of ore according to the Minnesota Tax Commission:[1]

Estimated reserves of manganiferous iron ore in the Cuyuna district, Minn.

Mn (per cent).	Fe (per cent).	Fe and Mn (per cent).	P (per cent).	Tons.
1.22	54.65	55.87	0.179	123,771
1.36	56.38	57.74	.159	3,122,031
3.53	53.69	57.22	.258	720,488
4.98	50.85	55.83	.350	644,750
5.90	49.15	55.05	.336	713,490
9.19	47.27	56.46	.058	468,566
10.99	46.46	57.45	.236	948,802
11.30	42.57	53.87	.226	1,939,417
11.44	43.49	54.93	.045	620,897
15.45	39.27	54.72	.090	408,878
15.96	43.26	59.22	.156	183,716
21.93	30.82	52.75	.070	100,000
				9,994,806

The estimates shown in the above table were made in 1913, before the possibilities of the extensive use of manganiferous iron ores were definitely realized. They include only ores whose metallic content is over 50 per cent. At the present time, however, the combined iron and manganese content of much of the ore that is shipped is less than 50 per cent. On the other hand, the estimates include a considerable quantity of material that is too low in manganese to constitute an important reserve of manganiferous ore. However, there has been much exploration work during the last three years,

[1]Appleby, W. R., and Newton, E., Preliminary concentration tests on Cuyuna ores: Minnesota School of Mines Exper. Sta. Bull. 3, p. 52, 1915. Minnesota Tax Commission Fourth Bienn. Rept., pp. 75 et seq. 1914.

and the known quantity of manganiferous iron ore of all grades has been increased greatly. There is no doubt that the Cuyuna district constitutes one of the most important sources of manganiferous ore in the United States.

OTHER LAKE SUPERIOR DISTRICTS.

Manganiferous iron ores are found in several other Lake Superior iron-ore districts besides the Cuyuna. Ores containing 5 per cent or more of manganese are being produced in the Penokee-Gogebic district of Michigan and Wisconsin and in the Iron River district of Michigan. In general relation these ores are similar to the manganiferous iron ore of the Cuyuna district, but their distribution is much more local and the quantity is comparatively small.

Besides manganiferous iron ores these districts, as well as the Marquette and Menominee districts of Michigan and the Mesabi district of Minnesota, produce considerable quantities of iron ore which contain between 1 and 3 per cent of manganese. Such ores can be used in the manufacture of high-manganese pig iron and should be reckoned among the sources of manganese.

APPALACHIAN REGION.

Small quantities of manganiferous iron ore have been produced intermittently at several localities along the Appalachian Valley from Vermont southward to Georgia. The manganiferous iron ore is generally associated with the brown iron ore or the high-grade manganese ore of the region,[1] and the conditions of occurrence and distribution are similar. The principal deposits are found along the west front of the Blue Ridge in Virginia, but many isolated deposits are known throughout the Appalachian Valley in Pennsylvania, Virginia, Tennessee, and Georgia.

The general features of most deposits of manganiferous iron ore along the Blue Ridge in Virginia and its southward extension in Tennessee and Georgia are very similar to those of the "mountain" brown ores. The shapes of the deposits vary with their structural associations; some occur in troughs, whereas others are in fault zones. The ores contain nodules of psilomelane with some manganite and limonite, embedded in clay resulting from the decomposition of the limestone and shale near by. No ores are known to persist 300 feet below the surface. In some of the deposits masses of manganiferous iron ore 50 or 60 feet long are known. Some deposits consisting of groups of large and small bodies or masses of manganiferous iron ore are many hundred feet in length and width.

[1] Harder, E. C., Manganese deposits of the United States, with sections on foreign deposits, chemistry and uses: U. S. Geol. Survey Bull. 427, pp. 27-102, 1910.

Manganiferous iron ore occurs also in association with the "valley" brown ore in Virginia and Tennessee and with the "Oriskany" brown ore in Virginia. Some deposits or parts of deposits of these ores are highly manganiferous. As in the Blue Ridge deposits, the ores are embedded in residual clay. They have been formed by surface concentration and replacement and do not extend far below the surface. In northwestern Virginia, in the New River region of southwestern Virginia, and in Shady Valley, Tenn., many such deposits are found. Until recently the demand for the ores has been slight, and many deposits have been abandoned. There is little doubt that a large quantity of manganiferous iron ore is available in the Appalachian region.

The iron and manganese oxides that make up the manganiferous iron ore are clearly distinguishable in many of the deposits. Manganese oxides, such as psilomelane or pyrolusite, occur as irregular pockets in the iron ore or small lenses of iron and manganese oxides may be found interlayered or irregularly intermixed. There are other deposits, however, in which the iron and manganese oxides are indistinguishable from each other, and the mixture forms a homogeneous black or brownish-black ore.

Much of the manganiferous iron ore of the Appalachian region, such as that occurring along the Blue Ridge, is very siliceous. Some shipments, however, show a high content in metal. Analyses of some of the ores are given below.

Analyses of manganiferous iron ore from the Appalachian region.

Mn.	Fe.	P.	SiO_2.
8.22	41.12	0.260	14.83
10.18	40.10	.536	10.52
25.09	29.17	.155	....
30.32	23.90	.100	6.37
36.48	15.83	.089	7.56
44.31	12.32	.101	5.47

The following table shows the production of manganiferous iron ore in the eastern part of the United States,[1] including the Appalachian region:

Manganiferous iron ore produced in eastern United States, 1887–1917, in gross tons.

	Virginia.	Other Eastern States.		Virginia.	Other Eastern States.
1887	1,025	[a] 726	1909	305	....
1888	....	[b] 1,096	1910	301	....
1892	3,000	....	1911	1,007	....
1893	1,188	[c] 20	1912	1,567	....
1897	....	[d] 1,200	1914	1,363	[f] 410
1898	....	[e] 100	1915	1,944	[g] 826
1901	....	[c] 20	1916	37,729	[h] 5,065
1902	3,000	....			
1903	2,802	....		55,505	9,463
1908	274	....	1917 (estimated)	45,000	750

[a] Georgia, Maine, and Vermont.
[b] North Carolina, South Carolina, Tennessee, and Vermont.
[c] North Carolina.
[d] Vermont.
[e] Pennsylvania.
[f] South Carolina.
[g] Georgia and Tennessee.
[h] Georgia, Pennsylvania, and Tennessee.

NORTHERN ARKANSAS.

During the past 12 years several thousand tons of manganiferous iron ore have been produced annually in northern Arkansas. Practically all this ore has come from one mine in the southern part of the district north of Batesville. The ore is found in horizontal strata, known as the Cason shale, which lie unconformably upon the next lower formation, the unconformity representing a long period of erosion. The strata consist of dark-red sandy shale 10 to 15 feet thick, containing a few layers of dark quartzite. In places the entire formation is heavily impregnated with iron and manganese oxides, and the shaly layers contain an abundance of small flattened buttons of manganiferous iron ore lying parallel to the stratification. The buttons range from half an inch to 2 inches in the longer diameter and are from a quarter to half an inch thick. Locally they merge into one another and form thin horizontal layers. The buttons are closely grouped, and generally make up more than half of the rock mass. They are more abundant in the upper part of the bed than in the lower part. Where many are present they constitute a low grade manganiferous iron ore.

The part of the Cason shale which contains manganiferous iron ore occupies a considerable area in the southern part of the Batesville district, and doubtless large quantities of this low grade material are available. As the ore has the nature of an original sediment and is not secondarily concentrated by surface weathering, it may occur in the Cason shale underneath the hills as well as along the outcrop. In the northern part of the Batesville district this bed carries high grade manganese ores.[1]

[1] Harder, E. C., Manganese deposits of the United States, with sections on foreign deposits, chemistry, and uses: U. S. Geol. Survey Bull. 427, pp. 102–118, 1910.

The following analyses show the composition of the northern Arkansas manganiferous iron ore:

Analyses of northern Arkansas manganiferous iron ore.

Fe.	Mn.	P.	SiO_2.	Moisture.
4.88	34.64	0.580	25.65	....
8.45	38.30	.380	....	....
10.75	41.08	.467	....	....
12.50	43.12	.339	1.54	....
15.70	35.40	.735	4.35	16.30
18.80	33.21	.194	6.05	15.10
21.63	24.31	.252	14.82	....
23.40	29.57	.452	5.10	19.00

Below is given the total production of manganiferous iron ore in Arkansas.

Manganiferous iron ore produced in Arkansas, 1893–1916, in gross tons.

1893	160	1909	3,325	1915	3,355
1904	600	1910	5,030	1916	3,869
1905	3,321	1911	2,177		51,888
1906	8,900	1912	1,332		
1907	4,133	1913	9,650		
1908	4,066	1914	1,970		

WESTERN UNITED STATES.

The manganiferous ores associated with precious and semiprecious metal deposits in the mining regions of the western United States are principally of two kinds—those containing a large proportion of both manganese and iron oxides and those containing manganese oxides, with little or no iron oxide. Ores of the first class are by far the most abundant and include those of Leadville, Colo.; Pioche, Nev.; and Silver City, N. Mex. Manganiferous ores containing little or no iron are found at Philipsburg and Butte, Mont., and at Tombstone, Ariz. Nearly all the ores contain small amounts of other metals, such as silver, gold, lead, zinc, and copper.

The manganese content of the manganiferous ores shows a great range. Where the proportion of the combined manganese and iron oxides is fairly high the ore may be used in the manufacture of spiegeleisen. Elsewhere, however, such impurities as silica, alumina, and lime are present in large quantities. Most of the ores that contain little or no iron contain a large proportion of the impurities mentioned above. Locally, however, as at Philipsburg, some ore that is fairly high in manganese is found. Thus, in the Western States, all gradations from manganese ore to low-grade manganiferous material are known. If silica and other impurities could be removed from such ores by cheap and efficient methods of concentration, large quantities would become available at Philipsburg, Butte, and other localities. The concentration would yield a high-grade manganese product, such as could not be produced from manganiferous ores containing iron.

Of the manganiferous ores containing both manganese and iron, those of Leadville, Silver City, and Pioche are of considerable value. The Leadville ores have for many years been mined in large quantities for use as flux and in smaller quantities for the manufacture of spiegeleisen. Those of Silver City and Pioche have also been used largely for flux in past years, but at the present time considerable ore is being mined at Silver City for use in the manufacture of spiegeleisen. The Leadville and Silver City ores are smelted at Pueblo, Colo.

The manganiferous ores are found in the upper oxidized portions of deposits containing silver, lead, gold, copper, zinc, and other metals. With increasing depth the oxides grade into unaltered manganese or iron carbonates or silicates, which form the gangue minerals associated with the sulphides of the other metals. Only the oxidized parts of deposits have been used for their iron or manganese content, as the unaltered gangue minerals are usually of too low grade. The depth of the oxidized zone varies from place to place.

A few average analyses of manganiferous ore from Leadville and Silver City are given below.

Analyses of manganiferous ore from Leadville, Colo., and Silver City, N. Mex.

Locality.	Fe.	Mn.	P.	SiO_2.	Al_2O_3.	CaO.	Moisture.
Leadville	17.05	33.14	0.061	7.97	1.32	1.18	14.80
Do	22.75	27.30	.115	6.50	1.53	1.84	14.10
Do	26.99	23.52	.060	4.31	1.21	1.55	14.96
Do	29.70	19.60	.052	10.60	2.25	1.84	14.28
Silver City	37.00	17.00	.015	9.00	....	5.00	....

The following table shows the production of manganiferou ores in the western part of the United States as far as has been recorded:

Manganiferous ores produced in the western United States, 1885–1916, in gross tons.[a]

Year.	Colorado.		Other States.	Year.	Colorado.		Other States.
	Used in the manufacture of iron-manganese alloys.	Used for flux.			Used in the manufacture of iron-manganese alloys.	Used for flux.	
1885			[b] 4,263	1902	13,275	194,132	
1886		[c] 60,000		1903	14,856	179,205	
1887		[c] 60,000		1904	17,074	105,278	
1888		[c] 60,000		1905	45,837	81,738	
1889		64,987		1906	32,400	([d])	
1890	6,397	51,840		1907	67,514	32,197	[e] 7,000
1891	964	79,511		1908	15,973	35,581	
1892	2,942	62,309		1909	12,905	52,119	
1893	5,766	55,962		1910		55,770	
1894	7,022	31,687		1911		41,753	
1895	13,464	54,163		1912		48,618	
1896	9,072	138,079		1913		49,753	
1897	16,519	149,502		1914	2,100	37,781	
1898	18,848	99,651		1915	15,956	14,965	[f] 106,005
1899	29,355	79,855		1916	16,263	90,850	[g] 150,642
1900	43,303	188,509					
1901	62,385	228,187			470,190	2,483,982	267,910

[a] Hewett, D. F., Manganese and manganiferous ores: U. S. Geol. Survey Mineral Resources, 1914, pt. 1, p. 175, 1916, and corresponding chapter for 1916 (in preparation).
[b] Montana.
[c] Contains some Montana ore.
[d] Not recorded.
[e] New Mexico.
[f] Arizona, Nevada, and Utah.
[g] Arizona, California, Montana, Nevada, New Mexico, Utah, and Washington.

Besides the districts which have been mentioned there are doubtless in many parts of the West areas containing appreciable quantities of manganiferous ores. Many such localities have been reported during the last few years, and some of them have been investigated by the United States Geological Survey in the summer of 1917. There are probably others that have thus far escaped observation.

SUMMARY.

There are in the United States large quantities of manganiferous ores containing varying amounts of manganese. A very small proportion of these can be used in the production of high-grade iron-manganese alloys, but a large proportion can be used for lower-grade alloys, and nearly all can be used in making high-manganese pig iron. Compared with the manganiferous ores, the reserves of high-grade manganese ores in this country are insignificant. Hence, although a search for manganese ore is desirable, a more promising solution of the manganese problem would seem to lie in the direction of the utilization of low-grade manganiferous ores. Up to the present time the use of these ores has been very slight. Until a few years ago they were considered to have little value and were mined only incidentally. In the West manganiferous ores would not be mined were it not for their association with ores of other metals.

There are several ways in which the utilization of manganiferous ores may be brought about: (1) It has been suggested that by methods of concentration resulting in the elimination of iron, silica, or other constituents a product high in manganese might be derived from them. Such concentration has been attempted locally but with very little success, owing mainly to the intimate mixture which manganese generally forms with associated materials. (2) The steel-making practice might be changed so that more spiegeleisen and less ferromanganese would be used for deoxidizing. By the addition of small quantities of high-grade manganese ore much of the manganiferous iron ore could be used in the manufacture of spiegeleisen. (3) The most effective solution, however, as has previously been suggested, seems to be to so change the practice in the manufacture of basic open-hearth steel as to make possible the use of high-manganese pig iron. Experimentation along this line is extremely desirable. The successful application of such a change would make large reserves of manganiferous iron ore commercially available and would greatly decrease the quantity of high-grade manganese ore consumed.

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