University of Arizona Bulletin

MANGANESE

BY

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Entered as second class matter November 25, 1915, at the postoffice at Tucson, Arizona, under the Act of August 24, 1912. Issued weekly, September to May.

PUBLISHED BY THE

University of Arizona
Bureau of Mines

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TUCSON, ARIZONA

1918-19
PREFACE

Since the great demand for domestic manganese ore has arisen as a result of conditions brought about by the war, Arizona has rapidly come to the front as a producer, and the Arizona Bureau of Mines has received a large number of requests for information of all sorts concerning manganese and its ores. As the Bureau's stock of Bulletin 4 on "Manganese" was exhausted, it was thought best to prepare a new bulletin on the same subject; and an attempt is made in this booklet to answer every question that has reached the Bureau in the course of the last year or two. Technical terms have been avoided so far as possible, and some very elementary material has been included because experience has shown that it will probably be welcomed by prospectors and others who have not had the advantage of a technical training. Everything presented has a direct bearing upon the development of manganese mining in Arizona.

The staff of the Bureau wishes to take this opportunity to express appreciation for the prompt replies made by the many users and purchasers of manganese to the letters sent out to them; and they wish further to express the desire that prospectors and miners will always feel perfectly free to call upon the Bureau for assistance in the classification of specimens, or for advice on any phase of the mineral industry.

MANGANESE MINERALS

Although manganese occurs in nature in a great variety of combinations with other elements, those minerals described below are the only ones with any considerable present or prospective value as ores of this metal.

PSILOMELANE

Composition: $\text{MnO}_2$ (manganese dioxide) with $\text{MnO}$ (manganese monoxide), $\text{H}_2\text{O}$ (water), $\text{K}_2\text{O}$ (potassium oxide), $\text{BaO}$ (barium oxide), etc. The mineral is essentially manganese dioxide, but the percentage of metallic manganese rarely reaches 60, and in hard, compact, homogenous material the percentage may amount to only 50 or even less. The percentage of water varies from about 3 to 10, and
none of the other oxides mentioned, with the possible exception of oxide of barium, are usually present in proportions as high as 3%.

*Luster:* Dull metallic to dull; occasionally satiny on a freshly broken surface.

*Color of Powder:* Usually grayish black; rarely brownish black.

*Hardness:* Usually too hard to be scratched with a knife, which leaves a shining mark on the surface of the mineral.

*Fracture:* Curving fracture like flint. Fractured surfaces are very smooth.

*Specific Gravity*: 3.7-4.7.

*Occurrence:* In veinlets or seams, nodules, and as massive, structureless material. The massive variety often contains cavities or vugs, the surfaces of which are usually coated with globular or kidney-like protuberances. Often associated with limonite (hydrus oxide of iron) and pyrolusite (see below), sometimes occurring as alternating layers with the latter mineral. Often found as a black stain in rock joint planes, and this stain sometimes takes the form of fern-like markings (dendrites). Crystals are unknown excepting when formed by the alteration to psilomelane of crystalline manganese minerals.

*Blowpipe and Chemical Tests:* When heated in a closed glass tube psilomelane gives off oxygen gas and always yields much water. When powdered and dissolved in hydrochloric acid (HCl) it gives off greenish yellow chlorine gas which has a very unpleasant stifling odor; and if sulphuric acid (H₂SO₄) is added to this solution, a white precipitate of barium sulphate (BaSO₄) is formed. The finely powdered mineral imparts distinctive colors to borax and soda beads as described elsewhere in this pamphlet.

*Miscellaneous:* The hardness, lack of structure, and smooth, curving fracture suffice to distinguish psilomelane from other manganese minerals with which it may be confused.

This is the commonest ore of manganese, but is not as pure as some of the minerals mentioned later.

**PYROLUSITE**

*Composition:* MnO₂ (manganese dioxide). When pure it contains 63.2% manganese, and 36.8% oxygen, but most specimens contain about 2% of water, and fractions of a per cent of CaO (lime), SiO₂ (silica), and oxides of copper, iron, nickel, cobalt, potassium, sodium, etc.

*Luster:* Metallic or dull, some forms showing the former and others the latter.
Color: Usually black; sometimes very dark steel-gray.

Color of Powder: Black, often sooty.

Hardness: Soft enough to be scratched with a finger nail. Often soils the fingers when handled.

Fracture: The massive material has an uneven fracture, but the prismatic variety shows a splintery fracture, and the faces of individual prisms are smooth and flat, and reflect light brilliantly.

Specific Gravity: 4.8.

Occurrence: Usually occurs as dull, rather earthy masses, or granular. The earthy variety sometimes contains numerous tiny, steely-lustered, prismatic or platy crystals of pyrolusite or manganite (see below). Often found in crusts with more or less sharply crystallized surfaces, and appearing to be made up of myriads of slender parallel or divergent prisms or crystals. The massive material often contains bands or patches of these parallel or divergent prisms or fibers, and is sometimes entirely prismatic or fibrous in texture. Intergrowths of pyrolusite and psilomelane are common, and these sometimes take the form of alternate bands of prismatic or fibrus pyrolusite and hard, structureless psilomelane.

Blowpipe and Chemical Tests: Pyrolusite is infusible in a blowpipe flame, but turns brown. When heated in a closed glass tube pyrolusite gives off oxygen gas, and most varieties yield some water. The finely powdered mineral imparts distinctive colors to borax and soda beads, as described elsewhere in this pamphlet.

Miscellaneous: The softness and jet-black powder suffice to distinguish pyrolusite from other manganese minerals with which it may be confused.

This is a very important ore of manganese, and may occur in deposits of sufficient purity to be used for the manufacture of chemicals and dry batteries.

MANGANITE

Composition: \( \text{MnO}_2, \text{H}_2\text{O} \) (hydrous manganese dioxide). When pure it contains 62.4% manganese, 27.3% oxygen, and 10.3% water, but the impurities mentioned under pyrolusite are often present in small amounts.

Luster: Usually bright metallic, sometimes dull metallic.

Color: Dark steel-gray to black.

Color of Powder: Usually brown, sometimes brownish black.

Hardness: Too hard to be scratched with a finger nail, but easily scratched with a knife. Does not soil the fingers.

Fracture: Individual grains or crystals break or cleave easily and
smoothly in one direction, yielding flat surfaces which reflect light brilliantly. Masses made up of an aggregate of such grains or crystals have an uneven fracture.

*Specific Gravity:* 4.2-4.4.

*Occurrence:* Occurs in slender, prismatic orthorhombic crystals which usually have a roughly diamond or lozenge-shaped cross-section; also as aggregates of prismatic or columnar crystals or grains; rarely granular. Manganite ore is usually quite porous, the cavities being lined with the prismatic crystals already described.

*Blowpipe and Chemical Tests:* Infusible in a blowpipe flame. When heated in a closed glass tube manganite yields water. When powdered and dissolved in hydrochloric acid (HCl) it gives off greenish yellow chlorine gas which has a very unpleasant stifling odor. The finely powdered mineral imparts distinctive colors to borax and soda beads, as described elsewhere in this pamphlet.

*Miscellaneous:* The hardness and the brown color of the powder suffice to distinguish manganite from other manganese minerals with which it may be confused.

This is a relatively unimportant ore of manganese, but is not infrequently present in deposits consisting chiefly of psilomelane or pyrolusite.

**WAD (Includes Bog Manganese)**

*Composition:* An impure hydrous mixture of various oxides of manganese, containing variable proportions of the oxides of cobalt, copper, iron, barium, and a number of other elements. The proportion of MnO₂ (manganese dioxide) varies between 30% and 75%, but is usually relatively low. The percentage of the other oxides mentioned varies to such an extent that no general figures can be given, but amounts exceeding 20% of some of them are sometimes present. The substance should probably be regarded as a mixture of several minerals rather than a distinct mineral species.

*Color:* Brown, reddish brown, brownish black.

*Luster:* Dull, earthy.

*Color of Powder:* Usually some shade of brown.

*Hardness:* Very soft. Cannot be handled without soiling the fingers badly, and can be used like soft charcoal to mark on paper.

*Fracture:* Uneven.

*Specific Gravity:* 2.5 to 4.2. It is usually so porous as to seem very light.

*Occurrence:* Occurs in soft, light, earthy masses or coatings, which
are usually rather porous, and are sometimes, although rarely, finely fibrous or scaly in texture.

**Blowpipe and Chemical Tests:** These vary with the composition, although all varieties yield the chlorine test described under psilomelane and pyrolusite. The borax and soda bead tests are usually satisfactory because of the interference of elements present as impurities, and which themselves impart distinctive colors to such beads.

**Miscellaneous:** The extreme softness and lightness, combined with the prevailing brown tint of the powder, should suffice to distinguish wad from other manganese minerals with which it may be confused.

Wad is usually too impure to have any value as an ore of manganese, but it sometimes contains sufficient copper, lead, or other valuable base metals to constitute it an ore.

**BRAUNITE**

**Composition:** \(3\text{Mn}_2\text{O}_3, \text{MnSiO}_3\) (sesquioxide and silicate of manganese). When pure it contains 78.3\% \(\text{Mn}_2\text{O}_3\) (manganese sesquioxide), 11.7\% \(\text{MnO}\) (manganese monoxide), or a total of 63.6\% metallic manganese, and 10\% silica. Water and other oxides may be present as impurities in amounts up to a per cent or two.

**Luster:** Dull metallic.

**Color:** Dark brownish or grayish black.

**Color of Powder:** Usually dark brownish black.

**Hardness:** Same as for psilomelane.

**Fracture:** Individual grains or crystals break or cleave easily and smoothly in several directions yielding flat surfaces which reflect light brilliantly. Masses made up of an aggregate of such grains or crystals have an uneven fracture.

**Specific Gravity:** 4.75 to 4.82.

**Occurrence:** In coarse to fine granular masses and in octahedral crystals, often mixed with psilomelane.

**Blowpipe and Chemical Tests:** Braunite is infusible in a blowpipe flame. When dissolved in hydrochloric acid it gives the chlorine test described under psilomelane and pyrolusite, leaving a residue of gelatinous silica after complete evaporation of the acid. The finely powdered mineral imparts distinctive colors to borax and soda beads, as described elsewhere in this pamphlet.

**Miscellaneous:** The hardness, dark brown powder, and tendency to show flat, glistening surfaces when broken should suffice to distinguish braunite from other manganese minerals with which it may
be confused. The gelatinization with acid will distinguish it from all other manganese minerals.

Braunite is never mined alone as an ore of manganese, but is frequently present as an impurity in other manganese minerals, especially psilomelane.

**RHODOCHROSITE**

*Composition:* MnCO$_3$ (manganese carbonate). When pure it contains 47.8% metallic manganese, or 61.7% MnO (manganese monoxide), and 38.3% CO$_2$ (carbon dioxide). Iron carbonate is usually present, and, less frequently, carbonates of calcium, magnesium, or zinc. Cobalt carbonate is a relatively rare impurity. Iron carbonates may be present in amounts up to 40% or more, and the percentage of calcium carbonate may exceed the percentage of manganese carbonate. The proportion of the other compounds mentioned is usually considerably smaller than the figures just given.

*Luster:* Glassy when transparent to stony or rather dull when translucent.

*Color:* Deep rose-red when glassy and transparent, and pink to almost white when translucent; occasionally fawn colored. Turns black when exposed to damp air.

*Color of Powder:* White.

*Hardness:* Easily scratched with a knife, but too hard to be scratched with a finger nail.

*Fracture:* Individual grains or crystals break or cleave easily and smoothly in three directions, yielding flat surfaces which reflect light brilliantly. Masses made up of an aggregate of such grains or crystals have an uneven fracture.

*Specific Gravity:* About 3.5.

*Occurrence:* Occurs in coarsely cleavable masses, coarse to fine granular masses, and as crystals which when complete are usually bounded by six lozenge or diamond-shaped faces and which are sometimes bent or warped. Openings or vugs in the massive material are usually lined with fine crystals. Often associated with fluorite (fluorspar), pyrite (iron sulphide), galena (lead sulphide), and other metallic ores.

*Blowpipe Chemical Tests:* Rhodochrosite is infusible in a blowpipe flame, but turns black and often flies to pieces. Dissolves with effervescence or boiling in hot concentrated hydrochloric acid. The finely powdered mineral imparts distinctive colors to borax and soda beads, as described elsewhere in this pamphlet.

*Miscellaneous:* The color, the softness, the fracture, and the acid
test usually suffice to distinguish rhodochrosite from any mineral which it may resemble.

Rhodochrosite was not considered an ore of manganese in this country, and had no commercial importance until recently. Large quantities are now, however, being shipped from Butte, Montana, to manufacturers of spiegeleisen. Owing to the absence of silica, and to the fact that the carbonate may easily be changed to the oxide by roasting, it seems likely that deposits of rhodochrosite may become increasingly important as sources of manganese.

**RHODONITE**

*Composition:* MnSiO$_3$ (manganese silicate). When pure it contains 42% metallic manganese, or 54.1% MnO (manganese monoxide) and 45.9% SiO$_2$ (silica). It almost never contains as much as 50% MnO, however, since CaO (lime) is practically always present in an amount exceeding 3%, and iron is also a very common impurity. Either lime or iron may, in fact, form 10% or more of the ore. MgO (magnesia) is nearly always represented, but in amounts usually under 2%, and zinc is a rather rare impurity.

*Luster:* Glassy when transparent to stony or rather dull when translucent.

*Color:* Deep rose red to light pink; occasionally flesh colored or brownish red. Turns black when exposed to damp air.

*Color of Powder:* White.

*Hardness:* Cannot be scratched with a knife, although the blade will sometimes sink between grains of finely granular varieties, and may seem to scratch such specimens. Even such material will scratch a knife blade, however.

*Fracture:* Individual grains or crystals break or cleave rather easily and smoothly in several directions, sometimes yielding flat surfaces which reflect light brilliantly. This cleavage is less noticeable upon stony than upon glassy lustered varieties, and may not be evident at all upon fine grained material. Coarsely granular specimens have an uneven fracture, while very fine grained varieties may show a smoothly rounded or curving fracture.

*Specific Gravity:* 3.4-3.68.

*Occurrence:* In fine grained, compact masses; less frequently coarsely granular, in crystals, or as disseminated grains. Often associated, like rhodochrosite, with deposits of metallic minerals.

*Blowpipe and Chemical Tests:* Rhodonite blackens and fuses easily in a blowpipe flame. Partially soluble in hydrochloric acid, and the
undissolved residue becomes white. The finely powdered mineral imparts distinctive colors to borax and soda beads, as described elsewhere in this pamphlet.

Miscellaneous: The color, the hardness, and the usual association with metallic minerals suffice to distinguish rhodonite from any mineral which it may resemble.

It is not known that rhodonite has ever been mined as an ore of manganese, and it seems improbable that it will ever become an important source of this metal unless an economical method of eliminating the silica can be discovered.

ALABANDITE

Composition: MnS (manganese sulphide). When pure it contains 63.1% manganese and 36.9% sulphur.

Luster: Dull metallic.

Color: Black or very dark gray. Tarnishes brown on exposure to damp air.

Color of Powder: Dark green.

Hardness: Easily scratched with a knife, but too hard to be scratched with a finger nail.

Fracture: Individual grains or crystals break or cleave in three directions at right angles to each other, exactly like the cleavage of galena, although alabandite does not cleave as easily or as perfectly as galena, and the resulting flat surfaces do not reflect light as brilliantly. Masses made up of an aggregate of such grains or crystals have an uneven fracture.

Specific Gravity: 3.95 to 4.04.

Occurrence: In coarse to fine granular masses, and in crystals which are often cubical.

Blowpipe and Chemical Tests: When heated in an open glass tube or on charcoal, this substance yields the odor of burning sulphur. Soluble in dilute hydrochloric acid with the evolution of hydrogen sulphide, a gas with the odor of bad eggs. After roasting, the finely powdered mineral imparts distinctive colors to borax and soda beads, as described elsewhere in this pamphlet.

Miscellaneous: The color of the powder and the cleavage suffice to distinguish this mineral from all others which it may resemble.

Alabandite ore must be roasted before it can be used, and the expense involved in this operation has until recently made it impossible to market this mineral profitably. Under the influence of the high prices for manganese now prevailing, large quantities of alabandite
have recently been mined in the Tombstone district, and it is not improbable that deposits of this mineral located elsewhere could be profitably developed.

**Borax Bead Test.**

A very little finely pulverized oxide, carbonate, or silica of manganese, if added to a drop or bead of melted borax, will cause the borax to assume an amethyst color when cold.

The most satisfactory method of making this test is to heat the end of some 26-gauge platinum wire in an alcohol lamp, touch it to some powdered or granulated borax, and repeat the process until a bead about as large as the head of a glass-headed pin has been formed. If this is not too large, it will show no tendency to drop from the wire. When a bead of the proper size has been formed, heat it until it is transparent, and then touch it to a few grains of the mineral to be tested. Finally heat the bead for a minute or two in the tip of the alcohol flame, and examine its color with a lens.

If platinum wire is not available, a bead may be formed by melting a little borax on a piece of charcoal with a blowpipe flame.

This test is very delicate, and the inexperienced operator is apt to introduce so much ore into the bead that the latter becomes black and opaque. When this occurs the best plan is to start again with a new bead, and to use less ore the second time.

If an ore contains considerable iron, the resulting bead will be orange or reddish brown rather than amethyst in color; while the presence of considerable percentages of cobalt or copper will result in blue beads which may or may not have a purplish tint.

A sulphide ore of manganese should be thoroughly roasted (pulverized and heated at a red heat until sulphur fumes are no longer noticeable) before attempting to make the borax bead test.

**Sodium Carbonate Bead Test.**

If sodium carbonate is substituted for borax in the test above described, the result will be an opaque bluish green bead, but a little nitre must be added to the bead if the ore is a sulphide, and has not been roasted.

**Chlorine Test.**

All the oxides of manganese yield the so-called chlorine test which should be conducted as follows: Place a little of the powdered material in a glass beaker or a porcelain tea-cup, and pour some dilute hydrochloric acid over it. If manganese dioxide is present, the mixture when heated will evolve greenish yellow chlorine gas which has a very unpleasant, stifling odor.
TO CONVERT PERCENTAGES OF MANGANESE DIOXIDE TO PERCENTAGES OF MANGANESE, AND VICE VERSA

In quotations and chemists' reports the manganese content of an ore is sometimes reported as metallic manganese, and sometimes as MnO₂ (manganese dioxide). To convert manganese dioxide to metallic manganese, multiply the percentage of manganese dioxide by 0.632. To convert metallic manganese to manganese dioxide, divide the percentage of metallic manganese by 0.632. Thus an ore containing 54% manganese dioxide contains 0.632 × 54.5% which equals 34.4 metallic manganese; and an ore containing 42.1% metallic manganese contains 42.1% ÷ 0.632 which equals 66.6% manganese dioxide.

OCCURRENCE AND ORIGIN OF MANGANESE ORE

While manganese is a very widely distributed element occurring in minute quantities in nearly all kinds of rock, formed or deposited in all geological periods, the metal when thus scantily disseminated cannot be mined profitably, and economically important ore is found only where some form of natural concentration or segregation has occurred. Such workable deposits are of four types which may be designated (1) deposits resulting from the alteration and decomposition of manganese-bearing rocks, (2) deposits occurring as veins or other related forms, (3) bog manganese deposits, and (4) sedimentary deposits.

Deposits Resulting from the Alteration and Decomposition of Manganese-bearing Rocks.

The manganese in ore formed in this way was originally disseminated through rocks that have been subjected to weathering on or near the earth's surface. As a result of this process the valueless rock constituents are gradually softened and decomposed, are eventually removed by mechanical erosion or in solution, and the heavier manganese minerals gradually accumulate in beds or blankets of varying thickness and purity. At the same time more or less of the manganese compounds thus released from the decomposed rocks may find their way downward in solution in rainwater and may be deposited in joints or other openings below the surface. Often decomposition from such solutions starts at certain centers, and around such nuclei layer after layer of manganese minerals are deposited, forming rounded nodules or concretions. These may be rather widely scattered, or they may be confined to relatively thin zones in which they are sometimes so
large and numerous as to form beds of valuable ore. Not infrequently the manganese compounds in solution completely replace portions of rock (especially limestone) with which they come in contact, the rock constituent passing off in solution, and the manganese minerals being deposited in their place.

The manganese minerals found in deposits formed as just outlined are oxides, usually psilomelane, and are apt to be more or less closely associated with limonite (hydrous oxide of iron).

This is probably the commonest and most important type of manganese deposit, although few manganese ore bodies in the west have so originated.

*Deposits Occurring as Veins or Other Related Forms.*

Many ore deposits in the form of veins, shear zones, brecciated zones, etc., together with connected replacements of surrounding rocks, contain primary rhodochrosite, rhodonite, manganiferous calcite, and occasionally alabandite associated with ores of gold and silver. In the oxidized zone near the surface the manganese ordinarily becomes highly concentrated in the form of oxides, and is usually mixed with much limonite (hydrous oxide of iron) and more or less silica. The outcrops of such deposits are usually black or very dark brown. Most of the manganese deposits known to exist in the western part of the United States are of this type, as are the majority of those in Arizona.

Operators of mines on deposits of this kind should remember that the oxides are certain to give place to the less valuable carbonate or sulphide, or the valueless silicate, at a depth that is usually measurable in a few scores or hundreds of feet.

*Relation of Manganese Dioxide and Gold Enrichment:* If a vein or similar form of deposit contains gold, manganese dioxide, and pyrite; does not occur in limestone or contain calcite (lime carbonate); and rainwater percolates down through the ore, certain chemical reactions are very apt to occur near the surface, which cause most of the gold to be dissolved, carried downward in solution, and precipitated at or a little below the groundwater level. In this way very important enrichments of gold have been formed, and the possibility of striking such enrichments at depth should always be considered by miners of deposits of the type described. The oxidized portion of such a deposit always contains a little gold, and occasional small pockets may be good gold ore. Considerable limonite (hydrous oxide of iron) is also always present, and often a little pyrite. No valuable gold enrichment need be expected if practically no gold exists in the oxidized zone, if there is very little or no limonite present, or if lime carbonate, in the
form of either calcite or limestone, exists in or adjacent to the deposit.

Relation of Manganese Dioxide and Silver Enrichment: Quoting from Ore Deposits, Transactions of the American Institute of Mining Engineers by W. H. Emmons, upon a summation of the evidence of various ore deposits, “there appears to be two types of enrichment in deposits of manganiferous gold and silver ores. In one of them silver chloride is concentrated in the manganiferous oxidized ores of the upper levels and gold is concentrated below. In the other, silver chloride is subordinate, while both gold and silver are concentrated below the oxidized zone. Possibly the difference could be explained if the amount of chlorine were determined in the waters of deposits of both types. Silver chloride is soluble in an excess of alkaline chloride. Those deposits in which horn-silver is not present may have been leached by waters unusually rich in chlorides.”

Bog Manganese Deposits.

Spring waters and, rarely, surface waters may contain manganese in solution, and, accumulating in swamps or marshes will then deposit this metal in the form, usually, of the impure, earthy, soft, hydrous oxide, wad, in layers up to several feet thick. Sometimes the ore consists of a skeleton of hard psilomelane with the cavities filled with earthy or powdery mineral. Less commonly rhodochrosite forms, but it soon becomes oxidized and hydrated on exposure to the atmosphere. Bog manganese ore may be overlain with soil and gravel, and is sometimes underlain by or occurs in alternate layers with bog iron ore (limonite) formed in the same way. Bog manganese is, however, much rarer than bog iron. Because of their impurity, limited extent, and prevailing thinness such deposits are very rarely valuable.

Sedimentary Deposits.

It is a well recognized fact that sandstone, shale, clay, limestone, and other sediments derived from the wearing down of old land areas often contain more or less manganese oxides or carbonates as stains or concretions, which seem to have been deposited at the same time as the sediments. It is possible that some valuable beds of manganese ore have been laid down in this way in lakes or seas, and subsequently covered with other sediments, but it is more likely that some form of enrichment after deposition has occurred in deposits which seem to be of this type.

ARIZONA MANGANESE DEPOSITS

E. C. Harder states in Bulletin 427 of the United States Geological Survey, issued several years ago, that the typical occurrences of man-
ganese ore then known in Arizona were the manganiferous silver ores such as occur at Tombstone where the ore lies mainly in limestone at contacts with porphyry dikes. Manganiferous silver ores are also found at Patagonia, Bisbee, Superior, Clifton, Morenci, Dos Cabezos, south of Globe, and elsewhere.

In the summer of 1917 E. L. Jones, Jr., a geologist of the United States Geological Survey, examined many of the known manganese deposits in Arizona, and the following descriptions of certain manganese deposits which do not contain silver were obtained from a Press Bulletin, issued by the United States Geological Survey:

“Several deposits occur in the Big Horn Mountains in the northern part of Maricopa County, and one is found in Yavapai County in the outlying spur of the Harcouvar Mountains, a few miles north of the Maricopa County line. Early in 1917 manganese ore from all these deposits was shipped from Aguila, on the Parker branch of the Atchison, Topeka & Santa Fe Railway. The ore from the Big Horn Mountain is hauled 15 miles, and that from the Harcouvar deposit 9 miles to the railroad. To September 1, 1917, approximately 500 tons of 40% manganese ore had been shipped from all these deposits to the Noble Electric Steel Company, Heroult, California; the Berkshire Iron Works, Sheridan, Pa., and the F. H. Balbee Company, of Chicago. These deposits have been worked only a short time, and the workings are limited to their known productive parts. At the time of the examination the deepest shaft had been sunk only forty feet, and most of the work consisted of open cuts. The meager amount of development indicates a reserve of 2000 to 5000 tons of ore containing 35% manganese and 10% silica, but it was thought that more extensive work might justify a larger estimate.

“The deposits in the Big Horn Mountains are at the north end of the range and extend from east to west in a zone about four miles long. The claims that have shipped ore comprise those of the Manganese Development Company, and those under lease and bond to the Noble Electric Steel Company, the Wheeler claims, and the Giblin claims. The ore is enclosed in a red andesite containing flakes of biotite (black mica). This andesite is part of a series of lava flows, of probable Tertiary age, that is found in many of the ranges of southwestern and central Arizona. The ore occurs in small veins, and as the cementing substance in andesitic breccia. The veins and brecciated zones vary in course from north nearly to east, and are from one foot to fifteen feet wide. In the deposit worked by the Noble Electric Steel Company the andesite fragments of the breccia
are from one-fourth inch to one foot or more in diameter, and the manganese oxide filling is generally less than two inches thick. In places, however, veins of fairly pure manganese oxides attain a width of a foot, but in order to obtain a shipping product containing 40% of manganese from most of these deposits, hand sorting and screening of the vein material are necessary. Most of the ore is soft and consists of small needle-like crystals of manganite, but some of it consists of hard crusts of psilomelane. The manganese oxides were probably derived from manganiferous calcite, as veinlets of secondary calcite are common.

"The deposit north of Aguila is owned by William Hatton and is under lease to Wood, Huddart & Gunn, of San Francisco. The property is being actively exploited and several carloads of ore have been shipped. Unlike the deposits in the Big Horn Mountains, the ore occurs in a well defined fissure vein which cuts beds of a coarse-grained red sandstone. At several places along the vein, for a distance of four hundred feet, shoots of ore have been uncovered, the largest of which is fifty feet long and three feet wide. The vein matter is a mixture of manganese oxides, principally manganite, calcite, and barite. Manganiferous calcite, which was noted from the bottom of a forty-foot shaft on the vein, may have been the source of the manganese minerals. The ore is sorted and screened in order to obtain a product of 40% manganese.

"The opening of these manganese deposits may lead to the opening of others in the more remote parts of Arizona, several of which are known, and undoubtedly others will be found in places where the geologic conditions are similar to those here described. The present high price of manganese ore permits the profitable working of comparatively small and remote deposits.

"In the course of his field work Mr. Jones examined certain undeveloped deposits in Mohave County that are unusual and that give promise of becoming large producers. These deposits are about 5 miles northwest of the Tappan ranch, on Williams River, in the mesa that flanks the Artillery Mountains. The principal difficulty to be overcome in the exploitation of these deposits is that of transportation. Congress Junction, on the Atchison, Topeka & Santa Fe Railway, the most accessible railroad station, is 45 miles east of the Tappan ranch. Between this station and the ranch there is a good road over a gently sloping mesa, but between the ranch and the deposits a road must be made and a bridge built over the broad sand-filled channel of Williams River."
The deposits were located in 1917 by Graham, Carr, Rider, and Benderwald, but up to September, 1917, were entirely undeveloped. The property is under the management of W. J. Graham, of Phoenix, Arizona. At the time the deposits were visited a minimum estimate of 50,000 tons of manganese ore was made from surface exposures, assays of which indicate from 31% to 45% manganese, and from 6% to 20% silica, with little iron. The greater part of this ore would probably carry less than 35% of manganese. Further exploration is reported by Mr. Graham to show not less than 110,000 tons of ore from which he estimates 30,000 to 35,000 tons can be mined that will average 38% of manganese.

"It is evident, at any rate, that a large quantity of ore is available which requires little or no sorting to be made marketable, and a still larger quantity remains that can be improved in grade by concentration—that is, by separating the hard manganese oxides from the sandstone matrix. The deposits offer exceptional advantages for cheap mining; they lie at the surface, large areas of clean ore being exposed with no overburden, and are readily accessible to trucks or other means of conveyance.

"The manganese deposits occur in low-lying ground at elevations above sea level not exceeding 2000 feet, along an arroyo that drains to Williams River. The largest deposit occurs near the head of the arroyo, in a basin that is partly enclosed by a basalt rim which at some places rises 800 feet above the deposit.

"Red and brown, slightly indurated sandstones and interbedded clays comprise the rocks of the small hills in the basin along the course of the arroyo. They strike about N. 30° W. and dip 15° S. W. In places the periodic flood waters of the arroyo have cut narrow channels with vertical walls fifty feet high in these sandstones. About two miles north of Williams River the sandstones are conformably overlain by a coarse pebble conglomerate. Both the sandstone and conglomerate are probably of late Tertiary age. The basalt flow overlies the sandstones and conglomerate and forms the rim about the head of the basin. The lava gives off abundant talus, which effectually conceals its contact with the underlying sediments and extends in places over the manganese deposits. The basalt is believed to have been formed in the Quarternary period.

"The exposed manganese ore is a replacement of the topmost stratum of the sandstone. Three principal deposits occur in this arroyo but other small deposits of similar origin are found in sandstone in a zone said to be fifteen miles long. The largest deposit exposed is 600 feet
long, about 300 feet wide, and has an average thickness of two feet. It dips into the arroyo at a low angle, continues to the north and is covered with abundant talus from the basalt rim rock. A short distance southeastward, across the arroyo, another deposit, about 300 feet long, 100 feet wide, and three to four feet thick, caps a hill 200 feet high. About one and a half miles south of these deposits a third deposit, 300 feet long, 100 feet wide, and three to six feet thick, is exposed on both sides of the arroyo. On the south side of Williams River, two miles east of Tappan ranch, a deposit 200 feet across and about two feet thick forms the capping of a small hill composed of red sandstone.

"The ore consists of manganese oxides that have replaced the minerals of the sandstone without destroying its texture. It is hard, and the replacing mineral is amorphous and is probably psilomelane, which in places forms characteristic botryoidal and mammillary masses on the surface. The replacement of the sandstone beds is variable; most of the ore contains visible unreplaceable quartz grains, which represent most of the silica. In addition scales of calcite and gypsum are commonly found in the ore, but they are nowhere abundant."

In a personal letter dated November 20th, 1917, R. V. Thurston, of Miami, Arizona, describes a deposit situated between Duncan and Solomonville, near Ash Peak, as follows: "The ore is psilomelane, and appears to be in a fissure vein. The gangue is entirely calcite. The width varies from an inch or two to a maximum of about eighteen inches. We have mined to a depth of sixty feet, and the bottom of the shaft still contains ore. Our shipments have run from 30% to 45% manganese, 4% to 6% silica, and very low in phosphorous."

Producers and Prospective Producers in Arizona: The following list of the producers and prospective producers of manganese in Arizona was compiled from the records of the Arizona Bureau of Mines, and is revised to June 1st, 1918:

Black, R. E., 500 Gila St., Yuma.
Briggs, Dos Cabezos, Arizona.
Buckingham Mining Company, Globe.
Bunker, E. V. and E. S. Rogers, Mayer.
Burmister and Wright, Mayer.
Chamberlain, F. A., Florence.
Copper Queen Consolidated Mining Company, Bisbee.
Drieser, P. B., Wenden.
Because of the important part that manganese plays in the steel industry, the demand for it is to a great extent controlled by the condition of the steel market. The war, which is being carried on largely by means of iron and steel and their products, has caused the production of steel to be almost doubled since 1914. The United States Geological Survey gives the production of steel for 1914 as 23,513,030 tons and the estimated production for 1917, according to the Engineering and Mining Journal, is about 42,500,000 tons.

The United States has never been an important producer of manganese ore. During the years 1904-14 the annual domestic production
ranged from 1500 to 7000 long tons, and the imports over the same period varied from 108,000 to 345,000 long tons. The chief sources of supply were India, Russia, and Brazil, but since the outbreak of the war Brazil has supplied practically all of the high grade ore. At the present time the requirements of the steel industry are from 700,000 to 800,000 long tons of high grade ore per year besides a large quantity of lower grade ore. In 1917 over 500,000 tons were imported from Brazil, 50,000 tons from India, and about 60,000 tons from the West Indies and Central America, besides 45,000 tons of ferro-manganese from England. The domestic production of high grade ore was 114,000 tons. In the United States the principal producing districts for high grade ore are in Arizona, Arkansas, California, Georgia, Montana, Tennessee, Utah, and Virginia. Large quantities of low grade ore come from Colorado, Minnesota, New Jersey, and New Mexico.

Arizona has rapidly become an important producer of manganese ore; the United States Geological Survey estimates that Arizona's production for 1917 was 4700 tons containing 40% or more manganese, and 12,000 tons running from 15% to 40%.

The chief producing districts in Arizona are those of Tombstone, Patagonia, and Bisbee in the southeastern part of the State, and the Aguila district between Congress Junction and Wenden. It is estimated that 1000 tons of manganese ore are now being shipped per month from the Bisbee district alone.

**IMPORTANCE OF MANGANESE**

The extensive use of manganese in all grades of steel and the importance of steel in war munition work makes it of vital importance to produce the largest possible tonnage of domestic ore. At the same time the shortage of shipping makes it increasingly difficult to import ore. The importation of ferro-manganese and spiegeleisen except by rail from Canada and Mexico has been restricted by the War Trade Board. This eliminates England to some extent as a source of supply.

**USES OF MANGANESE**

Manganese is used in the manufacture of iron and steel, electric dry batteries, and various alloys, and in the preparation of oxygen. The material is also in demand as a basic flux, and as a coloring agent in the manufacture of glass, pottery, tile, brick, paint, and calico cloth. *Ferrous Uses of Manganese.*

Manganese is utilized in foundries as a deoxidizer and as a de-
sulphurizer, and to alter the grain constitution of the metal; in steel works it is used as a deoxidizer and to impart certain static properties to the steel. It is at present introduced into steel in the form of two alloys, ferro-manganese and spiegeleisen.

Standard ferro-manganese contains 80% manganese, about 6% carbon, and 14% iron, but, due to the scarcity of high grade manganese ore, our steel manufacturers are now using ferro-manganese containing as low as 60% manganese.

Spiegeleisen contains from 10% to 20% manganese, 5% to 7% carbon, and the balance iron.

Ferro-manganese is considered necessary by the steel trade for use in the open hearth process, while spiegeleisen can be used in the Bessemer process. Since about 80% of the steel now produced is made in the open hearth, and only 20% by the Bessemer process, it is evident that ferro-manganese is in greater demand than spiegeleisen. This is unfortunate, since spiegeleisen can be made from relatively low grade ores. Ferro-manganese can be added directly to molten steel from the converter or open hearth furnace, but spiegeleisen must be melted before using. It is because of the constantly increasing demand for ore adapted to the manufacture of ferro-manganese that the value of relatively low grade manganese ore has decreased. Both ferro-manganese and spiegeleisen are added to steel for the purpose of introducing carbon as well as manganese. The manganese acts as a cleanser by combining with the oxygen, and, to some extent, with the phosphorous and sulphur which it carries into the slag; while the carbon imparts hardness and strength. When larger proportions of the alloys are used, manganese steel is produced.

According to Hibbard, the term manganese steel is commercially applied to a variety of iron containing from 11% to 14% manganese and 1.0% to 1.3% carbon. It is used in the equipment employed in the mining and treatment of ores, in dredging and quarrying, in railway tracks, and in other places where the metal is subjected to severe wear. It is also utilized in the manufacture of burglar-proof safes, in the cover of plates lifting magnets (because of its non-magnetic properties), and is used to some extent in making agricultural implements.

In manufacturing crucible steel oxide of manganese is sometimes used instead of ferro-manganese.

Non-Ferrous Uses.

The chief non-ferrous alloy of manganese is manganese bronze, but Heusler’s alloys of manganese, aluminum, and copper are important because of their magnetic properties. Because of its great affinity for
oxygen, manganese is used as a cleanser in the making of several other alloys.

Much of the low grade manganese ore of the western states is used as a basic flux in the reduction of copper, lead, and silver ores, since manganese can replace iron in and increase the fluidity of the slag.

**MANUFACTURE OF MANGANESE ALLOYS**

Both ferro-manganese and spiegeleisen may be made by smelting manganese and iron ores together in either an electric furnace or in the usual type of iron blast furnace. When the latter is used a higher temperature is required than in iron smelting, and this feature, together with the fact that manganese always enters the slag in proportions which may reach as high as 10%, make the process relatively an expensive one.

**SPECIFICATIONS OF ORE REQUIRED FOR MAKING VARIOUS PRODUCTS**

The peculiar conditions that exist as a result of the war prompted the belief that users of manganese ore had probably modified their methods to such an extent that ore which could not be marketed before the war might now be of value. In order to obtain reliable information concerning the requirements of the various users of manganese and the market that exists for different grades of manganese ores, the Arizona Bureau of Mines sent over a hundred form letters to reported users of manganese. The replies are summarized below. While the figures show considerable lack of uniformity, it is believed that they will suffice to indicate the possible uses for which any given grade of manganese ore may be sold. Each company reporting is designated by a separate letter.

**Glass Manufacture**

(A) Minimum percentage manganese dioxide........... 78.0
    (Minimum percentage metallic manganese........... 49.1)
    Maximum percentage iron........................... 1.0

**Chemical Purposes**

(B) Minimum percentage manganese dioxide........... 75.0
    (Prefer 80%)
    (Minimum percentage metallic manganese........... 47.3)
    Maximum percentage iron........................... 1.5
    Maximum percentage copper.......................... 0.01

(C) Minimum percentage manganese dioxide........... 63.5
    (Minimum percentage metallic manganese........... 40.0)
    Maximum percentage iron........................... 1.5
Maximum percentage copper.......................... 0.02
Must be practically free from other impurities.

(D) Minimum percentage manganese dioxide........ 70.0
(Minimum percentage metallic manganese........ 44.0 )
Maximum percentage iron......................... 2.0
Maximum percentage copper...................... 0.02
No nickel, cobalt, or arsenic.

Dry Batteries

(E) Minimum percentage manganese dioxide........ 80.0
(Minimum percentage metallic manganese........ 50.4 )
Maximum percentage of iron oxide............ 2.0
Not over a trace of copper or phosphorous.

This firm states that they have used some ore containing not over 65% manganese dioxide, but that they prefer higher grades.

(F) Before the war this firm obtained most of its ore from the Caucasus, and their specifications were as follows:
Minimum percentage manganese dioxide........ 85.0
(Minimum percentage metallic manganese........ 53.5 )
Maximum percentage iron.................... 1.0
No copper.

At the present time they are using ore of the following composition:
Minimum percentage manganese dioxide........ 80.0
(Minimum percentage metallic manganese........ 50.4 )
Maximum percentage iron.................... 1.5
Trace of copper.

(G) Minimum percentage manganese dioxide........ 80.0
(Minimum percentage metallic manganese........ 50.4 )
Maximum percentage iron.................... 1.0
Maximum percentage copper, cobalt, nickel,
barium, arsenic, etc., each.................... 0.03-0.04
A porous ore is desirable for the manufacture of dry batteries.

Carbon-free Pure Manganese Metal

(H) Minimum percentage manganese dioxide........ 85.0
(Minimum percentage metallic manganese........ 53.5 )
Maximum percentage iron.................... 1.0
Maximum percentage silica.................... 1.5
No other impurities.
Ferro-Manganese

(I) Minimum percentage manganese dioxide ............ 63.5

(Minimum percentage metallic manganese ............ 40.0)

Maximum percentage silica .......................... 8.0

Maximum percentage phosphorous .................. 0.2

(J) Minimum percentage manganese dioxide ............ 63.5

(Minimum percentage metallic manganese ............ 40.0)

Maximum percentage silica .......................... 10.0

Maximum percentage phosphorous .................. 0.2

No copper, lead, zinc, barium, etc.

(K) Minimum percentage manganese dioxide ............ 60.3

(Minimum percentage metallic manganese ............ 38.0)

(Prefer 50%)

Maximum percentage silica .......................... 13.0

(Prefer not over 10%)

Alumina is especially objectionable with high silica.

(L) Minimum percentage manganese dioxide ............ 60.3

(Minimum percentage metallic manganese ............ 38.0)

Maximum percentage silica .......................... 8.0

Maximum percentage phosphorous .................. 0.2

Maximum percentage iron ............................ 5.0

(M) Minimum percentage manganese dioxide ............ 72.8

(Minimum percentage metallic manganese ............ 46.0)

Maximum percentage silica .......................... 9.0

Must be low in iron and phosphorous.

(N) Minimum percentage manganese dioxide ............ 63.5

(Minimum percentage metallic manganese ............ 40.0)

Maximum percentage silica .......................... 20.0

Maximum percentage iron ............................ 5.0

Maximum percentage phosphorus .................. 0.225

This firm states that they can use a certain amount
of ore of the following grade:

Minimum percentage manganese dioxide ............ 57.1

(Minimum percentage metallic manganese ............ 36.0)

Maximum percentage silica not over half of the per-
centage of manganese.

Maximum percentage iron ............................ 1.0

No other detrimental elements.

Spiegeleisen

(O) Minimum percentage manganese dioxide ............ 23.8

(Minimum percentage metallic manganese ............ 15.0)
Maximum percentage silica: 8.0
Maximum percentage phosphorous: 0.2

(P) Minimum percentage manganese dioxide: 15.9
(Minimum percentage metallic manganese: 10.0)
Maximum percentage silica: 8.0
Maximum percentage phosphorous: 0.2

(Q) Minimum percentage manganese dioxide: 23.8
(Minimum percentage metallic manganese: 15.0)
Minimum percentage iron: 15.0
Silica must be low.

**Pig Iron**

(R) Minimum percentage manganese dioxide: 12.7
(Minimum percentage metallic manganese: 8.0)
Minimum percentage combined metallic iron and metallic manganese: 45.0

Although there is a limited market for the poorer grades of ore, it is doubtful if it would pay to ship them from the State. Arizona producers of low grade ore should, therefore, investigate the market for their ore and the cost of shipping it to the consumer before expending any money on development work.

**EFFECTS OF THE PRINCIPAL OBJECTIONABLE IMPURITIES**

Phosphorous causes cold shortness; that is, the iron or steel breaks easily when cold. Ordinary grades carry as much as 0.08% phosphorous, and the higher grades less than 0.04%, so it will be seen that the ferro-manganese or manganese ore used in steel manufacture must be as low in phosphorous as possible.

Silica must be fluxed in the manufacture of ferro-manganese, spiegeleisen, or pig iron, and an unduly high percentage increases the coke consumption, decreases the capacity of the blast furnace, and causes loss of manganese in the slag.

Sulphur causes the metal to crack, tear, and check when it is rolled, forged, heat-treated, or hot-worked. Sulphur combines readily with manganese, and this is one reason for the use of this metal in iron or steel; but a high percentage of sulphur causes an undue consumption of manganese.

Manganese oxide is used in glass manufacture either to counteract the yellow or green tint due to the presence of iron, or to impart an amethyst tint to the glass. The presence of iron in anything but very small amounts would, therefore, tend to counteract the action of the manganese oxide, and would give an unattractive tint to the deeply colored glass.
It is beyond the scope of this pamphlet to discuss the effect of this element when present in ore used for the manufacturing of the other products mentioned herein.

METHODS OF CONCENTRATION

The problem of the economical concentration of low grade manganese ore has only recently attracted the attention of metallurgists. Several stations of the United States Bureau of Mines are now investigating the possibility of concentrating low grade manganese ore, and producers of such ore are hopeful that the results will be favorable.

The substance present in manganese ore which it is hoped may be eliminated are silica, various siliceous minerals, and clays or shales.

The following quotations from the July 13th issue of the Mining and Scientific Press are of interest in this connection:

“In a recent bulletin issued by the University of California, entitled ‘The Possible Treatment of Manganese Ores in California,’ E. A. Hersam, Associate Professor of Metallurgy in the University, gives the results obtained in preliminary studies conducted under his supervision. These tests are of special interest at the moment. Electrostatic separation gave negative results, the siliceous constituents of the ore being thrown into the concentrate to a serious extent, while the magnetic oxides failed, in part, to respond to the electrostatic force. Magnetic separation, however, showed considerable promise. Most manganese minerals yield to treatment on a Wetherill machine, and afford good products when fed with ore that has been closely sized. Classification by screening alone also effects considerable concentration. In an ore from Patterson, California, the 200-mesh material contained about twice as much manganese as the grade between 40 and 48 mesh. The treatment of the finer sizes by magnetic separators generally show a low percentage of recovery.

“The indication is that a readily attracted, hard, high-grade material is present in the ore, and that a soft low-grade constituent, less strongly attracted, escapes with the tailing, thereby increasing its grade.

In so far as part of this soft material is caught in the concentrate the grade of that product is lowered. Much of this softer constituent consists of pyrolusite and other manganese minerals containing silica, and inseparably mixed with the gangue in the process of dry grinding.

“Magnetic separation applied to carbonate ore showed a recovery of 96.7% of the manganese in a concentrate assaying 38.6%, leaving a tailing that held 3.3% of the metal that had been present in the original ore. Calcination of the carbonate ore resulted in a magnetic concentrate assaying 50.9% Mn, leaving 6% of the original metallic
content in the tailing. It appears that the roasting and retreatment of the tailing offers an opportunity to effect a high saving in the magnetic concentration of manganese ores.

"Flotation proved unfavorable. Ores from Patterson and Davenport, California, were tested, using pine oil, crude pine oil mixed with tar oil, and crude petroleum, 14° B., from the McKittrick field. The Patterson ore, assaying 37.7% manganese, yielded, with the three flotative agents respectively (a) 18% of concentrate containing 34.3% manganese, (b) 30% of the weight of the ore as concentrate assaying 38.94%, and (c) a concentrate assaying 38% manganese and a tailing with 36.8% of the metal. The Davenport ore gave results equally unsatisfactory.

"Gravity concentration, that is, with jigs and tables, is effective only when the minerals are hard and pure, and break free from the gangue. The fine material obtained by classification is difficult to concentrate by any method. Magnetic separation appears to offer the larger possibilities for successful treatment of ores of manganese."

In Arkansas the manganese ore is disseminated in nodules and grains through clay resulting from the decomposition of lime, and is concentrated by means of log washers. The details of this process are described in the April 27th, 1918, issue of the Engineering and Mining Journal.

It was announced recently in the Anaconda Standard that experiments for concentrating rhodochrosite conducted at the Ophir mill of the Butte-Detroit Copper & Zinc Mining Company had been a success.

Many of the manganiferous silver ore bodies of Arizona are of such low grade as to appear to have no commercial value as manganese ores. The manganese minerals are so intimately intermixed with the gangue that mechanical concentration of the manganese ore seems impossible, but considerable research is now being carried on in an effort to solve this problem.

Magnetic separation has been successfully applied to franklinite ore (franklinite is a rare oxide of zinc, manganese, and iron, not described in this pamphlet).

The following list of purchasers of manganese ore in the United States was prepared by the U. S. G. S.:

a—Purchase manganese ore with more than 40% manganese and less than 1% iron.
b—Purchase manganese ore with more than 40% manganese and more than 1% iron,
c—Purchase manganese ore with less than 40% manganese.
Arizona State Bureau of Mines

N. A. Adler, Batesville, Ark.
American Carbon and Battery Co., East St. Louis, Ill.
American Smelting and Refining Co., Murray, Utah.
American Steel Foundries Co., Chicago, Ill.
Binney and Smith, 81 Fulton St., New York City.
Bethlehem Steel Corporation, South Bethlehem, Pa.
Arthur B. Bibbins, Baltimore, Md.
Chas. A. Burdick, E.M., 74 Broadway, New York City.
C. F. Burgess Laboratories, Madison, Wis.
Cambria Steel Co., Pittsburgh, Pa.
Central Iron and Coal Co., Holt, Alabama.
Charcoal Iron Co., Detroit, Mich.
Colorado Fuel and Iron Co., Pueblo, Colo.
W. R. Cuthbert, Lynchburg, Va.
Delaware River Steel Co., Chester, Pa.
W. H. Denison, Cushman, Ark.
Empire Steel and Iron Co., Catasauqua, Pa.
Eureka Manganese Co., Birmingham, Ala.
Fuller and Warren Co., Troy, N. Y.
Robert Gilchrist, Elizabethtown, N. J.
Goldschmidt Thermit Co., New York City.
R. L. Hanford, Cushman, Ark.
Harshaw, Fuller and Goowin Co., Electric Bldg., Cleveland.
Hickman, Williams and Co., St. Louis, Mo.
C. W. Hill Chemical Co., Los Angeles, Cal.
Illinois Glass Co., Alton, Ill.
Illinois Steel Co., South Chicago, Ill.
International Smelting Co., Salt Lake City, Utah.

Jones and Laughlin Steel Co., Pittsburgh, Pa.


Lackawanna Iron and Steel Co., U. S. Express Bldg., Buffalo.

J. S. Lamson and Brothers, Inc., 80 Maiden Lane, New York.

Lebanon Blast Furnace Co., Lebanon, Pa.


David Loeser, 1400 Broadway, New York.

Los Angeles Pressed Brick Co., Los Angeles, Cal.

Lowmoor Iron Co. of Virginia, Lowmoor, Va.

Manganese Products Co., 30 East 42nd Street, New York.

Manhattan Electrical Supply Co., 41-47 Morris St., Jersey City, N. J.

Miami Metals Co., Peoples Gas Bldg., Chicago, Ill.


National Carbon Co., Cleveland, Ohio.

Noble Electric Steel Co., Heroult, Cal.

Oakley Paint Mfg. Co., Los Angeles, Cal.

Pacific Coast Steel Co., Seattle, Wash.

Pacific Sewer Pipe Co., Los Angeles, Cal.

Pittsburgh Lamp, Brass and Glass Co., Pittsburgh, Pa.


A. P. Rice, Spencer, Ohio.

Ricketson Mineral Paints Works, Milwaukee, Wis.


Frank Samuel, Philadelphia, Pa.

Seaboard Manganese and Steel Corporation, Temple, Pa.

Arthur Seligman, 165 Broadway, New York.

Sligo Furnace Co., Sligo, Mo.

Sloss-Sheffield Steel and Iron Co., Birmingham, Ala.

Southern Manganese Corporation, Anniston, Ala.

Oscar Stromberg, Tribune Bldg., New York.

South Tennessee Coal, Iron and Railroad Co., Birmingham, Ala.


Utah Iron and Steel Co., Salt Lake City, Utah.

United States Steel Corporation, Pittsburgh, Pa.; South Chicago; Birmingham, Ala.

Vanadium Steel Alloys Co., Latrobe, Pa.
Many other makers of flint glass and dry batteries use ore of grade "a."

**VALUE OF MANGANESE ORE**

The present prices paid for manganese as given by the following schedule of prices on manganese ores produced in the United States, has been agreed to by the American Iron and Steel Institute and has been approved by the War Industries Board. The prices are fixed at a figure higher than the prices on this ore that have prevailed in past months. The new price schedule is to be used on transactions taking place after midnight of May 28th. No announcement is made as to the length of time that this schedule of prices is to remain effective.

The following schedule gives domestic metallurgical manganese ore prices per unit of metallic manganese per ton of 2,240 pounds for manganese ore produced and shipped from all points in the United States west of South Chicago, Ill. *This schedule does not include chemical ore as used for dry batteries, etc.* When shipped to other destinations than Chicago the freight rate per gross ton from shipping point to South Chicago, Ill., is to be deducted to give the price f. o. b. shipping point.

Schedule for 35% or more metallic manganese:

<table>
<thead>
<tr>
<th>PER CENT</th>
<th>PER UNIT</th>
</tr>
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<tbody>
<tr>
<td>35 to 35.99</td>
<td>$ .86</td>
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<tr>
<td>36 to 36.99</td>
<td>.90</td>
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<td>.94</td>
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<td>1.28</td>
</tr>
<tr>
<td>54 and over</td>
<td>1.30</td>
</tr>
</tbody>
</table>
PREMIUMS AND PENALTIES

For manganese ore produced in the United States and shipped from points in the United States east of South Chicago, 15 cents per unit of metallic manganese per ton shall be added to above unit prices.

The above prices are based on ore containing not more than 8% silica and not more than 0.25% phosphorous, and are subject to the following premium and penalties.

Silica: For each 1% of silica under 8% down to and including 5% there shall be a premium at the rate of $0.50 cents per ton; below 5% there shall be a premium at the rate of $1.00 per ton for each 1% under 5%.

For each 1% of silica in excess of 8% and up to and including 15%, there shall be a penalty of $0.50 cents per ton; for each 1% in excess of 15% and up to and including 20%, there shall be a penalty of $0.75 per ton; and for each 1% in excess of 20% and up to and including 25%, there shall be a penalty of $1.00 per ton.

Ore containing over 25% silica is subject to acceptance or refusal at the buyer’s option, but if accepted shall be paid for at the above schedule of $1.00 penalty per ton for each extra unit of silica. All premiums and penalties are figured in fractions.

Phosphorous: For each 1% in excess of 0.25% phosphorous, there shall be a penalty assessed against the unit price paid for the manganese amounting to one-half cent per unit, figured to fractions.

In view of existing conditions, and for the purpose of stimulating production of domestic manganese ores, there will be no penalty for phosphorous so long as the ore shipped can be used to advantage by the buyer. The buyer reserves the right to penalize excess phosphorous as above stated by giving sixty days notice to the shipper.

Basis of Settlements: Settlements are to be based on an analysis of an ore sample dried at 212° F. The percentage of moisture in the ore sample as taken is to be deducted from the weight.

The prices previously given are to be net to the producer; any expense other than freight, such as salary or commission to buyer’s agent are to be paid by the buyer.

Payments: Eighty per cent of the estimated value of the ore (less moisture and freight from shipping point) based on actual railroad scale weights is to be payable against a railroad bill of lading, if accompanied by the certificates of sampling and analysis of an approved independent sampling chemist. The balance is payable on receipt of the ore by the buyer. The cost of sampling and analysis is to be equally divided between buyer and seller.
Purchase of Ore of Grade Specified Not Obligatory: Although manufacturers of ferro-manganese will now accept ore at the price schedule arranged by the War Industries Board and the American Iron and Steel Institute, and quoted in a preceding page, all manufacturers will not accept ore containing the minimum of manganese (35%), and the high proportions of silica and phosphorous on which prices are quoted. There is, however, a limited market for such poorer grades of ores.

Meaning of Term “Unit” as Used in Manganese Quotations: A unit, as the term is applied to manganese quotations, is equivalent to 1% of a long ton (2,240 pounds) of the ore, or 22.4 pounds. In other words, if the ore contains 44% of metallic manganese, it is quoted at $1.10 per unit, and is worth $44 \times 1.10 = $48.40 per ton. If this ore contains 27% silica and is accepted by a buyer, it is subject to a penalty of $3.00 per ton, $1.00 of this amount because it contains at least 25% silica, and $1.00 for each unit in excess of this figure. As there is a total excess over 25% of two units, the total penalty is $3.00.

If the same ore contains 0.30% of phosphorous and is accepted by a buyer, the penalty will be $0.005 for each 0.01% in excess of 0.25%, or $5 \times 0.005 = $0.025 per unit, and the value of the ore per unit (not considering the penalty for the high silica) will be $1.10 - $0.025 = $1.075 per unit, or $47.30 per ton.
The majority of the manganese markets are in the steel producing centers of the east. Although some manganese ore is used on the Pacific coast the market there is taken care of by local ores. Freight rates to San Francisco from Arizona points are therefore not quoted.

The following are the rates from western points to the eastern iron and steel centers:

**Manganese ore CL per ton of 2,000 pounds, minimum CL weight 60,000 pounds**

<table>
<thead>
<tr>
<th>From stations in—</th>
<th>Group D</th>
<th>Group 2</th>
<th>Group B and C</th>
<th>Group A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oregon</td>
<td>$11.00</td>
<td>$12.50</td>
<td>$12.50</td>
<td>$15.50</td>
</tr>
<tr>
<td>Washington</td>
<td>11.00</td>
<td>12.50</td>
<td>12.50</td>
<td>13.50</td>
</tr>
<tr>
<td>California</td>
<td>11.00</td>
<td>12.00</td>
<td>12.50</td>
<td>13.50</td>
</tr>
<tr>
<td>Montana</td>
<td>8.00</td>
<td>9.50</td>
<td>9.50</td>
<td>10.50</td>
</tr>
<tr>
<td>Arizona</td>
<td>9.00</td>
<td>9.00</td>
<td>10.50</td>
<td>11.50</td>
</tr>
<tr>
<td>Colorado</td>
<td>7.00</td>
<td>7.00</td>
<td>8.50</td>
<td>9.50</td>
</tr>
<tr>
<td>Nevada</td>
<td>10.00</td>
<td>11.00</td>
<td>11.50</td>
<td>12.50</td>
</tr>
<tr>
<td>Utah</td>
<td>9.00</td>
<td>10.00</td>
<td>10.50</td>
<td>11.50</td>
</tr>
<tr>
<td>New Mexico</td>
<td>7.00</td>
<td>7.00</td>
<td>8.50</td>
<td>9.50</td>
</tr>
</tbody>
</table>

1Group D: Chicago, Indiana Harbor, and Erie.

2Group 2: Points in Alabama and Tennessee taking Group C rates.

3Group B and C: Youngstown, Pittsburgh, Buffalo, and points in Ohio.

REFERENCES

Bulletin American Institute of Mining Engineers; February, 1917; pp. 199-207.

Bulletin American Institute of Mining Engineers; September, 1917; pp. 1-21.

Crisis in the Manganese Trade; Mining and Scientific Press; August 25, 1917.

Ferro-Manganese and Spiegeleisen; G. C. Stone; Engineering and Mining Journal; January 12, 1918.

Manganese; Irving A. Palmer; Colorado School of Mines Circular. Manganese at Butte, Montana; J. T. Pardee; Bulletin No. 690-E, U. S. G. S.

Manganese and Chromium; E. S. Boalich; California State Mining Bulletin, Preliminary Report No. 3 (Second Edition), March, 1918.

Manganese Deposits of the United States; Edmund C. Harder; Bulletin No. 427, U. S. G. S.

Manganese from Steel Slags; Mining and Scientific Press; April 6, 1918.

Manganese Ores of Russia, India, Brazil, and Chile, by E. C. Harder; Trans. A. I. M. E., Vol. LVI.

Manganese Ores of the Lafayette District, Minas Geraes, Brazil; J. T. Sinewald and B. L. Miller; T. A. I. M. E., Vol. LVI.


Possible Treatment of Manganese Ores in California; E. A. Hersan; University of California Bulletin.

Principals of Economic Geology; William Harvey Emmons; McGraw-Hill Book Co., Inc.; 1918.

Prospecting for Manganese; H. V. Maxwell; Engineering and Mining Journal; February 9, 1918.

Significance of Manganese in American Steel Metallurgy, by F. H. Willcox; T. A. I. M. E., Vol. LVI.

Utilization of Low Grade Manganese Deposits—A Metallurgical Problem, by J. E. Johnson; Engineering and Mining Journal; December 15, 1917.