Bureau of Mines
Report of Investigations 4754

CONCENTRATION OF OXIDE AND SILICATE MANGANESE ORES FROM THE VICINITY OF GOLCONDA, NEV.

BY B. K. SHIBLER AND R. R. WELLS

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UNITED STATES DEPARTMENT OF THE INTERIOR
Oscar L. Chapman, Secretary
BUREAU OF MINES
James Boyd, Director

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B. K. Shibler[1/] and R. R. Wells[2/]

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1/ Metallurgist, Metallurgical Division, Northeastern Region VIII, Bureau of Mines, College Park, Md.

2/ Metallurgist, Metallurgical Division, Northwestern Region II, Bureau of Mines, Albany, Oreg.

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INTRODUCTION

During the investigation of the occurrence of manganese deposits in the Western United States, examining engineers of the Bureau of Mines collected 2-ton samples from five manganese properties near Golconda, Nev. Extensive laboratory tests were made to determine the amenability of these ores to standard ore-dressing methods of concentration.

The Tom Major property, one of those sampled, is situated 12-1/2 miles south of Golconda, Humboldt County, Nev. The deposit is described as a bed about 5 feet thick in a thinly bedded shale and dolomite formation. The sample tested was obtained from the manganese bed, but the examining engineer reported: "The mining of an appreciable tonnage at reasonable cost would perhaps cut in half the grade represented by the sample."

The Black Top claims are 17 miles south of Golconda, Nev. Ore occurs as a 7-foot bed of intermixed manganese oxides and silicate in quartzite country rock. Three samples of ore were submitted, one representing massive vein material and two representing mineralized footwall. The vein ore (14.6 percent manganese) was used for all laboratory work. As the highest-grade ore was not amenable to mechanical concentration, work on the lower-grade, more complex footwall samples (6.4 and 1.9 percent manganese, respectively) was considered unnecessary.

Ore from the Black Hawk claim, which is separated from the Black Top property by a small gulch, is highly siliceous and contains rhodonite, a manganese silicate, as the major constituent. The ore occurs as a bed 12 to 20 feet thick in a quartzite host rock. Test work was done on a composite of the higher-grade ore samples submitted.

The Black Diablo claim is 20 miles south of Golconda, Nev. Ore occurs in two lenses, each about 400 feet long, which are replacements along one bed of a series of sedimentary rocks. Wall rock is quartzite and chert. Laboratory test work was carried out on a sample representative of the ore body.

The O'Leary deposit, 3/4 mile north of the Black Diablo property, contains massive, tough manganese oxides that replace sedimentary rock. Interbedded with the ore are thin beds of silicified shale and lenses of jasper rich in hematite. Ore dressing was carried out on a sample representative of the deposit.

For the sake of clarity and convenience in presenting data, the description of the ores and discussion of methods of concentration used, together with the results obtained from laboratory testing, will be divided into five sections, each pertaining to the treatment of ore from a single property.

ACKNOWLEDGMENTS

The authors acknowledge the assistance of R. S. Dean, former assistant director of the Bureau of Mines, under whose supervision the manganese program was initiated in 1940, and the valuable suggestions of S. R. Zimmerley, now chief, Metallurgical Division, Region IV. Acknowledgment also is made to H. G. Poole and C. H. Schack for their suggestions and contributions to the organization and prosecution of the work of the Ore Dressing Section. Microscopic work on the ores and many ore-dressing products was done by L. G. Evans and the late R. E. Head. Our appreciation is extended also to H. E. Peterson, chief chemist, and members of the analytical staff for the many analyses of the ores and ore-dressing products.

SPECIFICATIONS FOR MANGANESE ORES

At the beginning of the investigation of manganese-ore beneficiation in December 1940, the only product marketable to Metals Reserve Company was ferro-grade manganese grade B, the requirements for which are tabulated below:

Assay, percent					
Mn	Fe	SiO_2	P	Al_2O_3	Zn
min.	max.	max.	max.	max.	max.
48.0	7.0	10.0	0.18	6.0	1.0

Later specifications were modified gradually. As of May 15, 1943, manganese products were acceptable if they contained over 35 percent manganese, less than 3 percent zinc, and less than 1 percent phosphorus. Prices were based upon material containing 48 percent manganese, 6.0 percent iron, and 11 percent silica plus alumina. Premiums were paid for manganese content exceeding 48 percent and iron content below 6 percent, penalties being imposed on products containing less than 48 percent manganese, more than 6 percent iron, or more than 11 percent silica plus alumina.

Specifications for marketable manganese further required that 75.0 percent of the product be coarser than 20-mesh. Therefore, fine material such as table and flotation concentrates must be nodulized or sintered. Sintering further concentrates the manganese, owing to loss of oxygen, carbon dioxide, and other constituesnts during the heat treatment. The impurities, such as silica, iron, alumina, and phosphorus, also are concentrated by sintering. Sintering was done to determine the chemical composition of the final product. The physical nature of the sinter was not studied, as the commercial nodulizing or sintering of manganese concentrates is not included as part of this project.

After the close of World War II, the Metals Reserve Company ceased purchasing manganese ores and concentrates. Therefore, the specifications given here, although correct at the time of the laboratory investigations, are no longer in effect.

PART I. - TOM MAJOR PROPERTY

Nature of the Ore

Physical

The sample of ore from the Tom Major deposit contained pyrolusite and psilomelane as the principal manganese minerals. Chief impurities were iron, silica, zinc, and lead very intimately combined with the manganese oxides. Most of the manganese oxides were contaminated with particles of calcite and silica ranging in size from 200- to 560-mesh. Iron oxide and manganese oxides were intimately associated in a lacelike network so fine in texture that they could not be liberated by grinding to minus 200-mesh. Hetaerolite ($ZnO.Mn_2O_3$) was tentatively identified and appeared to be distributed fairly uniformly throughout the ore. About one-third of the total lead content occurred as tarnished galena and as cerussite; the remainder of the lead appeared to be directly associated with manganese in some unidentified form. A very small amount of iron occurred as tarnished pyrite.

Chemical

Chemical analysis of the Tom Major ore follows:

TABLE 1. - Chemical analysis

Assay, percent										
Mn	Fe	SiO_2	Insol.	P	Al_2O_3	Zn	Ba	CaO	MgO	Pb
23.5	10.0	22.4	28.2	0.027	5.7	2.5	Nil	4.5	Trace	1.9

Study of the above data showed that the ore-dressing problem consisted of liberation and rejection of considerable silica and iron together with lesser amounts of lime, alumina, and the base metals zinc and lead.

Size Distribution of Manganese

When a sample of ore was crushed to minus 10-mesh and subsequently sieve-sized, the following distribution of manganese, iron, and zinc was obtained:

TABLE 2. - Distribution of manganese, iron, and zinc

Product	Weight, percent	Assay, percent			Distribution, peercent		
		Mn	Fe	Zn	Mn	Fe	Zn
-10+14-mesh......	29.4	25.7	9.5	2.40	33.1	28.1	29.4
-14+28-mesh......	22.6	25.8	9.7	2.65	25.6	22.0	25.0
-28+48-mesh......	12.9	24.6	9.9	2.65	13.9	12.8	14.3
-48+100-mesh.....	6.7	22.6	10.0	2.50	6.6	6.7	7.0
-100+200-mesh....	5.8	19.9	9.5	2.15	5.1	5.5	5.2
-200-mesh sand...	3.2	20.1	10.1	2.15	2.8	3.3	2.9
Slime...........	19.4	15.2	11.1	2.00	12.9	21.6	16.2
Calculated head..	100.0	22.8	10.0	2.40	100.0	100.0	100.0

The results given in table 2 show that the proportions of manganese, iron, and zinc in all sized fractions are nearly constant, and that no appreciable concentration of manganese can be obtained by simple sizing.

Methods of Concentration

The physical and chemical nature of the ore indicated that beneficiation by ore dressing would be difficult owing to the extremely intimate association of the minerals that would require extremely fine grinding for liberation. Investigations carried out in detail included tabling, fatty-acid flotation of manganese, cationic flotation of silica, magnetic separation, and various special procedures such as attempts to remove lead and zinc by sulfidizing and xanthate flotation. As no encouraging results were obtained, only brief summaries of the various tests are given in this report.

Tabling of Sized Fractions

A sample of ore was crushed to minus 10-mesh, ground wet to minus 28-mesh, and deslimed. The sands were wet-screened into minus 28-plus 48-mesh, minus 48- plus 100-mesh, minus 100- plus 200-mesh, and minus 200-mesh fractions. Each sand fraction was tabled to make a lead concentrate, a manganese concentrate, a middling, and a tailing. The middlings contained over 40 percent of the manganese in the ore; therefore, they were combined and reground to 100-mesh to effect further liberation and were then retabled to make a manganese concentrate, a middling, and a tailing. The corresponding products from each sized fraction were combined. Results are given in table 3.

TABLE 3. - Tabling sized fractions

Product	Weight, percent	Assay, percent					Distribution Mn, percent
		Mn	Fe	Insol.	Zn	Pb	
Combined concentrate......	23.2	33.5	11.0	10.5	2.8	2.6	34.1
Combined middling.........	10.4	25.2	-	24.2	-	-	11.5
Combined tailing..........	36.8	17.8	-	34.2	-	-	28.7
Combined lead concentrate.	0.2	27.7	6.0	4.8	3.0	20.1	0.2
Slime.....................	29.4	19.8	10.3	33.0	-	-	25.5
Calculated head...........	100.0	22.8	-	27.3	-	-	100.0

The combined manganese concentrates represented a recovery of 34.1 percent of the manganese in the ore, assayed 33.5 percent manganese, and would sinter to plus 35 percent manganese. The combined lead concentrate assayed 20.1 percent lead but represented a recovery of only 21 percent of the lead in the ore. No clean table tailing was made, and a large portion of the manganese was contained in the slime fraction. The results indicated that the minerals are not sufficiently liberated from one another, even at minus 100-mesh, for concentration to be effected.

Flotation of Manganese

Owing to the relative inefficiency of tabling finely ground ore, fatty-acid flotation of manganese was next investigated. Ore was stage-ground to minus 65-mesh and deslimed. The sand portion was pulped with Salt Lake City tap water, and the manganese was floated by using an aqueous emulsion of oleic acid stablized with Emulsol X-1 as collector-frother. The manganese concentrate was cleaned twice. The recleaner concentrate assayed 30.2 percent manganese and contained only 16.6 percent of the manganese in the ore, and lowest grade tailing product assayed 22.1 percent manganese. Over 31 percent of the total manganese was contained in the slime fraction. As preliminary flotation tests gave no effective concentration of manganese minerals, fatty acid flotation of ore ground to finer sizes was not investigated, because slime loss would be prohibitive.

Flotation of Silica

Further attempts to beneficiate Tom Major ore included cationic flotation of siliceous gangue from ore stage-ground to minus 100-mesh and deslimed. The manganese product thus produced assayed 29.4 percent manganese, 10.8 percent iron, 11.4 percent insoluble, 2.3 percent zinc, and 2.6 percent lead, and represented a recovery of only 12.6 percent of the total manganese. Lowest-grade silica concentrate obtained assayed 18.8 percent manganese, indicating lack of liberation at sizes treated.

Magnetic Separation

To determine the amenability of Tom Major ore to magnetic separation, some of the highest-grade manganese products obtained by tabling, flotation of manganese, and flotation of silica were each treated on a disk-type, high-intensity magnetic separator. Only small amounts of lead and insoluble were rejected, and no significant concentration of any of the minerals was obtained.

Flotation of Lead and Zinc

Experiments were made to float selectively the lead and zinc minerals in the ore. The higher xanthates were used as collectors, and tests were made with both sulfidized and unsulfidized pulps. Although the concentrates obtained assayed as high as 24 percent lead, the amount of total lead recovered was not large enough to justify treatment. No concentration of zinc was obtained.

Conclusions

1. The complex oxide manganese ore from the Tom Major deposit was not amenable to mechanical methods of concentration to yield either intermediate- or high-grade marketable products, owing to lack of liberation, even when fine grinding was employed.

2. The highest-grade concentrate was made by tabling but assayed only 33.5 percent manganese and represented only 34.1 percent recovery of the manganese. The value of this product is doubtful because of the low recovery and the objectionably high iron, zinc, and lead content.

3. The almost constant ratio of iron, zinc, and lead to manganese in products obtained, regardless of the ore-dressing method applied, emphasizes the complexity of the ore.

PART II. - BLACK TOP CLAIMS

Nature of the Ore

Physical

The vein ore from the Black Top Claims is composed of quartzite, manganese silicate, and manganese oxide intimately intermixed with one another. Virtually all of the manganese silicate (rhodonite) particles have manganese oxides associated with them as replacement shells or as veinlets along the fracture planes. The association of the minerals is so intimate that only part of them are liberated by fine grinding.

Chemical

Chemical analysis of the Black Top vein ore is given in table 4.

TABLE 4. - Chemical analysis

Assay, percent								
Mn	Fe	SiO_2	Insol.	P	Al_2O_3	Zn	Ba	CaO
14.6	1.3	71.2	86.8	0.030	2.1	Nil	0.29	0.1

As may be seen from the above data, the ore-dressing problem involves the liberation and rejection of siliceous gangue. The presence of considerable rhodonite prevents production of a low-silica manganese concentrate that represents a high recovery of manganese.

Size Distribution of Manganese

A sample of ore was crushed through 10-mesh and wet-screened into sized fractions. The distribution of manganese in each fraction is shown in table 5.

TABLE 5. - Size distribution of manganese

Product	Weight, percent	Assay, percent Mn	Distribution Mn, percent
-10+28-mesh......	66.6	15.3	67.4
-28+48-mesh......	12.9	14.7	12.5
-48+100-mesh.....	8.0	15.5	8.2
-100+200-mesh....	4.1	16.1	4.4
-200-mesh sand...	7.7	13.8	7.0
Slime...........	.7	10.4	.5
Calculated head..	100.0	15.1	100.0

As is shown in the above table, the amount of primary slime formed by crushing is small, indicating the hardness of all ore constituents. Manganese grade in the various sized fractions is quite uniform, and no preliminary enrichment by screening and rejecting barren material is possible.

Methods of Concentration

As the major portion of the manganese occurred as rhodonite in intimate association with siliceous gangue, it was evident that little, if any low-silica manganese concentrates could be made. A hand-picked specimen of rhodonite from this ore assayed over 45 percent SiO_2. Therefore, the ore-dressing investigation was directed toward rejection of quartzite gangue and thereby concentrating the manganese minerals to a marketable intermediate-grade concentrate. As microscopic evidence pointed to the necessity of extremely fine grinding to liberate manganese minerals, concentration methods employed were tabling and cationic flotation of silica.

Tabling

To determine the amenability of the Black Top ore to gravity concentration, a sample of ore was stage-ground to minus 100-mesh and tabled unsized to make a concentrate, middling, and tailing. Results are shown in table 6.

TABLE 6. - Tabling

Product	Weight, percent	Assay, percent Mn	Distribution Mn, percent
Concentrate.......	17.7	28.6	34.6
Middling..........	55.6	11.9	45.2
Tailing and slime.	26.7	10.8	20.2
Calculated head...	100.0	14.6	100.0

Data given in table 6 show that neither high-grade concentrate nor low-grade tailing was made by tabling minus 100-mesh ore. A similar test on 200-mesh ore showed no improvement as to grade of concentrate or tailing obtained. The small amount of manganese oxide liberated could not be tabled into a separate product. These experiments, therefore, indicate that the association of silica with the manganese mineral is so intimate that little liberation is obtained by even very fine grinding.

Flotation of Silica

As table concentration gave unsatisfactory results, an attempt was made to beneficiate the ore by floating and rejecting silica. Ore was ground to minus 100-mesh and deslimed by decantation. The sand fraction was pulped with Salt Lake City tap water in a mechanically agitated laboratory cell, and lauryl amine hydrochloride was employed as collector and frother to remove successive silica concentrates. A total of 0.33 pound of reagent per ton of original ore was used. Results of cationic flotation of silica are summarized in table 7.

TABLE 7. - Flotation of silica

Product	Weight, percent	Assay, percent Mn	Distribution Mn, percent
Slime..................	5.0	12.0	4.1
Silica concentrate No. 1	27.4	8.9	16.6
Silica concentrate No. 2	20.4	9.8	13.6
Silica concentrate No. 3	25.0	15.3	26.1
Manganese tailing.......	22.2	26.1	39.6
Calculated head.........	100.0	14.7	100.0

By cationic flotation of silica, only 39.6 percent of the manganese was recovered in a product that assayed 26.1 percent manganese. Rhodonite occurred in both the silica concentrates and the manganese tailing, thereby contributing to the manganese content of the silica reject and the silica content of the manganese product.

Conclusions

1. The mineralogical nature of the manganese occurring in the Black Top ore is unfavorable to concentration by ore-dressing methods. Much of the manganese is present as silicate and the remainder as oxide very intimately associated with silica. Only partial liberation of minerals was obtained by fine grinding.

2. No high-grade manganese concentrates were made, and benefecation to produce intermediate-grade products was not successful. Only 34 to 39 percent of the manganese was recovered at grades of 26 to 28 percent manganese by gravity and flotation methods.

PART III. - BLACK HAWK CLAIM

Nature of the Ore

Physical

The Black Hawk ore is an intimate association of black manganese oxides with manganese silicate and quartzite and is unusually hard and compact. It is quite similar to ore from the Black Top claim described in the preceding section. Rhodonite, the chief manganese mineral present, is traversed by veinlets of manganese oxides ranging in thickness from 150- to 300-mesh. Black areas in the ore are composed of quartzite intimately associated with rhodonite, which contains 150- to 1,500-mesh grains of manganese oxides. A carefully selected specimen of rhodonite assayed 27.4 percent manganese and 55.6 percent silica. Theoretically pure rhodonite ($MnO\ SiO_3$) contains 45.9 percent silica.

Chemical

The chemical analysis of the Black Hawk ore is given in table 8.

TABLE 8. - Chemical analysis

Assay, percent									
Mn	Fe	SiO_2	Insol.	P	Al_2O_3	Zn	Ba	CaO	MgO
24.2	1.4	52.2	68.3	0.211	3.6	Nil	Nil	Tr.	0.05

Size Distribution of Manganese

A sample of Black Hawk ore was crushed through 10-mesh and subsequently screen-sized. As with the similar Black Top ore, no segregation of manganese and gangue was noted, and rhodonite was evenly distributed throughout the entire size range.

Methods of Concentration

A study of the foregoing data indicated that fine grinding would be necessary to liberate the rhodonite from the siliceous gangue and also that the liberation of manganese oxides would require grinding beyond economical limits. As rhodonite is the major manganese-bearing constituent of the ore, no high-grade manganese concentrate could be expected; ore dressing was done to produce an intermediate-grade rhodonite concentrate together with such manganese oxides as are liberated during grinding. Although preliminary tabling tests indicated that a very small amount of plus 40 percent manganese concentrate could be made, the separation of rhodonite and quartzite was not encouraging, owing to lack of liberation. Cationic flotation of silica, therefore, appeared to be the most feasible method of beneficiating ore.

Flotation of Silica

A sample of ore was stage-ground to minus 100-mesh and sized into three products: minus 100- plus 200-mesh, minus 200-mesh sand, and slime. Silica was floated from each sized product by using a total of 1.34 pounds lauryl amine hydrochloride per ton of original ore. Results are given in table 9.

TABLE 9. - Flotation of silica

Combined products	Weight, percent	Assay, percent Mn	Assay, percent SiO_2	Distribution Mn, percent
Silica concentrate No. 1.	8.5	8.5	78.2	3.0
Silica concentrate No. 2.	28.6	16.9	62.6	20.4
Silica concentrate No. 3.	26.3	23.0	53.1	25.6
Manganese tailing........	36.6	32.9	39.2	51.0
Calculated head..........	100.0	23.6	52.9	100.0

By cationic flotation of silica, 51 percent of the manganese was recovered in a combined product that assayed 32.9 percent manganese and 39.2 percent silica. The manganese concentrate assayed higher in manganese and lower in silica than the hand-picked specimen, indicating either a concentration of some of the manganese oxides with the rhodonite or that the hand-picked specimen contained some finely divided silica.

Although this test showed that some concentration could be achieved by flotation of silica, the amount of siliceous gangue that can be liberated within possible economic grinding limits is small, and the possibilities of beneficiation by any ore-dressing method are limited.

Conslusions

1. The Black Hawk ore, containing the greater part of its manganese as rhodonite, was not amenable to the production of high-grade manganese concentrates by ore-dressing owing to lack of liberation, even when fine grinding was employed.

2. By flotation and rejection of siliceous gangue, 51 percent of the manganese in the ore was recovered at a grade of 32.9 percent manganese. However, as the degree of beneficiation is limited, the value of this treatment is doubtful.

PART IV. - BLACK DIABLO CLAIM

Nature of the Ore

Physical

Manganese in the Black Diablo ore is present as manganese oxides, chiefly psilomelane and pyrolusite, intimately associated with siliceous gangue. The ore may be classified roughly into three types on the basis of mineral association. Type 1 contains chert fragments and grains of secondary quartz, ranging in size from 65- to minus 200-mesh, scattered uniformly through areas of manganese oxides. Type 2 contains 150- to 200-mesh inclusions of manganese oxides in secondary quartz that occurs in veins and as a filling in interstices in the ore. Type 3 is composed of chert and quartzite fragments, as coarse as 1 inch, that are virtually barren of manganese oxide inclusions.

Chemical

The chemical analysis of the ore is given in table 10.

TABLE 10. - Chemical analysis

Assay, percent								
Mn	Fe	SiO_2	Insol.	P	Al_2O_3	Zn	CaO	S
27.4	2.3	45.2	52.0	0.052	3.3	Nil	1.1	0.05

Size Distribution of Manganese

A sample of ore was crushed through 10 mesh and subsequently screen-sized. Distribution of manganese and insoluble in the various sized fractions is shown in table 11.

TABLE 11. - Size distribution of manganese

Product	Weight, percent	Assay, percent		Distribution, percent	
		Mn	Insol.	Mn	Insol.
-10+14-mesh.....	39.1	38.2	52.2	39.8	39.4
-14+28-mesh.....	25.9	29.2	51.2	27.3	25.6
-28+48-mesh.....	12.2	29.4	50.8	12.9	11.9
-48+100-mesh....	6.6	28.6	50.8	6.8	6.5
-100+200-mesh...	4.1	28.3	51.0	4.2	4.0
-200-mesh sand..	6.5	24.8	53.6	5.8	6.7
Slime...........	5.6	16.1	54.4	3.2	5.9
Calculated head.	100.0	27.7	51.8	100.0	100.0

The preliminary size-analysis test indicated no marked concentration of manganese in any sized fraction.

Methods of Concentration

Preliminary study indicated that some of the coarse and relatively barren chert probably could be rejected by coarse gravity methods, but that production of high-grade manganese concentrates probably would entail grinding to at least minus 100 mesh. Consequently, the following concentration methods were investigated:

1. Combined heavy-media separation and tabling.

2. Tabling.

3. Flotation of manganese

4. Tabling followed by (a) flotation of Manganese and (b) flotation of silica.

Each will be discussed.

Combined Heavy-Media Separation and Tabling

A sample of ore was crushed through 1-inch and sized on 3- and 10-mesh screens. The plus 10-mesh fractions were treated separately by the sink-and-float or heavy-media process for the removal of two sink products at media specific gravities of 3.3 and 2.8. Minus 10-mesh deslimed material was crushed through 20-mesh and tabled to make a concentrate and a tailing that was reground to minus 48-mesh and retabled.

Results of this combined treatment are summarized in table 12.

TABLE 12. - Sink-and-float and tabling

Product	Weight, percent	Assay, percent Mn	Distribution Mn, percent
Combined sink No. 1.................	46.4	40.5	67.4
Combined sink No. 2.................	23.2	22.3	18.6
-20-mesh table concentrate..........	3.7	41.4	5.5
-20-mesh tailing and slime..........	5.0	12.3	2.2
Primary slime.......................	5.1	12.2	2.2
Combined float......................	16.6	6.8	4.1
Calculated head.....................	100.0	27.9	100.0
Combined sink and table concentrate	73.3	34.8	91.5
Combined sink No. 1 and table concentrate................	50.1	40.6	72.9

By heavy-media separation of plus 10-mesh ore and tabling of the minus 10-mesh ground through 20-mesh, 91.5 percent of the manganese was recovered in a marginal-grade product assaying 34.8 percent manganese. Over 72 percent of the manganese was obtained as a 40-percent manganese product that is marketable without sintering.

Additional low-grade reject was made by tabling the combined sink No. 2 product ground to minus 100-mesh. Inclusion of this step in the above procedure resulted in manganese recoveries of 83.4 and 78.9 percent in products assaying 39.4 and 40.6 percent manganese, respectively.

To determine whether high-grade manganese concentrate could be made from Black Diablo ore, a sample of sink No. 1 was ground to minus 100-mesh and tabled. A concentrate was made that assayed 52.2 percent, but recovery was too low to warrant the additional treatment.

Tabling

Numerous tabling tests were run on ore ground to 48-, 100-, and 200-mesh to determine whether higher-grade concentrates could be made with acceptable recoveries. In one such test, a sample of ore was ground to minus 48-mesh, sized on 100- and 200-mesh screens, and each sand fraction tabled separately to make a concentrate, middling, and tailing. Results are given in table 13 with sinter made from table concentrate shown in table 14.

TABLE 13. - Tabling sized fractions

	Weight, percent	Assay, percent Mn	Assay, percent Insol	Distribution Mn, percent
Combined concentrate (to sinter)	34.0	47.3	25.4	57.0
Combined middling...	15.6	26.6	57.0	14.7
Combined tailing....	28.7	11.3	75.4	11.5
Slime...............	21.7	21.9	55.4	16.8
Calculated head.....	100.0	28.2	51.2	100.0

TABLE 14 - Results of sintering

	Assay, percent						
	Mn	Fe	SiO_2	Al_2O_3	P	Zn	SiO_2+ Al_2O_3
Sinter..........	49.0	-	24.3	-	-	-	-
M.R.C. base-price marketing specifications.....	48.0	6.0	-	-	Max. 1.0	Max. 3.0	11.0
M.R.C. minimum marketing specifications.....	Min. 35.0	-	-	-	Max. 1.0	Max. 3.0	-

By tabling sized fractions of ore ground to minus 48-mesh, 57 percent of the manganese was recovered in a concentrate that, when sintered, assayed 49.0 percent manganese. Tabling finer ground material produced concentrates as high as 55.8 percent manganese grade, but with marked decrease in recovery owing to greater loss of manganese in the slime fraction.

Flotation of Manganese

A number of flotation tests were made on deslimed and undeslimed ore pulp to determine the amenability of Black Diablo ore to this method of concentration. Best results were obtained by floating the manganese from minus 200-mesh undeslimed ore, using an aqueous emulsion of oleic acid stabilized with Emulsol X-1 as collector-frother. By this treatment, 35.8 percent of the manganese was recovered in a product that, when sintered, assayed over 48 percent manganese. As these results are inferior to those obtained by coarse gravity methods, no further details are given.

Combined Tabling and Flotation

To eliminate grinding of the entire ore to minus 200-mesh for flotation, tests were run wherein ore was tabled at 100-mesh and the table concentrate ground to minus 200-mesh and re-treated by flotation of manganese or cationic flotation of siliceous gangue. These treatments gave manganese recoveries of 56 and 60 percent, respectively, and produced concentrates that assayed plus 46 percent manganese prior to sintering. As results obtained by these involved methods are no better than the results of tabling of minus 48-mesh ore, no further details will be given.

Conclusions

1. The Black Diablo ore contains manganese oxides and silica so intimately associated that production of high-grade manganese concentrates involves fine grinding for liberation.

2. Combined heavy media separation and tabling recovered 78.9 percent of the manganese at 40.6 percent manganese grade, or 83.4 percent of the manganese at 39.4 percent grade. These products would be marketable without sintering.

3. Tabling of ore ground to minus 48-mesh recovered 57 percent of the manganese in a product that, when sintered, assayed 49.0 percent manganese.

4. Involved treatment, including tabling ore ground to minus 100-mesh, followed by regrinding and re-treatment of table concentrate by flotation gave results no better than were obtained from simple tabling.

5. Fatty acid flotation proved ineffective in beneficiating the ore.

PART V. - O'LEARY PROPERTY

Nature of the Ore

Physical

The O'Leary ore consists of very fine grains of pyrolusite and psilomelane uniformly distributed throughout a quartzite gangue. In some instances, manganese oxides have partly replaced the quarzite, so that the individual quartz grains appear "smoky." Such partly replaced quartz grains tend to float with manganese oxide grains, thus diluting manganese flotation concentrates with gangue.

Chemical

Analysis of a representative head sample on which ore dressing was done is shown in table 15.

TABLE 15. - Chemical analysis

Assay, percent								
Mn	Fe	SiO_2	Insol.	P	Al_2O_3	Zn	Ba	CaO
22.9	2.1	55.8	63.4	0.039	1.9	Nil	1.06	0.1

Size Distribution of Manganese

A sample of ore was ground to minus 48-mesh and subsequently screen-sized. No concentration of manganese was noted, the tenor of the various fractions being almost identical.

Methods of Concentration

As the association of manganese and silica is exceedingly intimate, it appeared doubtful that any high-grade manganese concentrate could be made. Beneficiation of this ore, therefore, was directed toward making an intermediate-grade product with a high manganese recovery. Methods tried included sink-and-float, tabling, and fatty acid flotation.

Sink-and-float

A sample of ore was crushed through 3/4-inch and screen into 3/4-inch plus 3-mesh, minus 3- plus 4-mesh, minus 4- plus 6-mesh, and minus 6-mesh fractions. Each of the plus 6-mesh fractions was treated separately by sink-and-float methods at media specific gravities of 3.2 and 2.9.

Only 23 percent of the manganese was recovered by this method of treatment in a product that assayed 33.4 percent manganese, and no tailings were made that were sufficiently low grade to be discarded as waste. Therefore, the sink-and-float process was rejected as a possible treatment method. Complete details of this test are omitted from this report.

Tabling Sized Fractions

Sink-and-float results indicated that finer grinding would be required to beneficiate O'Leary ore; consequently, a sample of ore was ground to minus 48-mesh, deslimed, and sized on 100- and 200-mesh screens. Each sand fraction was tabled separately to produce a concentrate, middling, and tailing. Results are given in table 16.

TABLE 16. - Tabling sized fractions

Product	Weight, percent	Assay, percent		Distribution Mn, percent
		Mn	SiO_2	
Concentrate.........	5.2	44.0	15.9	10.7
Middling...........	9.1	38.6	26.8	16.4
Slime..............	18.0	20.3	-	17.0
Tailing............	67.7	17.7	-	55.9
Calculated head.....	100.0	21.4	-	100.0
Combined concentrate and middling.	14.3	40.6	22.8	27.1

By tabling sized fractions of O'Leary ore, only 27.1 percent of the total manganese was recovered in a product that assayed 40.6 percent manganese. Tabling ore of various grinds (minus 20- to minus 100-mesh) showed no improvement in grade or recovery.

Flotation of Manganese

Fatty acid flotation of manganese from samples of ore ground to minus 65-, 100-, and 200-mesh gave no encouraging results. Typical flotation concentrate assayed 23.5 percent manganese with a tailing of 19 percent manganese grade. Poor flotation selectivity was due to the nature of the manganese-impregnated siliceous grains, which were floated easily.

Conclusions

1. Intimate association of manganese oxides and siliceous gangue prohibited beneficiation of O'Leary ore to marketable products with appreciable recovery.

2. Only 27.1 percent of the manganese was recovered by tabling sized fractions of ore in a product that assayed 40.6 percent Mn.

3. No appreciable concentration was achieved by fatty acid flotation of manganese or by heavy media separation methods.