Kin cc. H. K.
McMillan WDM
Shaw J.T.A.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF MINES
1600 EAST FIRST SOUTH STREET
SALT LAKE CITY 1, UTAH

Mining Division
Date Rec'd.
NOV 13 1951
BUREAU OF MINES
Denver, Colorado

November 8, 1951

Memorandum

To: Paul T. Allsman, Bureau of Mines, Denver, Colorado

From: S. R. Zimmerley, Bureau of Mines, Salt Lake City, Utah

Subject: 1. Mead manganese property, Johnson County, Wyoming.

2. Summary of test results of Western Manganese Ores.

Yesterday when I was in Denver, you and Mr. McMillan asked about your letter of October 9 requesting information on metallurgical testing on Mead manganese ore from Johnson County, Wyoming. Upon returning today, George Potter mentioned that he answered the memorandum on October 12, the memorandum being directed to J. H. East, Jr. and from me. Attached is a copy of the memorandum. In any event, you will note that the deposit was not considered of sufficient importance in 1942 to justify metallurgical work and that the sample submitted by Gunnell, 8 or 9 years ago has been discarded. If you wish to submit another sample for metallurgical testing, we would be glad to do the work.

You perhaps will recall that I mentioned an R. I. giving the summary of results of test work done at Salt Lake on a large number of manganese ores and I could not remember the number of the R. I. It is R. I. 4117, Beneficiation of Western Manganese Ores, by C. H. Schack and H. G. Poole. In the appendix given on page 23 on through to the end of the R. I., is a key classification group arranged according to types, states, and districts. The original 100 authors' copies have already been distributed and fortunately a new batch arrived several days ago. Two copies are enclosed for your use.

p.T.a.

S. R. Zimmerley
S. R. Zimmerley

Copy to: J. H East, Jr.
W. D. McMillan

Enclosure

224 New Customhouse
Denver 2, Colorado

October 16, 1951

Memorandum

To: Tom Lyon, Director, Supply Division, Washington, D. C.

From: Executive Officer, DMA Field Team, Region IV

Subject: DMA Docket 422, Wyoming Manganese Company,
Thomas A. Guynn

Attached herewith is copy of a letter from Thomas A. Guynn indicating that he wishes to drop his application for assistance for exploration on the Meade Manganese Deposit in Wyoming.

J. H. East, Jr.

J. H. East, Jr.

Attachment
PTA:oj
cc: SRWilson
AHKoschmann
DMA Subject and Chron.

REGIONAL DIRECTOR'S
OFFICE
REGION IV
OCT 15 1951
BUREAU OF MINES
DENVER, COLORADO

Manganese
DMA 427

Box 4156
Washington, D. C.
October 12, 1951

Mr. J. H. East, Jr.
Executive Officer
DMA Field Team, Region IV
224 New Customhouse
Denver 2, Colorado

DearMr. East

Conditions beyond our control have prevented further consideration of the Mead manganese deposit at the present time. Accordingly we wish to drop our application until and unless we contact you further.

Respectfully

Thomas A. Gwynn
Geological Engineer

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF MINES
1600 EAST FIRST SOUTH STREET
SALT LAKE CITY 1, UTAH

October 12, 1951

OFFICE
REGION IV
OCT 15 1951
BUREAU OF MINES
DENVER, COLORADO

Memorandum

To: J. H. East, Jr., Denver, Colorado

From: S. R. Zimmerley

Subject: Mead Manganese Property, Johnson County, Wyoming

This refers to your memorandum of October 9, inquiring as to whether or not metallurgical tests were made on a 150-pound sample of 20.4 percent manganese ore from the Mead property, Johnson County, Wyoming.

We have checked our files carefully and find that no tests were made on this sample, and the sample is no longer available. Apparently the District Engineer did not deem the deposit promising enough to warrant the expense of metallurgical testing, as our records indicate that, after assaying, the ore sample was ordered discarded.

S. R. Zimmerley

S. R. Zimmerley

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF MINES
1600 EAST FIRST SOUTH STREET
SALT LAKE CITY 1, UTAH

October 12, 1951

OFFICE
REGION IV
OCT 15 1951
BUREAU OF MINES
DENVER, COLORADO

Memorandum

To: J. H. East, Jr., Denver, Colorado

From: S. R. Zimmerley

Subject: Mead Manganese Property, Johnson County, Wyoming

This refers to your memorandum of October 9, inquiring as to whether or not metallurgical tests were made on a 150-pound sample of 20.4 percent manganese ore from the Mead property, Johnson County, Wyoming.

We have checked our files carefully and find that no tests were made on this sample, and the sample is no longer available. Apparently the District Engineer did not deem the deposit promising enough to warrant the expense of metallurgical testing, as our records indicate that, after assaying, the ore sample was ordered discarded.

S. R. Zimmerley

224 New Customhouse
Denver 2, Colorado

October 9, 1951

Memorandum

To: S. R. Zimmerley

From: Regional Director, Region IV

Subject: Metallurgical Tests on Meade Manganese Deposits, Johnson County, Wyoming

In 1942, the Meade Manganese Deposit was examined by Frank Gunsell of the Bureau of Mines. According to the War Minerals Memorandum, a 150 pound metallurgical sample was taken which assayed 20.4 percent manganese.

Please inform us as to whether or not metallurgical tests were made on this sample, and the results obtained, if any.

J. H. East, Jr.

J. H. East, Jr.

WDM:oj
cc: DMA Subject and Chronological

224 New Customhouse
Denver 2, Colorado

October 2, 1951

Mr. Thomas A. Gwynn
515 Gale Street
Houston 22, Texas

Dear Mr. Gwynn:

Reference is made to your application DMA-422. On April 17, 1951 we received a letter from you concerning your plans for exploration on the Head manganese deposit, Johnson County, Wyoming.

We are attempting to clean up the older applications and desire some advice from you as to whether you expect to go on with the project. If you do, it will be necessary to furnish complete information as required on Forms MF-103 and MF-100. We are attaching one of each form for your convenience.

If we do not hear from you within 30 days, we will assume that you are no longer interested in the project.

Very truly yours,

J. H. East, Jr.

J. H. East, Jr.
Executive Officer
DMA Field Team, Region IV

PTA:oj
cc: DMA Subject and Chron.

DMA.

REGIONAL DIRECTOR'S OFFICE REGION IV APR 20 1951 BUREAU OF MINES DENVER, COLORADO

515 Gale Street
Houston 22, Texas
April 17, 1951

Mr. J. H. East, Jr.
Regional Director
Bureau of Mines
224 New Customhouse
Denver 2, Colorado

Dear Mr. East

I received your letter dated February 20, 1951, and since that time have visited the location of the manganese properties. I made the trip with the purpose of deciding what type equipment would be needed for the exploration. The weather was very bad, and it now looks as if we may have a late spring in that section of the Big Horn Mountains.

After considering the depth and the material to be drilled I am somewhat skeptical as to whether an auger will give us the desired samples. I have just about decided that we will have to trench the deposits and then obtain wall samples. For this purpose I will have to obtain heavier equipment, including some large dozers. I am presently working on this, and will notify you when I have the required equipment, and when weather conditions will allow us to start our investigation.

Sincerely

Thomas A. Gwynn
Geologist

422

JTE

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF MINES

REGIONAL DIRECTOR'S OFFICE
REGION IV
APR 4 - 1951
BUREAU OF MINES
DENVER, COLORADO

Mining Division
Region IV

224 NEW CUSTOMHOUSE
DENVER 2, COLORADO

April 4, 1951

Memorandum

To: DMA Field Team, Region IV

From: Chief, Mining Division

Subject: DMA Docket 422, Wyoming Manganese Company, Thomas A. Gwynn

Mr. M. S. Mead, Jr., 51 South Main Street, Buffalo, Wyoming, called this morning and talked with Mr. McMillan in regard to the above docket. Mead is one of the owners of the manganese claims.

This deposit was examined by the Bureau of Mines in 1942. Correspondence on this calls it the Mean manganese deposit, but in the text of the report mention is made of Mead.

Mr Mead states that there is practically no snow on the deposit at the present and that it could easily be visited by the end of the month.

Paul T. Allsman

P. T. Allsman

422

February 20, 1951

Pending

Mr. Thomas A. Gwynn
P. O. Box 4156
Washington, D. C.

Dear Mr. Gwynn:

We are in receipt of instructions from the Operating Committee of the Defense Minerals Administration to investigate the property of the Wyoming Manganese Company in regard to your recent application for loan on Docket DMA 422.

It is our understanding that the area is covered with snow until about May 1. Will you kindly arrange to advise this office, 224 New Customhouse, Denver, Colorado, when the snow has melted sufficiently that a geological examination can be made. In the meantime, we will hold your application in abeyance without action until receipt of this information from you.

Sincerely yours,

J. H. East, Jr.

J. H. East, Jr.
Regional Director

JHE/cl

Copy to - Allsman
DMA files
Pending
Koschmann

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF MINES

Mining Division
Region IV

224 NEW CUSTOMHOUSE
DENVER 2, COLORADO

February 27, 1951

Memorandum

To: Field Team, DMA, Region IV

From: P. T. Allsman

Subject: DMA Docket 422, Wyoming Manganese Company,
Thomas A. ~~Quinn~~ Gwynn

The applicant has requested a loan of $800,000 for the purpose of purchasing the necessary equipment to produce 300,000 tons of metallurgical grade manganese. This manganese occurs as nodules in a clay matrix over an area of 500 acres with a reported thickness of 30 feet.

A deposit named the Mean Manganese Deposit in the same general area was exmained by Frank Gunnell of the Bureau of Mines during 1942. Copies of a War Mineral Memorandum on this deposit are attached. Two deposits are described, the best one being the northern deposit, which is composed of a nodular unconsolidated bed of manganese ore in an arenaceous clay gangue. A 150 pound metallurgical sample from this deposit averaged 20.4 percent Mn. Maximum thickness report was 8 feet, the bed thinning in all directions. There were not any estimates of tonnage of this deposit. It is probable that Gwynn's estimate of available tonnage is over optomistic.

P. T. Allsman

P. T. Allsman
by W. D. McMillan

Mining Division
Region IV

April 4, 1951

Memorandum

To: DMA Field Team, Region IV

From: Chief, Mining Division

Subject: DMA Docket 422, Wyoming Manganese Company, Thomas A. Gwynn

Mr. M. S. Mead, Jr., 51 South Main Street, Buffalo, Wyoming, called this morning and talked with Mr. McMillan in regard to the above docket. Mead is one of the owners of the manganese claims.

This deposit was examined by the Bureau of Mines in 1942. Correspondence on this calls it the Mean manganese deposit, but in the text of the report mention is made of Mead.

Mr Mead states that there is practically no snow on the deposit at the present and that it could easily be visited by the end of the month.

P. T. Allsman

PTA/dl
cc-DMA files
Allsman

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF MINES

Mining Division
Date Rec'd.
FEB 19 1951
BUREAU OF MINES
Denver, Colorado

1600 EAST FIRST SOUTH STREET
SALT LAKE CITY 1, UTAH

February 16, 1951

Memorandum

To: Paul T. Allsman, Chief, Mining Division, Region IV

From: Chief, Utah-Wyoming Branch, Mining Division

Subject: Manganese, Johnson County, Wyoming - your memorandum February 13, 1951.

We have checked the files here but have found nothing that would indicate that the property referred to by Mr. Thomas A. Gwynn is the same as that held by Norman Mead. However, I have discussed the area with Art Young, and he believes the property to be the one he examined with Everett under the Missouri Basin program. A copy of the report of this examination is probably included in Everett's Missouri Basin file. Frank Gunnell examined the Mead property during 1942 and prepared a War Minerals Memorandum at that time. A copy is enclosed. Art Young concurs with the tonnage estimate shown in this report.

Other manganese deposits have been reported in the general area of the Mead property. One owned by A. L. Gheen of Worland, Wyoming, is located in Washakie County, a short distance from the Johnson County line. W. E. Young attempted to examine this property in November 1950, but heavy snow prevented access to the property.

Stephen R. Wilson
Stephen R. Wilson

Docket No. 422

Wyo. Mn. Co.
Buffalo, Wyo.

/s/ P. T. Allsman

Mead, M. S., Jr. - 51 So. Main
Buffalo.
Brother - Norman Douglas.

Mining Division
Region IV

February 27, 1951

Memorandum

To: Field Team, DMA, Region IV

From: P. T. Allsman

Subject: DMA Docket 422, Wyoming Manganese Company,
- Thomas A. Quinn.

The applicant has requested a loan of $800,000 for the purpose of purchasing the necessary equipment to produce 300,000 tons of metallurgical grade manganese. This manganese occurs as nodules in a clay matrix over an area of 500 acres with a reported thickness of 30 feet.

A deposit named the Mean Manganese Deposit in the same general area was exmained by Frank Gunnell of the Bureau of Mines during 1942. Copies of a War Mineral Memorandum on this deposit are attached. Two deposits are described, the best one being the northern deposit, which is composed of a nodular unconsolidated bed of manganese ore in an arenaceous clay gangue. A 150 pound metallurgical sample from this deposit averaged 20.4 percent Mn. Maximum thickness report was 8 feet, the bed thinning in all directions. There were not any estimates of tonnage of this deposit. It is probable that Gwynn's estimate of available tonnage is over optomistic.

P. T. Allsman

WDM/cl
cc-Allsman
c DMA files
McMillan
Koschmann

February 20, 1951

Mr. Thomas A. Gwynn
P. O. Box 4156
Washington, D. C.

Dear Mr. Gwynn:

We are in receipt of instructions from the Operating Committee of the Defense Minerals Administration to investigate the property of the Wyoming Manganese Company in regard to your recent application for loan on Docket DMA 422.

It is our understanding that the area is covered with snow until about May 1. Will you kindly arrange to advise this office, 224 New Customhouse, Denver, Colorado, when the snow has melted sufficiently that a geological examination can be made. In the meantime, we will hold your application in abeyance without action until receipt of this information from you.

Sincerely yours,

J. H. East, Jr.
Regional Director

JHE/cl

Copy to - Allaman
DMA files
Pending
Koschmann

UNITED STATES
DEPARTMENT OF THE INTERIOR
DEFENSE MINERALS ADMINISTRATION
WASHINGTON 25, D. C.

REGIONAL DIRECTOR'S
OFFICE
REGION IV
FEB 13 1951
BUREAU OF MINES
DENVER, COLORADO

February 9, 1951

Memorandum

To: Mr. J. H. East, Executive Officer, Region IV

Through: Operating Committee

From: P. R. Bradley, Chief, Manganese-Tungsten-Chrome Branch

Attached find DMA docket 422, a proposal of the Wyoming Manganese Company to operate manganese properties located in sections 30 and 32, T. 47 N., 83 W. Neither the Geological Survey or the Bureau of Mines has sufficient information to determine the extent of the reserves which may be present in this area or the feasibility of the present proposal, but there appears to be promise of an important operation. For these reasons it is recommended that the property be examined in the field by representatives of the Geological Survey and the Bureau of Mines to determine the following:

(1) Tonnage and grade of ore reserves.
(2) Character of material in the ground and of washed nodules.
(3) Feasibility and cost of operations of the character proposed.

The area is snow-covered until about May 1, but at that time the owner has indicated his willingness to undertake churn or auger drilling at his own expense whenever the ground is clear. It is suggested that the field team take advantage of this and time their visit so as to coordinate with this exploration. This should be arranged by communicating directly with Mr. Gwynn.

P. R. Bradley Jr., Chief
Manganese-Tungsten-Chrome Branch

Enclosure 2

APPROVED

C. O. Mitteudorf
Acting Chairman, Operating Committee

J. H. Hedges
J. H. Hedges

T. P. Thayer
for Olaf N. Rove

Dma-422

WYOMING MANGANESE COMPANY
POST OFFICE BOX 4156
WASHINGTON, D. C.

January 15, 1951

PROPOSAL BY THE WYOMING MANGANESE COMPANY TO PRODUCE AND MARKET 300,000 TONS OF MANGANESE:

It is proposed that Wyoming Manganese Company produce 300,000 tons of manganese ore (40-45%Mn), for government stockpiling or other use as directed by the government.

LOCATION AND EXTENT OF RESERVES

Located in the vicinity of Buffalo, Wyoming, substantial deposits of Manganese dioxide (MnO_2) have been discovered. This body of ore is apparently of high grade and is found in large quantity. It occurs in the nodular form within a sandy clay matrix and the body lies within a few inches to a few feet of the surface. The ore has been studied in ravines cut through the area by streams, and additional pits twelve feet deep have been dug and core holes thirty feet in depth have been sunk to further determine the quantity and the quality of the deposit.

In the fifteen locations in which the ore was studied it was present in about equal amounts volumetricly to the surrounding matrix. Thus, by weight, the ore body is 60% manganese dioxide ore and 40% sandy clay matrix. In the ten core holes sunk, the ore was found to be at least thirty feet in thickness, the bit having never left the ore body when drilling ceased at thirty feet in each case. In extent, the leases cover the area in which the outcroppings of ore occur, extending well over a mile in length and covering approximately five hundred acres.

A thirty foot body of ore would contain 24,200,000 cubic yards of ore and matrix for the five hundred acres of reserves. By computation with specific gravities for the materials involved, 60% of this ore (by weight) is the manganese dioxide ore. Thus there is 2,331.4 lbs of ore per yard of material (the weight of ore and matrix combined being 5,551 lbs per yard). By further computation this indicates a reserve of 18,109,940 tons of manganese ore available. I recognize the fact that further coring must be done to determine the extent and uniformity of this ore body. Some ore bodies will vary in thickness whereas many remain quite constant. In this case we must accept the random coring and sampling over the entire area as sufficient evidence that a substantial body of ore does exist. While every core hole drilled to date has found the ore present in excess of thirty feet with the total depth not known, we can realize the immense tonnage available when we compute that it would only take a body of ore five feet in thickness over an area of 250 acres (half that presently under claim) to give us an ore tonnage of 2,331,000 tons. With apparent reserves of this size, the proposal to produce 300,000 tons of ore is conservative.

GRADE

The next consideration of importance is the grade of ore which can be delivered. Numerous samples were taken from the various sampling points and these were assayed by the Van Clieve Laboratories Inc. in Minneapolis, Minnesota. These samples ranged from a few pounds in weight to as much as 500 pounds. The report on the ore shows no difficult contamination. Most of the samples showed silica as the only contamination, and the two samples containing iron had only 0.9% and 1.3% respectively. The ores averaged 63 to 73% manganese dioxide which is 40 to 45% manganese ore, a high grade ore. Samples of this ore have been submitted to smelters and other users of manganese including Republic Steel with reports from these sources that it is high grade and satisfactory.

Of considerable importance in the matter of the quality of the ore is the fact that only simple inexpensive gravity concentration is necessary to yield very high concentrates because of the lack of serious contamination.

POWER-WATER-TRANSPORTATION-ETC.

Energy--A power line extends within approximately two miles of the proposed location of the concentration plant. Diesel fuel and other petroleum products can be brought in by rail from the two oil refineries at Newcastle, Wyoming, 200 miles away.

Transportation--Trucks will be used in the fifteen mile haul from the concentration plant to the rail siding in Buffalo, Wyoming. A United States highway runs within two miles of the proposed location of the concentration plant. From the rail siding in Buffalo, a short-line railroad (the Wyoming Railway Company) would connect with the main line of the Burlington RRY, 28 miles distant.

Water supply--Adequate water is available. One perennial mountain stream flows through the middle of the leases and two or three other streams lie within two or three miles of the property. The gradient is such that the other streams could be partially diverted, if necessary, to the concentration site.

Manpower--Several towns in the general area will probably furnish all the general manpower needed, although skilled personnel will have to be brought in from the mining districts of Colorado or Montana.

Housing--Housing will not be necessary at the project site because of the close proximity to Buffalo, Wyoming, where limited housing is available.

RATE OF PRODUCTION

Based on the amount of equipment projected in our plans and the availability of the ore, it seems within reason that a rate of production of three hundred tons of ore per day can be attained when production is in full progress. This is essentially a strip-mining project with very little overburden.

COST OF PRODUCTION

The cost of production cannot be determined until after qualified engineers have been consulted.

TYPE OF BENEFICATION

The benefication process will be simple and will not require elaborate equipment. The ore is rather easily separated from the matrix and an arrangement of jig screens coupled with a washing plant will be all that is needed to prepare the ore for shipment.

EQUIPMENT TO BE PURCHASED

Equipment needed will not be fully determined until after a thorough examination by competent mining engineers, but at present it appears that the following larger equipment will be required:

Bulldozers - 2
Power shoves
Heavy trucks - 10
Pickup trucks - 2
Concentration plant with jig screens and washing plant
Belt or cable conveyor for ore down hillside from deposit to concentration plant
Core drilling outfit for blocking out reserves
Tool sheds - 2 (one Quonset hut for truck service & repair)

SOURCE AND AVAILABILITY OF QUALIFIED PERSONNEL

Although one or two key men have already been contacted, most of the key men necessary for such an operation will have to be brought in from the mining areas of Montana and Colorado. It is anticipated that finding qualified men in that part of the country will not be difficult.

* * * * * * *

The preliminary work on these manganese properties has advanced to the point where we know that considerable ore is available. While additional investigations are to be conducted, this program has advanced to the point where a formal proposal is considered appropriate. Because of the scarcity of Manganese and its importance in the national defense program, it appears advisable that the development of these properties be expedited. We will require help from the government in developing these properties if the manganese is to be made available any time in the near future. While it is necessary to plan a definite program with experienced mining engineers, it appears that the sum of approximately $900,000 should be made available to safely equip and operate these properties.

Any suggestions or inquiries regarding the matter here presented will be welcomed. All correspondence should be mailed to:

Mr. Thomas A. Gwynn
Post Office Box 4156
Washington, D. C.

These ore properties would be operated under leases owned by myself (Thomas A. Gwynn), Riley A. Gwynn, and Edward R. Gwynn, doing business as the Wyoming Manganese Company.

Respectfully submitted

Thomas A. Gwynn

R. I. 4117 SEPTEMBER 1947

UNITED STATES
DEPARTMENT OF THE INTERIOR
J. A. KRUG, SECRETARY

BUREAU OF MINES
JAMES BOYD, DIRECTOR

REPORT OF INVESTIGATIONS

BENEFICIATION OF WESTERN MANGANESE ORES

BY

C. H. SCHACK AND H. G. POOLE

R. I. 4117,
September 1947.

REPORT OF INVESTIGATIONS

UNITED STATES DEPARTMENT OF THE INTERIOR - BUREAU OF MINES

BENEFICIATION OF WESTERN MANGANESE ORES[1]

By C. H. Schack[2] and H. G. Poole[2]

CONTENTS

	Page
Introduction	2
Acknowledgments	3
The problem	4
Oxide ores	5
Carbonate ores	6
Silicate ores	7
Complex ores	7
Concentration methods	9
Crushing, grinding, and sizing	9
Log washing and attrition	10
Sink-and-float	10
Jigging	11
Tabling	11
Fatty-acid flotation	12
Cationic flotation	14
Sulfide flotation	15
Magnetic separation	16
Specific application of laboratory procedures	16
Rhodocrosite ore from Utah (log washing, fatty-acid flotation)	16
Manganese ore from California (fatty-acid flotation)	18
High-grade oxide manganese ore from Arizona (cationic flotation)	19
Oxide manganese ore from Montana (sink-and-float, jigging, tabling, and magnetic separation)	19
Manganese ore from Nevada (tabling)	20
General discussion and summary	21
Appendix	23
Summary of the results obtained in the study of 288 lots of ore	23

1/ The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgment is used: "Reprinted from Bureau of Mines Report of Investigations 4117."

2/ Metallurgists in charge of Ore Dressing Section, Salt Lake City Division, Metallurgical Branch, Bureau of Mines.

TABLES

Page

1. Geographic distribution of western manganese ores..... 3
2. Flotation of low-grade carbonate ore from Utah..... 17
3. Fatty-acid flotation of manganese ore from California..... 18
4. Silica flotation from deslimed and unsized high-grade oxide manganese ore from Arizona..... 19
5. Gravity and magnetic concentration of Montana oxide manganese ore... 20
6. Tabling oxide manganese ore from Nevada..... 21

INTRODUCTION

In 1940, Congress appropriated funds to the Bureau of Mines for investigating methods and processes whereby high-grade manganese products could be made from domestic low-grade ores. The study of the concentration of western manganese ores by ore-dressing methods was an important part of this larger investigation.

The literature on dressing of manganese ore was abundant but contained little information of practical or specific value in formulating plans and programs for developing a large domestic industry. Descriptions of the few domestic plants and their practice were available, as were discussions of laboratory testing of a few isolated domestic deposits. Without a backlog of adequate study of the possibilities of milling domestic ores, the Bureau of Mines initiated its comprehensive program of investigating the milling of domestic manganese ores.

Mining engineers were assigned to examine each manganese deposit brought to the attention of the Bureau of Mines. If the deposit was considered of sufficient size and grade to warrant ore testing, a representative 2-ton sample was selected from the ore showings. Often the sample was submitted in separate smaller lots, each of which was representative of a specific type or grade of ore. About 288 lots of ore from 135 deposits were shipped to the Bureau's Salt Lake City laboratory for testing. Each lot was carefully crushed, coned, and quartered, and split into thoroughly mixed samples for individual ore-testing studies. A head sample for control chemical analysis was cut from the final quarter; and typical specimens of the various mineral associations were selected for microscopic study. Based on the chemical, microscopic, and wet-screen analyses, a tentative program of routine laboratory tests was planned. However, each ore was tested at least by both gravity and flotation methods. Often all ore-dressing methods and combinations of such methods were tried. No inflexible rules of testing were adhered to, as it was necessary that each ore-dressing engineer to whom the study of a specific ore was assigned assume the initiative in observing and developing favorable lines of attack.

The methods of concentration employed in the laboratory are as follows: (1) log washing and classification or sizing, (2) sink-and-float, (3) jigging, (4) tabling, (5) flotation of manganese minerals, (6) flotation of gangue constituents, (7) magnetic separations, and (8) combinations of one or more of the foregoing methods.

The extent of the test work on each ore was determined by the complexity of the milling problem and the estimated size of the specific deposit. Thus, a few ores were studied continuously over a period of months, whereas the testing of others of less importance and complexity was completed in a few days.

The scope of the program prevented consideration of each ore as a specific research problem; however, the almost complete lack of published useful data and precedent to follow required that considerable attention be given to finding a set of general rules of concentration for manganese ores of various types. Classifiable as original manganese-milling studies were the innumerable tests devoted to determining optimum crushing, grinding, classification, jigging, tabling, flotation, and magnetic separation conditions. The observations and facts resulting from the testing are discussed later under the heading "Concentration Methods."

The scope of the program is clear from a study of table 1, which gives the geographic distribution of the individual ores tested. Many of the deposits and groups of most of the deposits warrant individual discussion; however, this paper will present only the generalized facts and factors determined by the investigation.

In the tables appended to this report are summarized the results obtained in the study of 288 lots of ore from 12 Western States.

TABLE 1. - Geographic distribution of western manganese ores

Location	Properties	Samples
Arizona	35	73
California	19	42
Colorado	6	11
Idaho	4	4
Montana	7	16
Nevada	30	65
Oregon	2	2
Utah	43	64
Washington	2	3
Wyoming	3	3
South Dakota	2	2
New Mexico	2	3
	154	288

ACKNOWLEDGMENTS

In 1940, R. S. Dean, formerly assistant director of the Bureau of Mines, organized a program for the testing of domestic manganese ores. This report covers the ore-dressing work done at the Salt Lake experiment station under the direction of S. R. Zimmerley, chief, Salt Lake City Division, Metallurgical Branch. The ores for the test work were collected by the Mining Branch of the Bureau, which was under the direction of E. D. Gardner, assisted by

P. T. Allsman and his staff of mining engineers. Acknowledgment is made to them for their cooperation in obtaining representative samples from the many deposits. Microscopic work on the ores was done by the late R. E. Head and by L. G. Evans, and the analytical work was by H. E. Peterson, chief chemist, assisted by the analytical staff. Acknowledgment is made to the following metallurgists, who performed the many ore-dressing tests: J. V. Batty, H. L. Gibbs, R. Havens, W. J. Long, K. Dean, G. M. Potter, W. G. Sandell, H. D. Snedden, and R. R. Wells.

THE PROBLEM

At the outset of the investigation, only plus 48 percent manganese ore was acceptable for the manufacture of ferromanganese alloy. Such ore commanded, in the open market, $0.50 per unit of contained manganese. With the advent of the Metals Reserve Company stock-piling program, the price paid was immediately increased from $0.50 to $0.75 per unit, and later was increased to $1 per unit for plus 48-percent manganese ore. Moreover, the Metals Reserve Company schedules recognized the need for accepting lower grade ores and concentrates. It established two additional base classifications originally termed "Low-Grade A" for plus 44-percent manganese ore, and "Low-Grade B" for plus 35-percent ore. The base price ranged between $0.55 per unit of manganese for "Low-Grade B" 35-percent ore and $0.80 per unit for "Low-Grade A" ore. As of May 15, 1943, the schedules were simplified by eliminating all ore classifications and placing the specifications on a base of 48 percent manganese, 6 percent iron, and 11 percent silica plus alumina. Premiums are paid for manganese in excess of 48 percent and iron content below 6 percent and penalties imposed on products containing less than 48 percent manganese, more than 6 percent iron, and more than 11 percent silica plus alumina. The net effect of this change was that in general lower-grade materials were paid for at a higher rate than under previous schedules.

In addition to the chemical specifications, a size limit must be met by all ores and concentrates. This specification requires that the material be all minus 12 inches and at least 75 percent plus 20-mesh. Thus, fine-size material, such as table and flotation concentrates, must be nodulized or sintered. All carbonate manganese ores and products must be sintered. Sintering further concentrates manganese products, owing to the loss of oxygen, carbon dioxide, water, and other volatile constituents. Concentration by sintering is particularly important with manganese carbonate ores that could not meet 48 percent manganese specifications without having the chemically combined carbon dioxide driven off. Sintering also concentrates the nonvolatile impurities such as iron, silica, and alumina.

All types of manganese ore are represented among the 288 lots tested. They range in grade from a low of 4 percent to a high of 47 percent manganese. Mineralogically, the ores range from carbonate ores containing rhodochrosite, manganodolomite, or manganocalcite, through oxide ores containing psilomelane, pyrolusite, wad, or manganite to silicate ores containing braunite, bementite, and rhodonite, with complex mixtures of the three types of ore being less common. The principal gangue constituents - silica as quartz, chalcedony, and chert; lime as calcite and limestone; magnesium as dolomite; iron as hematite,

limonite, and ocher; and alumina as feldspars and clay - are likewise complexly associated with one another in virtually all manganese ores. Other less common impurities are iron and other base-metal sulfides, mica, gypsum, barium, and phosphorus.

In addition to the wide variance in chemical and mineralogical composition, the ores also show great variety in their physical nature and properties. Thus, in some ores the manganese minerals occur as relatively pure large aggregates, whereas in others the impurities are uniformly and intimately distributed through the manganese mineral as particles a few microns in size. Some ores are soft and friable, others are hard and tough. Some are crystalline, others are virtually amorphous in nature. All these factors bear directly on the concentratability of manganese ores and make generalized statements, as applied to an individual ore, inconclusive. However, a number of such generalizations are broadly applicable to an understanding of the problem as related to specific types of ore.

For convenience in generalizing on the amenability of manganese ores to ore-dressing methods, the following discussion is divided into sections on oxide, carbonate, silicate, and complex ore types.

Oxide Ores

In general, oxide ores containing wad or manganite as the principal manganese mineral are not readily amenable to concentration. Wad, by definition, is a complex mixture of unidentifiable manganese oxides with lime, clay, and iron minerals. It is very soft and on grinding or handling disintegrates into slimes that are not treatable. Manganite is usually crystalline, however, the crystals are needlelike and very friable. Their shape makes them very difficult to recover by gravity or flotation methods of concentration.

Psilomelane and pyrolusite ores are the most common types, and when the association with gangue minerals is simple, they are readily concentrated by most ore-dressing methods. Other factors being equal, higher recoveries are generally obtained on psilomelane ores owing to the comparative hardness and toughness of this mineral. However, considerable barium is often chemically combined with this manganese oxide; therefore, the grade of final product is sometimes low. Ores have been noted in which the manganese oxide contained as much as 15 percent chemically combined barium. Ores wherein pyrolusite is the principal oxide manganese mineral are often easily slimed, but less so then wad ores. This tendency may sometimes be utilized if the gangue constituents are comparatively hard and tough, in that attrition grinding will selectively slime the soft manganese mineral, and by subsequent sizing the low-grade or barren gangue material can be rejected. Both psilomelane and pyrolusite ores are difficult to concentrate if iron oxides are the chief gangue constituent, as the iron oxides are chemically allied to manganese oxides and have many similar physical properties. Calcite and gypsum, also, are troublesome if the association is so intimate as to require fine grinding for liberation, as tabling is difficult on fine sizes and these gangue constituents are readily floated by the same fatty-acid collectors used in floating the manganese oxides.

The principal difficulty in concentrating the oxide minerals is to prevent the formation of slimed manganese oxide, which is much more important in this field than in sulfide-mineral concentration because of the inherent difficulty of obtaining highly selective flotation conditions with fatty-acid collectors. Large middling products are the rule rather than the exception in the concentration of most oxide manganese ores, so most flow sheets must contain a middling regrind circuit. It is unusual to find an ore in which the manganese oxides occur as relatively pure mineral aggregates, and the gangue constituents and particularly silica often are found diffused throughout the manganese oxides. Those ores having much silica occurring intimately associated with the manganese oxide are generally not amenable to beneficiation. Generally, those oxide ores that can be concentrated by gravity methods also are readily concentrated by flotation or magnetic separation. The reverse of this observation is not necessarily true.

Carbonate Ores

Rhodochrosite is the only manganese carbonate mineral that can be considered of economic importance. Manganodolomite, manganocalcite, and manganosiderite all can be concentrated from the common gangue constituents but in themselves contain too little manganese to meet minimum-grade specifications.

Rhodochrosite ores, being of primary and deep-seated origin, are not common among the known western deposits. Only four such deposits of any size have come to the attention of the Bureau of Mines. In general this type of ore is readily amenable to concentration by flotation methods using fatty-acid collectors. As the manganese mineral is crystalline and easily cleavable, sliming is a minor problem; consequently, fine grinding can be employed to obtain maximum liberation. This is the chief property distinguishing rhodochrosite from oxide manganese ores. Some difficulty is introduced when much calcite, limestone, or dolomite occurs with the ores; however, by careful control of flotation conditions good separation can generally be effected. Silica as quartz and minor amounts of some metal sulfides are the most common gangue constituents. In some carbonate replacement deposits the rhodochrosite mineral contains small amounts of unreplaced limestone, dolomite, or iron carbonate. This limits the grade of the concentrates that can be made, as such impurities may be considered virtually chemically combined. Generally, gravity methods are not suitable for the concentration of rhodochrosite ores. Sink-and-float or jigging at coarse sizes often can be employed to reject much gangue before grinding and thus effects considerable economy in subsequent treatment. Log-washing to disintegrate and discard gougelike materials often found with rhodochrosite ores also may be employed to advantage.

As the theoretical composition of rhodochrosite includes about 48 percent manganese and 38 percent carbon dioxide, sintering is essential. Because the concentration effect of sintering is as high as 35 percent, the concentrates going to sintering must be very low in nonvolatile impurities, as these are likewise concentrated in the same proportion.

Silicate Ores

Silicate ores are of very minor importance as a source of manganese, although rhodonite ores are quite common. Theoretically, rhodonite contains about 42 percent manganese; however, lime and extra silica usually are either so intimately associated with this mineral or so chemically combined as to preclude their liberation. Thus, many selected specimens of rhodonite assay as little as 30 percent manganese. The chemical and physical properties are likewise similar to other silicate minerals, making a separation of these constituents impossible. Sintering of rhodonite ores does not concentrate the ore, owing to lack of volatile constituents and the fact that the manganese is already in the lowest state of oxidation. The high silica content, up to 45 percent of the pure mineral, likewise precludes its use as an ore of manganese.

Braunite is sometimes found in many cherty, siliceous, manganese oxide ores. Its behavior toward concentration is similar to that of the oxides, as it contains only about 10 percent silica.

A group of oxide manganese ores characterized by the impregnation of chert, chalcedony, or opal by psilomelane or pyrolusite may be classed most conveniently as silicate ore. Such ore is very difficult to concentrate into a high-grade product because complete liberation of manganese oxides from silica is virtually impossible, and the concentration of such ores involves the separation of mineral particles relatively rich in manganese from those poor in manganese. Generally, only a small amount of high-grade concentrate can be made from this type of ore, the remainder of the manganese content being distributed in a large amount of middling and tailing products.

Complex Ores

This rather broad classification includes ores that are complex owing to the association of mixed oxide, silicate, and carbonate manganese minerals or because of the complex composition of the associated gangue. A common complex ore is one in which the primary rhodonite mineral is partly or almost wholly oxidized to pyrolusite. Concentration of such ores is invariably difficult, as even if all the silicate mineral is oxidized, the silica part of the rhodonite molecule is very intimately and evenly distributed throughout the manganese. Generally, concentration of this type ore is the concentration of middling particles. As the degree of oxidation of rhodonite decreases, concentration becomes more difficult.

A less common complex ore is that featuring the oxidation of rhodochrosite ore to oxide manganese ore. All degrees of oxidation are possible, however; this type of ore is usually readily beneficiated, as both the oxide and carbonate manganese minerals are easily concentrated. Usually, the recovery on this type ore is lower than on simple carbonate ores, because a portion of the oxide manganese is lost as an untreatable slime product. However, when the primary ore is a very intimate association of gangue and rhodochrosite, the concentration may be difficult because of the very fine grinding required for liberation, which on oxide minerals invariably leads to large slime losses.

Ores containing oxide, carbonate, and silicate minerals of manganese are unusual. None of this type is included among those tested; however, the concentration of such ore probably would involve problems peculiar to oxide-carbonate ores and oxide-rhodonite ores. The degree to which rhodonite or its oxidation product is present probably would dictate the extent of success in beneficiating the ore.

In discussing manganese ores, which owe their complexity to the association of a variety of gangue constituents with one another, an almost endless number of types might be considered. For the purpose of this discussion, only the more common groups will be mentioned.

Ores having calcite-silica, dolomite-silica, gypsum-silica, and combinations of these minerals involve concentration difficulties unless liberation can be obtained at relatively coarse sizes, so that gravity concentration methods can be employed. This is so because a flotation treatment involves selective flotation of, first, the calcite, dolomite, or gypsum from manganese and then the flotation of manganese mineral from the siliceous gangue. The first separation is invariably only partly successful, because depression of the manganese minerals in the presence of fatty-acid collectors is not wholly successful. A carbonate-gypsum manganese middling product is always obtained, and over-all manganese recoveries at acceptable grade are lowered accordingly. A similar ore is one containing a barite-silica gangue. Such ore cannot be concentrated by gravity methods, and the flotation problem is the same as that for lime-gypsum-silica gangue ores.

A common type of complex manganese ore is that containing critical amounts of iron oxides associated with other gangue constituents. The iron oxides can be so similar in physical nature and chemical properties as to make them almost indistinguishable from manganese oxide minerals in their behavior toward ore-dressing methods of concentration. Except for a flotation method involving the use of a complex laboratory procedure and a number of costly reagents, magnetic separation is the only method applicable to this separation. Even magnetic separation is not too successful, as it involves close sizing and treatment at moderately coarse sizes. By employing a reducing roast to enhance the magnetic susceptibility of the iron minerals, better results are possible; however, such treatment is expensive. Too often the association between the manganese and iron oxides in the ore is so intimate that liberation into separate particles of the oxides is not possible.

Manganese ores containing large amounts of such slime-forming constituents as clay, gouge, iron ochre, and wad assoicated with harder gangue minerals involve special treatment. A preliminary washing treatment, simulating log-washing, to disintegrate and reject the slime-forming constituents is always necessary. This sometimes leads to the loss of considerable oxide manganese, if present in the ore as pyrolusite, as this mineral is soft and friable. Subsequent treatment follows the previously mentioned patterns. The occurrence of much slime-forming gangue materials is not always a handicap, because in most instances the rejection of a large portion of the ore by a relatively simple washing procedure makes the subsequent processing of the ore possible in much smaller plant units.

CONCENTRATION METHODS

The foregoing discussion has centered attention on the amenability of various manganese ores to concentration by ore-dressing methods. What follows will describe the laboratory methods of concentration employed so far as they bear on obtaining optimum recovery and grade of the final concentrate in plant practice.

Crushing, Grinding, and Sizing

The formation of slimes during the preparation of oxide manganese ores is the most serious problem in the treatment of such ores. Not only is manganese mineral as slime not concentratable, but the slime fraction, if left combined with the sand fraction, interferes with subsequent gravity, flotation, and magnetic methods of concentration. This is particularly true of flotation, as selectivity is impaired, frothing conditions are poor, and consumption of reagents is increased. To minimize this effect, care must be taken to prevent overgrinding and sliming of the mineral particles. This entails removal of the manganese particles from the grinding circuit as soon after liberation as possible. Often the grind should be somewhat coarser than that necessary for optimum liberation to avoid high losses of slime. A balance has to be struck between locked middling loss and slime loss with manganese ores, wherein a portion of the gangue can be liberated at relatively coarse sizes; it is sometimes necessary to effect a primary concentration before final fine grinding is done. By this procedure the grade of the slime fraction made by regrinding concentrates is often high enough so that it can be mixed with the finished sand concentrates before sintering. This prevents most of the loss that would invariably result if the ore had been ground to the fine size in the initial stage.

Recommended plant practice is jaw-crushing to a coarse size followed by roll-crushing in closed circuit with dry screens. Grinding should be done preferably with a rod mill in closed circuit with wet screens or in open circuit with the concentrating unit, from which coarse middling products can be returned for regrind. A ball mill has a greater tendence to overgrind manganese ore than a rod mill, and closed-circuit drag or special classifiers operating on hindered settling principles return much high-specific-gravity manganese already liberated to the mill for regrind. Large circulating loads between the rod mill and sizing unit should be the rule. However, it is a mistake to employ too low a pulp density in the mill or to use too small rods or too small a rod charge, because these conditions contribute to attrition grinding and consequent formation of slimes.

The laboratory procedure found most nearly to approach optimum grinding conditions was roll-crushing followed by careful stage-grinding and screening. Fineness of grind was determined by microscopic examination and screen analyses. As an example, assuming that 48-mesh was the coarsest size at which manganese liberation was obtained, the ore was roll-crushed through 10-mesh and screened on 48-mesh. The minus 10- plus 48-mesh fraction was ground for a short period, undersize was removed by screening, and oversize was returned to the ball mill. Alternate grinding and screening were continued until all of the material passed

48-mesh. Grinding stages were short and of equal length. Cast-steel ball mills carrying a ball load of about 10 kilograms and rotating at 60 to 70 r.p.m. were used throughout the investigation. Whenever possible, grinding pulp density was held at approximately 60 percent solids. Screening was done with standard Tyler sieves on wet pulp; standardized wet-screening technique was adopted so that results could be closely paralleled in subsequent tests.

Log Washing and Attrition

To beneficiate ores containing manganese occurring as comparatively large but scattered nodules and stringers in a claylike or loosely consolidated gangue, it is sometimes possible to remove the gangue by log-washing. This method was simulated in the laboratory by tumbling a large sample of ore (minus 1-1/2 inches) in a ball mill without balls until the gangue was disintegrated. The material was classified either hydraulically or by screening, and the undersize was discarded. The oversize fraction thus obtained is occasionally high enough in grade to be marketed without further treatment; more often, however, the oversize requires further concentration by gravity or flotation methods. Log-washing also may be employed to disintegrate and reject slime-forming constituents, presence of which would interfere with subsequent concentration.

For ores in which the manganese occurs as a soft, friable coating on hard gangue particles or hard manganese nodules are coated with an easily slimed gangue covering, attrition grinding often effects separation. The ore is ground in a ball mill with a small load of balls, pebbles, or boiler plate punchings, and the sand and slime are separated by screening or hydraulic classification.

Sink-and-Float

The sink-and-float or heavy-medium process is receiving increasing attention in ore dressing. Fundamentally, it consists of the separation of an ore into low and high specific-gravity portions by immersion in a solid-liquid suspension of intermediate specific gravity. As the operation usually takes place in a semiquiescent suspension, the effect of the shape and size of the mineral aggregates is much less marked than in jigging. The separation on a specific-gravity basis is accurate, and by this method mineral aggregates with very small density differences can be separated. The process is particularly applicable to coarse material, and close sizing is not essential.

For test work in the laboratory, an aqueous suspension of minus 325-mesh galena has been used for the sink-and-float medium, and separations have been made in mediums ranging from 2.6 to 3.4 specific gravity. For the sake of convenient handling, laboratory test work was usually conducted on minus 1-1/2-inch plus 1/2-inch and minus 1/2-inch plus 6-mesh fractions. The plus 6-mesh fractions were treated separately with a medium of such specific gravity as would reject a comparatively clean tailing. The sink products sometimes met marketing specification; otherwise, they were crushed and combined with the original untreated minus 6-mesh portion for further concentration by jigging, tabling, or flotation.

Jigging

Jigging in coarse sizes is being superseded to a large extent by the heavy-medium process. This latter method of concentration, where applicable, is more selective, has greater capacity per unit of floor space, and is not affected by such factors as size and shape of the ore fragments being treated. However, jigging still maintains certain definite advantages for specific problems. The jig is very simple to operate, is relatively cheap, and can be installed as small flexible individual units. For the small operation or for use as a gravity-concentration unit as part of a more complex flow sheet it is an ideal machine. The jig can treat much finer material than the heavy-medium process and fills the gap between sizes that can be tabled and those that can be concentrated by sink-and-float. The jig also can handle ores having constituents that tend to disintegrate. Such ore cannot be treated by the heavy-medium process owing to the rapid contamination of the heavy mediums and thus the destruction of its carefully controlled specific gravity and its effectiveness in making mineral separations.

Material as coarse as 1-1/2 to 3 inches has been handled in plant practice, but for small laboratory jigs best results were obtained on ore crushed to minus 1-inch or finer. The material was screen-sized, and each of the plus 20-mesh fractions was jigged. Where practicable, each fraction was separated into a finished concentrate, a finished tailing, and a middling that was crushed and combined with the next finer fraction. The final middling was usually crushed and combined with the original minus 20-mesh material and treated by tabling.

Excellent results can be obtained with a jig on ores in which the gangue and manganese minerals are liberated at coarse sizes; however, a few such ores cannot be effectively beneficiated. This is due to the shape of the particles being treated. These few ores tend to crush to platy or lathlike fragments, which do not respond to concentration under the hindered settling conditions of jig beds. The concentrates from such ores often represent a product made of high-specific-gravity fragments of platy shape and relatively low-specific-gravity fragments of equidimensional shape. In general, jigging of manganese ores does not feature or anticipate the production of a hutch concentrate, as the feed requires close sizing owing to low density differential between products. Thus, for jigging an effort should be made to make the sizing of the ore efficient, otherwise a considerable amount of hutch product would need to be resized and re-treated.

Tabling

Tabling is one of the most effective means of concentrating manganese ores; it was the method most universally applicable to western ores. This is so not because other gravity methods of flotation are inapplicable, but because most of the ores either required grinding to obtain liberation or contained gangue constituents that tended to float with manganese. As in long-established table practice, best results are obtained by using hydraulically sized feed, preferably in as many fractions as possible, each to be treated on a separate table. Every effort should be made to table the ore at as coarse a size as possible

and in the grind to obtain a major portion of the ore in the coarse sizes. Such practice often entails making large middling fractions for regrinding and resizing; however, it minimizes the loss of manganese in slimes and fine sand sizes, which are fractions that cannot be concentrated effectively by the table.

In laboratory tests, the foregoing facts were applied whenever possible. The ore sample was stage-ground to the size at which some of the manganese in the coarsest particles was liberated. It was then hydraulically sized and tabled to produce a finished concentrate, a finished tailing, and a middling from each fraction. The middlings were resized and retabled to scavenge additional manganese before further grinding and re-treatment. Regrinding and resizing of middlings was continued, as necessary, until the middling product had been reduced to a minimum. Slime fractions were not tabled and, depending on their grade, were either combined with the composite final table concentrate for sintering or discarded as a part of the final combined tailing product. For convenience in making the initial table tests on many ores, screen-sized rather than hydraulically sized fractions were made and tabled. However, the final results obtained were, in general, checked against hydraulically sized material. Comparison of results obtained by tabling screen-sized, as against hydraulically sized, ore confirmed often-stated advantages of employing hydraulic sizing.

The principal advantage of tabling over flotation of manganese ores lies in the simplicity of the table operation and its greater flexibility in separating manganese minerals from complex gangue constituents. The separation is based upon the specific gravity of particles treated, not upon the surface condition of the particles or their behavior toward flotation collecting reagents. Thus, gangue particles filmed with thin coats of manganese mineral find their way into the tailing or middling product by tabling, but in flotation would be concentrated with high-grade manganese particles. Similarly, such easily floated minerals as calcite, gypsum, and dolomite are effectively rejected on the table, but not so well by flotation. The most serious disadvantage of tabling is the rapid decrease in capacity and selectivity in treating sizes below 100-mesh and the lack of applicability in concentrating porous manganese particles.

Fatty-Acid Flotation

The collecting property of fatty acids for manganese minerals has long been known and is described abundantly in the literature. The application of flotation to concentration of western oxide manganese ore is somewhat limited, owing to the usually greater simplicity and applicability of tabling. However, a number of ores cannot be effectively concentrated by tabling. Most rhodochrosite ores are in this group; another is that type requiring grinding to fine sizes. Flotation may be useful in treating the fine-sized fractions of hydraulically sized ore rather than employing tabling. It is not to be implied that true slimes can be concentrated by flotation, but only that sands below 100- to 200-mesh often are treated more easily by flotation than tabling. Many oxide manganese ores are very porous even when crushed and ground to table sizes.

These ores cannot be beneficiated effectively by tabling because too much manganese mineral, although liberated, finds its way into the table middling or tailing product. Flotation, which acts on a principle of surface filming, makes no such false segregation, and therefore this type of ore is usually readily concentrated by flotation.

For flotation of manganese minerals in the laboratory, the ore was stage-ground through 48-mesh or finer. The ground material was deslimed only when preliminary testing indicated that slime was likely to interfere with subsequent flotation. When selectivity is poor, hydraulic sizing and separate flotation of each fraction often improve the results. Both pneumatic and mechanical subaerated cells were employed, and all pulps were made up with Salt Lake City tap water at 18° C. or above. The pulp densities employed were generally 20 to 25 percent solids, except for cleaning operations or where the initial grind was to minus 200-mesh. Ores containing interfering slime were conditioned with sodium silicate, which acted as a slime dispersant and silica depressant. An aqueous emulsion of fatty acid (usually 2.5 percent oleic acid stabilized with 0.5 percent Emulsol X-1) was employed as collector and frother; sulfuric acid was used to maintain the pH of pulp at about 6.5 to 6.8 during flotation. When removal of calcite, barite, and fluorite was desired, the pulp was first raised to pH 9.0 to 10.0 by the addition of sodium hydroxide and subsequently lowered to about pH 6.5 for the manganese flotation.

The considerable amount of test work done employing fatty-acid flotation of manganese has resulted in the formation of rules for obtaining optimum results by this method of concentration. Chief among these are the following: Selectivity and collecting properties of fatty acids for manganese minerals are best in a slightly acid circuit. Care must be taken when using sodium silicate or similar silica depressants, as they also depress the manganese minerals when added in even slight excess. Slimes decrease selectivity, consume reagents, and usually make the froths voluminous and hard to handle. When enough sodium silicate is added to disperse the slimes, the manganese minerals are often difficult to float without using large amounts of collector. In general, best results are obtained on deslimed or partly deslimed pulps; in fact, a high concentration of undispersed slime in the flotation cell can virtually prevent flotation. Low pulp densities give best selectivity; however, this same condition leads to high consumption of reagent. Adding the fatty acid as an emulsion and in stages to the flotation cells is more efficient and effective than adding it to the grinding circuit in a single addition. However, even when added as an emulsion, a short period of conditioning before flotation is best. Part of the fatty-acid collector can be added to the grinding circuit, thus taking advantage of the possibility of conditioning here. As the fatty acids, if added in sufficient quantity, will float virtually all the common gangue constituents found in ores, control of the additions of reagent is imperative. It is for this reason that stage addition of the collector (thereby giving a better opportunity for selective filming) is recommended as the best practice. A separate frother very often will reduce the amount of collector required. In this connection, partial saponification of fatty-acid collector by caustic is not recommended, because control of saponification, and therefore frothing, is very poor. Also, modification of the collector to give it frothing properties is not economical, as more collector must be added to obtain the same

result. Often, in this type of flotation, additional frother will result in floating considerable filmed particles, whereas the addition of more frother-collector merely starts the gangue minerals to float. The effect of hardness of water in the pulp is definite but, within limits, it is not marked. The net effect is slightly higher consumption of reagents and possibly slightly poorer selectively. Salt Lake City tap water employed in the laboratory test work is medium hard and ordinarily averages about 150 parts per million $CaCO_3$ hardness. Tests in the laboratory comparing results in tap water as against those in soft water showed little difference if proper flotation conditions were maintained.

Cationic Flotation

The use of cationic flotation reagents to float gangue constituents such as siliceous minerals, gypsum, and barite from manganese oxides is a virtually new field of concentration. The factors governing the applicability of this method of concentration are outlined in subsequent paragraphs.

The types of ore best suited to treatment by cationic reagents are medium- or high-grade ores wherein the gangue to be floated and rejected is a minor part of the ore. Hard, compact ores that can be ground to flotation size without forming large slime or very fine sand fractions are concentrated more easily than softer, porous ores.

Slimes in the pulp definitely preclude effective flotation, as their presence causes voluminous tough, watery froths virtually impossible to handle. If slime is present, it is preferentially floated from the pulp without regard to the chemical composition of the individual particles of slime. Dispersal of the slimes with sodium silicate merely delays their flocculation and flotation by cationic reagents and does not permit flotation of sand particles. Slimes cause high consumption of reagents and the flotation of a product that might as well have been discarded by desliming. It has been found that small additions of certain gums (0.01 to 0.1 pound per ton of ore) will flocculate slime particles into large aggregates easily floated. However, their action is not selective and, if added in too large an amount, they will also flocculate the sand particles. The simplest solution for the slime problem is desliming of the pulp. The deleterious effect of slime limits the use of this method, as many manganese ores are easily slimed, even by agitation in a flotation cell. To minimize this result, pneumatic flotation cells having a minimum of moving parts are to be preferred over mechanically agitated machines. Also, large volumes of finely dispersed air bubbles seem to give optimum flotation and result in lower consumption of reagents, better froth conditions, and more rapid flotation.

The ore generally, but not always, must be classified into sized fractions to obtain best results. Cationic reagents are not completely selective and, if added in sufficient quantity, will float manganese minerals in addition to the gangue constituents. A few compact and hard oxide manganese ores, however, can be beneficiated without preliminary sizing.

Pulp density, hydrogen-ion concentration, and conditioning periods are not important in the use of cationic reagents. Although slightly greater selectivity

is possible at low pulp densities, particularly on the fine sand fractions, the effect is not marked. Cationic reagents float siliceous and other gangue minerals over a wide pH range. Because they are effective between pH 3 and pH 9.5, the natural pH of the pulp is generally satisfactory. Conditioning periods before flotation were not found necessary, because filming, collection, and frothing almost instantaneously follow the addition of cationic reagent.

Consumption of cationic reagents depends on the amount of gangue to be floated, the amount of slime in the pulp, and the porosity of the mineral particles. Low-grade ores, porous ores, and slime all contribute to high consumption of reagents. Some high-grade compact ores can be concentrated effectively with a few tenths pound of reagent per ton of ore, whereas lower-grade and porous ores require as much as 3 pounds of reagent per ton of ore. As cationic reagents are relatively expensive, it is clear that every effort should be made to correlate grinding and flotation studies so as to obtain the optimum combination of liberation, slime loss, and consumption of reagents.

Although addition of the cationic reagent in stages is not essential, better results and lower consumption of reagents are usually obtained by such a practice. One reason for this may be that, as most cationic reagents have frothing properties and act as both frother and collector, too much frothing may result from a single lump addition of reagent and thus inhibit selectivity. It is also pertinent to restate that the concentration of cationic reagent in the flotation pulp at any one time definitely controls the selectivity. This effect is not so marked during the initial moments of flotation, when considerable gangue particles are present in the pulp, but is very marked toward the end of the flotation period. At this stage, even a small excess of reagent will flocculate the entire remaining pulp and destroy all selectivity. In fact, there appears, to be a progressive decrease in selectivity as flotation is continued. Thus, when the reagent is added in small stages, the first few concentrates may contain only a small percentage of manganese, whereas the final concentrates by stage flotation may contain only slightly less manganese than the pulp remaining in the flotation cell. This effect is decreased by close sizing of the fraction being floated, as the finest manganese particles are always the first to be filmed and floated with the gangue minerals.

The use of pulp-conditioning reagents, such as sodium silicate, copper sulfate, caustic, lime, acid, and many others, seem to have little, if any, effect upon the action of cationic reagents, except in some instances to slow the collection and flotation of minerals. Additional frothers are necessary with a few cationic reagents and in most instances may effect slightly lower cationic-reagent consumption. However, the advantage thus gained is usually small and may interfere in the reflotation of middling fractions generally obtained during the latter part of the flotation period.

Sulfide Flotation

Flotation of sulfide minerals from manganese ores is attended by no difficulties. Any of the common collectors and frothers may be used, as none of the common manganese minerals are collected by these reagents.

Magnetic Separation

This method of concentration can be employed in two ways on many manganese ores. By giving manganese concentrates containing iron oxides a reducing roast to make the iron minerals susceptible to attraction by a low-intensity magnetic field, excellent separation of iron from manganese minerals is possible. In fact, this method is the only reliable one for making the iron-manganese separation. However, it is expensive when fine sizes are treated, because of the low capacities of the magnetic separator (either wet or dry) on such material. Also, if dry, it generally is necessary to treat closely sized fractions.

Some manganese ores can easily be concentrated by high-intensity magnetic separators. However, close sizing is necessary for good results and, because minus 150-mesh material cannot be effectively so concentrated, tabling or flotation is usually more effective for over-all results. Because of their physical nature, a few ores are best treated by a combination of tabling and magnetic separation. Such ore is characterized by the presence of lime carbonate and silicate minerals, making flotation difficult, and the presence of an appreciable portion of the oxide manganese minerals as porous aggregates that are not concentratable by tabling. Such ores can be crushed, ground if necessary to obtain liberation, classified into sized fractions, and then first tabled to recover the nonporous portion. The table middling or tailing products from each fraction can then be treated by a magnetic separator for recovery of the porous manganese particles that otherwise would have been lost.

SPECIFIC APPLICATIONS OF LABORATORY PROCEDURES

As it is not feasible to summarize the data obtained from the concentration of 288 lots of ore, the following examples from laboratory practice are given merely to illustrate the methods employed and the average results obtained. For this purpose, details of the laboratory test results obtained on five ores are given. These examples employ, singly or in combination, the various methods of concentration previously discussed as applicable to the beneficiation of manganese ores.

Rhodochrosite Ore from Utah (Log Washing, Fatty-Acid Flotation)

Manganese occurred in this low-grade (15-percent) ore as comparatively large but scattered stringers of rhodochrosite finely intergrown with pyrite, quartz, and unreplaced dolomite. A large sample of minus 1-1/4-inch ore was tumbled in a ball mill without balls until the claylike gangue was disintegrated. It was then screened on 80-mesh and the undersize discarded. The plus 80-mesh fraction was crushed to minue 10-mesh and stage-ground to minus 100-mesh, before being pulped with tap water, to approximately 30 percent solids in a mechanically agitated flotation cell. The sulfides were floated with standard sulfide collectors. A bulk manganese concentrate then was floated, using fatty-acid emulsion, and a rougher tailing was discarded. The rougher manganese concentrate was cleaned and recleaned by flotation for production of a finished concentrate.

Consumption of reagents results of flotation, and analyses of the sinter made from the recleaner concentrate are given in table 2.

TABLE 2. - Flotation of low-grade carbonate ore from Utah

Consumption and distribution of reagents

Flotation stage	Pound per ton of ore				
	Oleic acid emulsion	Sodium silicate	Xanthate Z-3	Frother B-23	H_2SO_4
Sulfide	-	1.0	0.1	0.05	0.9
Manganese rougher	1.0	1.0	-	-	-
Manganese cleaner	.5	-	-	-	-
Manganese recleaner	1.0	1.0	-	0.05	-
	2.5	3.0	0.1	.10	.9

Flotation results

	Weight, percent total ore	Weight, percent flotation feed	Assay, percent			Distribution, percent manganese	Over-all distribution, percent manganese
			Mn	Fe	Insol.		
Pyritic concentrate	2.5	5.1	10.0	25.1	18.8	2.2	1.7
Recleaner concentrate	31.0	64.0	33.8	4.0	8.7	89.4	68.7
Recleaner tailing	3.3	6.8	9.1	1.7	37.2	2.5	1.9
Cleaner tailing	7.1	14.6	7.2	1.9	76.8	4.3	3.3
Rougher tailing	4.6	9.5	4.1	2.1	80.6	1.6	1.2
Calculated flotation heads	48.5	100.0	24.2	4.5	28.0	100.0	76.8
Primary minus 80-mesh reject	51.5	-	6.9	4.3	63.5	-	23.2
Calculated ore	100.0	-	15.3	4.4	46.2	-	100.0

Results of sintering

	Assay, percent						
	Mn	Fe	SiO_2	P	Al_2O_3	Zn	$SiO_2 + Al_2O_3$
Sintered recleaner concentrate	52.0	5.7	7.9	0.159	5.1	-	13.0

Results given in the above table show that 89.4 percent of the manganese contained in the flotation feed was recovered in a recleaner concentrate that, when sintered, met chemical specifications for 48 percent manganese ore. This recovery represents approximately 70 percent of the manganese in the original ore before the claylike gangue is disintegrated and discarded. As more than 50 percent of the gangue can be rejected by simple and inexpensive log-washing, costs of milling this low-grade ore should be small. It will be noted that rhodochrosite ores are normally so amenable to fatty-acid flotation that the usual dictum of floating the minor constituent may often be disregarded.

Manganese Ore from California (Fatty-Acid Flotation)

This oxide manganese ore assayed 23.7 percent manganese. The gangue was chiefly quartz and rhyolite country rock, with calcite as a minor constituent. The manganese was present as psilomelane, which contained considerable chemically combined barium. As the manganese occurred as rather thin films and fine aggregates cementing virtually barren quartz and fragments of country rock, fine grinding was necessary for liberation. However, the quantity of slimes produced was relatively small owing to the hardness of psilomelane; desliming before flotation was unnecessary.

The ore sample was crushed to minus 10-mesh and stage-ground to minus 100-mesh. Ground ore was then pulped, without desliming, to approximately 25 percent solids in a mechanically agitated laboratory flotation cell, and the manganese oxides were floated with stage additions of an aqueous emulsion of oleic acid stabilized with Emulsol X-1. The rougher concentrate was cleaned with small additions of reagent.

Sodium silicate was used in both roughing and cleaning operations as a silica depressant, and the pH was maintained in the range of 6.5 to 7.0 by additions of sulfuric acid. The cleaner concentrate was sintered. The consumption of reagents and the results are given in table 3.

TABLE 3. - Fatty-acid flotation of manganese ore from California

Consumption and distribution of reagents

Flotation stage	Pounds per ton of ore			pH
	Oleic acid, emulsion	Sodium silicate	Sulfuric acid	
Rougher	3.5	6.0	0.9	6.7
Cleaner	1.6	1.5	1.2	6.7
Total reagents	5.1	7.5	2.1	-

Flotation results

Product	Weight, percent	Mn	SiO_2	Distribution, percent	
				Mn	SiO_2
Cleaner concentrate	46.0	41.9	8.6	81.4	12.4
Cleaner tailing	7.4	19.9	37.0	6.2	8.6
Rougher tailing	46.6	6.4	54.2	12.4	79.0
Calculated heads	100.0	23.7	31.9	100.0	100.0

Results of sintering

	Assay, percent						
	Mn	Fe	SiO_2	P	Al_2O_3	Ba	CaO
Sintered manganese cleaner concentrate	49.0	1.1	10.1	0.041	4.0	8.25	3.1

By fatty-acid flotation of manganese a satisfactory separation was obtained between oxide manganese and siliceous gangue. The presence of chemically combined barium in the manganese mineral served to limit the final grade of concentrate. Over 81 percent of the manganese was recovered in a cleaner concentrate that assayed 41.9 percent Mn and 8.6 percent SiO_2. As a result of sintering, the grade was increased to 49 percent Mn and 10.1 percent SiO_2.

High-grade Oxide Manganese Ore from Arizona (Cationic Flotation)

This high-grade ore contained psilomelane associated with virtually barren quartz gangue. Satisfactory liberation was obtained by grinding through 65-mesh. The ore is mineralogically simple and is ideally suited to flotation of silica. Although, after grinding, an appreciable portion of the manganese is contained in a slime fraction, this fraction is high enough in grade to be combined with the manganese product obtained by flotation of silica from the sand product. The results are given in table 4.

TABLE 4. - Silica flotation from deslimed and unsized high-grade oxide manganese ore from Arizona

Product	Weight, percent	Assay, percent		Recovery Mn, percent	Reagent, lb./ton
		Mn	SiO_2		
Silica concentrate.....	14.0	9.8	76.1	3.6	0.5
Manganese tailing.....	67.1	45.3	5.9	78.3	-
Slimes.....	18.9	37.2	16.1	18.1	-
Calculated heads.....	100.0	38.7	17.7	100.0	0.5
Slimes and manganese tailings...	86.0	43.6	8.1	96.4	-

When sintered, the combined slime and manganese product assayed plus 50 percent manganese and met the base price marketing specifications of the Metals Reserve Company. Selectivity obtained during flotation of the sand fraction was excellent. Over 95 percent of the manganese in the sands to flotation was recovered in the unfloated manganese product, whereas 73 percent of the silica was rejected in the silica concentrate.

Oxide Manganese Ore from Montana (Sink-and-float, Jigging, Tabling, Magnetic Separation)

This ore, assaying 24.5 percent manganese, was difficult to concentrate and required rather elaborate treatment because of the mineralogical associations and the physical nature of the ore. The gangue comprised silicate and calcium minerals irregularly associated with manganese oxides. Even at fine sizes the manganese minerals were not completely liberated from the gangue, and the problem became one of separating high and low manganese-content particles. Flotation proved ineffective, owing to the high lime content and the presence of both calcite-manganese and silica-manganese middlings. The manganese occurred as both high-density, relatively high-grade coarse aggregates and as porous fine particles. To obtain a maximum recovery, the ore was first treated by sink-and-float and jigging to recover the coarse manganese aggregates. The reject products from gravity treatment then were crushed, ground, hydraulically sized,

and the plus 100-mesh fractions dried for high-intensity magnetic separation and the minus 100-mesh fractions fed to tables. No tailing products were made by sink-and-float or jigging, and all discard products of these operations eventually were reduced to minus 10-mesh. The results obtained are given in table 5.

TABLE 5. - Gravity and magnetic concentration of Montana oxide manganese ore

Product	Weight, percent	Assay, percent Mn	Recovery, percent Mn
Sink-and-float concentrate	15.3	40.0	25.0
Jig concentrate	8.4	42.7	14.7
Combined magnetic concentrate	14.0	41.0	23.4
Table concentrate	1.1	42.0	1.9
Combined tailing	61.2	14.0	35.0
Calculated heads	100.0	24.5	100.0
Combined gravity and magnetic concentrates	38.8	41.0	65.0

A composite sample of gravity and magnetic concentrates was sintered with coke to give a product that assayed as follows:

Results of sintering

	Assay, percent					
	Mn	Fe	$SiO_2 + Al_2O_3$	P	Zn	S
Sintered combined gravity and magnetic concentrates	48.0	3.0	15.9	0.04	0.7	-

Using the above method of treatment to remove the mineral as soon as liberated, a 65-percent recovery of manganese was obtained in a product that, when sintered, met basic specifications for 48 percent manganese ore with a slight silica plus alumina penalty. Even higher recovery is possible if a lower-grade product is economically desirable.

Manganese Ore from Nevada (Tabling)

The main gangue constituents of the ore were two distinct complex iron silicates. Quartz and calcite occurred in minor amounts. Pyrolusite and psilomelane are the principal manganese minerals, although some braunite also is present. The compact, greenish, iron silicate contained manganese oxides that could be liberated at fairly coarse sizes, whereas the soft, brown, iron silicate was intimately impregnated with manganese minerals. As most of the manganese occurred in medium-size aggregates, the ore was crushed and stage-ground to minus 28-mesh and classified into sized fractions. The fractions were tabled separately to produce concentrates, middlings, and tailings. Each middling was reground, classified, and re-treated with the next finest fractions. The slime fraction was not treated. Corresponding products were combined, and the results are given in table 6.

TABLE 6. - Tabling oxide manganese ore from Nevada

Product	Weight, percent	Assay, percent			Recovery, percent
		Mn	Fe	SiO_2	
Combined manganese concentrates.....	26.1	48.4	2.4	4.4	46.4
Middling.....	15.6	38.3	4.7	10.6	22.0
Tailing.....	25.5	10.5	10.2	42.4	9.8
Slime.....	32.8	18.1	10.1	29.1	21.8
Calculated heads.....	100.0	27.2	7.3	23.2	100.0
Combined concentrates and middling.....	41.7	44.6	3.3	6.7	68.4

After sintering, the combined concentrate and middling product assayed plus 50 percent manganese and 4.1 percent iron and otherwise met the base-price marketing specification of the Metals Reserve Company.

The principal loss of manganese (21.8 percent) was in the slimes. However, this fraction contained a large percentage of the total iron and silica and was considerably lower in manganese content than the original ore. On the sand portion of the ground ore, excellent separation was obtained, as 87.4 percent of the manganese in this fraction was recovered as a high-grade concentrate. The middling product, although finally ground to minus 150-mesh, contained many locked particles of manganese oxide and iron silicate; however, the high grade of the coarse sand concentrates permitted combining the final lower-grade middling to make a composite of acceptable grade for sintering.

GENERAL DISCUSSION AND SUMMARY

Western manganese ores vary greatly in mineralogical composition and physical properties. The present known deposits are predominant oxide ores. However, except in a few instances, such as in the Butte and Philipsburg districts, only surface deposits have been explored, and it is possible that important deep-seated primary rhodochrosite deposits may be found. Rhodonite ores and oxide deposits apparently derived from the oxidation of primary silicate ores are fairly common.

Virtually all oxide manganese ores can be beneficiated to some extent, if a sufficiently complex treatment method is employed to take advantage of all the properties distinguishing the manganese minerals from gangue constituents. The recovery of manganese in high-grade products on many ores is low. This type of ore is not considered amenable to ore-dressing methods. The grade, physical nature, and mineralogy of manganese ores are the factors that determine the amenability of the ores to specific methods of concentration. These factors afford a means of roughly classifying manganese ores.

High-grade oxide ores (plus 30 percent manganese) are readily concentrated, except when iron oxides are the principal gangue constituent, or when siliceous gangue occurs so finely disseminated in the manganese mineral as to preclude its liberation within economic limits of grinding. High or moderate recoveries (65 to 90 percent) are unusual for low-grade ores, since as much as 25 percent of the manganese is generally lost as untreatable slime. Exceptions to this

rule are ores that are characterized by the occurrence of high-grade but scattered nodules of oxide manganese in a clay or loosely consolidated barren gangue. Bog and wad manganese ores cannot be concentrated, owing to their physical nature.

As a rule, rhodochrosite ores are readily concentrated. This may be attributed to the chemical and physical nature of the manganese mineral, which makes possible effective separations of manganese and gangue constituents by flotation, even though fine grinding may have to be employed. Ores containing considerable calcium, magnesium, or barium carbonate minerals are somewhat more difficult to treat than strictly siliceous ores, but proper flotation conditions for effective separation usually can be obtained. Manganocalcite, manganodolomite, and manganosiderite ores cannot be concentrated to high-grade manganese products.

Except for braunite ores, which are uncommon, silicate manganese ores cannot be beneficiated effectively. Rhodonite is similar to the usual siliceous gangue minerals, and none of the common concentration methods are effective in making a separation.

Oxide manganese ores classed as complex either because of the variety of manganese or gangue minerals occurring in the ore are usually concentratable if the manganese minerals can be liberated without the formation of a large slime fraction. However, lower recovery than on simple ores is general, and a combination of treatment methods may have to be employed.

The properties that distinguish manganese from gangue minerals make possible separation of these minerals to some extent by virtually every ore-dressing method. Some ores are easily concentrated by simple washing and classification, others by gravity methods, flotation of manganese or gangue minerals, magnetic separation, or combinations of these methods. Generally, the simpler the treatment method, the better the results. Ores from which the oxide manganese minerals can be liberated at coarse sizes can be concentrated by the sink-and-float process or jigging. Those requiring finer grinding are amenable to treatment by tabling. The factors that limit the applicability of gravity methods of concentration are principally the difficulty of obtaining liberation without forming a large untreatable slime fraction and the porous or platy nature of some ores, which make for unsatisfactory gravity-concentration conditions.

Flotation methods cannot be applied as extensively as gravity methods, owing largely to the simplicity of tabling. However, when fine grinding is necessary, flotation usually gives better results than tabling. Flotation also can be employed advantageously on porous ores, which are difficult to beneficiate by gravity methods. High-grade manganese ores often are beneficiated best by floating the small amount of gangue with cationic reagents. On rhodochrosite ores, flotation with fatty acids is preferred over gravity methods, as fine grinding is usually necessary and flotation-inhibiting manganese slimes are not commonly produced in grinding rhodochrosite ores. Careful control of the flotation conditions, the addition of fatty acid and depressing

reagents, pulp conditioning, and pH control are important to obtain efficient flotation of oxide manganese minerals. The flotation of gangue constituents with cationic reagents usually requires classification of the ore into sized fractions and careful desliming of the flotation pulp. Neither fatty-acid nor cationic collectors are wholly selective and if added in excess of requirements will readily float gangue and manganese minerals indiscriminately.

Magnetic-separation methods will make a manganese oxide-gangue separation on most ores, but generally not so efficiently as either gravity or flotation methods. Coupled with a reducing roast to make the iron oxides more susceptible to magnetic attraction, the method is the only feasible means of making an iron oxide-manganese oxide separation. High-intensity magnetic separation is also suitable as an adjunct to tabling to scavenge liberated porous manganese particles from table middlings and tailings. The conditions limiting employment of this method are the necessity for close sizing and the poor results usually obtained in treating finely sized material.

Five specific examples of the ore-dressing procedures employed in the laboratory and the results obtained are given. These tests embody each of the concentration methods applicable to manganese ores and illustrate a few of the more common problems encountered in beneficiating various types of manganese ores.

Of the 288 lots of ore tested, 104 were found amenable to production of high-grade manganese products and 137 could be beneficiated to meet low-grade ore specifications either for direct emergency use or for subsequent pyrometallurgical or hydrometallurgical processing. Only 47 ores, owing to their low grade and chemical or physical nature, proved unconcentratable by ore-dressing methods.

APPENDIX

Summary of Manganese Ore Samples and Test Results

Key 1. - Deposit classification

1. Manganese oxide
2. Manganese carbonate
3. Manganese silicate
4. Mangano-calcite
5. Iron-manganese oxide
6. Manganese oxide-carbonate
7. Manganese oxide-silicate
8. Manganese carbonate-silicate
9. Manganese oxide-carbonate-silicate

Key 2. - Ore-dressing treatment

1. Crushing, grinding, and sizing.
2a. Log washing and attrition grinding.
2b. Sink-and-float.
2c. Jigging.
2d. Table concentration.
3a. Fatty acid flotation.
3b. Fuel oil, fatty acid flotation.
3c. Cationic flotation.
4a. Low intensity magnetic separation for iron removal.
4b. High intensity magnetic separation for manganese concentration.
5a. Sintering or nodulizing.
5b. Roasting for removal of zinc, lead, copper, and silver.
5c. Reduction roast to render iron magnetic.

State and county	Property	Nearest town	Class of ore 1/	Grade Mn, percent	Recovery Mn, percent: At 35-40 Mn	At 44 Mn	At 48 Mn	Treatment: Size started	Method 2/
ARIZONA:									
Cochise	Oregon mine	Tombstone	1	31.6	-	-	85.6	14-mesh	1, 2a, 2d, 5b, 5a.
Do.	do.	do.	1	43.4	-	-	100.0	-	5a.
Do.	Contact mine	do.	1	14.6	-	-	24.9	48-mesh	1, 2d, 5c, 4a, 5a.
Do.	Comet mine	do.	1	10.1	-	-	-	-	Not amenable.
Coconino	Valazza	Long Valley	1	40.0	-	-	-	-	See other samples of Valazza ore.
Do.	do.	do.	1	38.3	-	-	96.4	65-mesh	1, 2a, 3c, 5a.
Do.	do.	do.	1	36.9	-	-	92.4	6-mesh	1, 2c, 2a, 2d, 5a.
					-	-	92.2	150-mesh	1, 2a, 3c, 5a.
Do.	do.	do.	1	29.2	95.5	83.9	70.3	48-mesh	1, 2a, 2d, 5a.
Do.	do.	do.	1	8.4	-	-	49.7	6-mesh	1, 2c, 2a, 2d, 5a.
Do.	Conner-Hough	do.	1	40.4	-	100.0	-	-	5a.
					-	90.0	-	1-inch	1.
					-	-	97.0	1-inch	1, 2a, 5a.
Do.	Shroup	do.	1	43.3	-	-	99.0	6-mesh	1, 2c, 2a, 2d, 5a.
					-	-	98.2	150-mesh	1, 2a, 3c, 5a.
Do.	do.	do.	1	5.5	63.7	59.6	-	6-mesh	1, 2c, 2a, 2d, 5a.
							48.9	48-mesh	1, 2a, 2d, 5a.
Gila	Davis Property	Coolidge Dam	1	9.2					Not amenable.
Do.	Orsen Branch	Winkelman	1	23.4					
Do.	do.	do.	1	25.8	-	-	76.9	3-mesh	1, 2a, 2c, 2d, 5a, 5c, 4a. (Weighted composite used for test work)
Do.	do.	do.	1	26.4					
Do.	Benningfield	do.	1	26.0	-	-	59.0	20-mesh	1, 2a, 2d, 5a.
					-	78.4	-	3-mesh	1, 2c, 2a, 2d, 5a.
Do.	do.	do.	1	33.6	-	-	84.0	3-mesh	1, 2c, 2a, 2d, 5a.
Do.	do.	do.	1	0.2				No test work.	

1/ See key 1 at beginning of table.
2/ See key 2 at beginning of table.

State and county	Property	Nearest town	Class of ore[1]	Grade Mn, percent	Recovery Mn, percent: At 35-40 Mn	At 44 Mn	At 48 Mn	Treatment: Size started	Method[2]
ARIZONA (Cont'd.):									
Gila.....	Swingle	Winkelman	1	19.9					Not amenable.
Do.	North Star Group	do.	1	8.4	-	-	56.3	48-mesh	1, 2a, 2d, 5a.
Do.	do.	do.	1	32.3	-	-	87.0	20-mesh	1, 2a, 2d, 3a, 5a.
Do.	Geronimo Group	do.	1	29.2	-	-	87.3	6-mesh	1, 2c, 2a, 2d, 5a.
Do.	Gray Claims	Globe	1	33.0	97.3	-	-	1-inch	2b, 5a.
					-	87.4	82.4	1-inch	2b, 1, 2d, 5a.
Do.	do.	do.	1	44.4	-	-	100.0	-	5a. (Meets low-grade A specifications without 5a.)
Greenlee.....	Pyrolusite Group	Clifton	1	17.7					Test results similar to following ore.
Do.	do.	do.	1	14.5	-	-	64.1	65-mesh	1, 3a, 2a.
Maricopa.....	Black Queen Claim	Aguila	1	27.6	92.1	88.5	71.8	28-mesh	1, 2a, 2d, 5a.
Do.	Black Nugget Group	do.	1	31.0	-	-	70.7	48-mesh	1, 2a, 2d, 5a.
Do.	Sambo Aguila Claim	do.	1	37.4	-	-	90.3	48-mesh	1, 2a, 2d, 3a, 5a.
Do.	Black Vulture	-	1	21.8	76.2	-	-	28-mesh	1, 4b, 5a.
Mohave.....	Artillery Peak	Yuma	1	11.0	68.7	51.7	26.4	200-mesh	1, 2a, 3a, 5a.
Do.	do.	do.	1	13.5	61.2	49.1	31.5	200-mesh	1, 2a, 3a, 5a.
Do.	do.	do.	1	15.0	74.8	-	-	100-mesh	1, 3b, 5a.
Do.	do.	do.	1	14.8	74.8	-	-	200-mesh	1, 2a, 3b, 3a, 5a.
Do.	Artillery Peak (open pit)	do.	1	6.3					Not amenable.
Do.	Artillery Peak (Priceless group)	do.	1	1.5					Do.
Do.	Artillery Peak (Manganese Ore Co., open pit)	do.	1	6.2					Do.
Do.	Artillery Peak (Manganese Ore Co., Priceless group)	do.	1	1.4					Do.

State and county	Property	Nearest town	Class of ore[1]	Grade Mn, percent	Recovery Mn, percent: At 35-40 Mn	At 44 Mn	At 48 Mn	Treatment: Size started	Method[2]
ARIZONA (Cont'd.):									
Mohave.....	Chapin Ore	Yuma	1	6.2					Not amenable.
Do.	Young	Peach Springs	1	28.1	-	-	70.5	20-mesh	1, 2a, 2d, 5a.
Do.	J. H. Jones	Powell	1	24.5	64.7	-	33.3	1-inch	2a, 1, 2d, 5a.
Do.	R. H. Thompson	Parker	1	33.7	-	-	87.7	48-mesh	1, 2a, 2d, 3a, 5a.
Do.	do.	do.	1	2.9					Not amenable.
Do.	Adams-Woody	Peach Springs	1	29.7					No test work.
					63.2	-	-	3-mesh	1, 2c, 2d, 5a.
Do.	do.	do.	1	15.1	-	-	56.9	48-mesh	1, 2a, 2d, 5a.
Do.	Black Warrior	-	1	23.2	-	78.5	-	65-mesh	1, 3a, 5a.
Do.	do.	-	1	25.0	-	88.0	-	65-mesh	1, 3a, 5a.
Do.	do.	-	1	30.9	-	81.0	-	20-mesh	1, 4b, 3a, 5a.
Do.	do.	-	1	33.2	-	96.8	-	20-mesh	1, 4b, 5a.
Pima.....	Baboquivari (high-grade)	Tucson	1	25.6	-	-	76.2	65-mesh	1, 2a, 2d, 3a, 5c, 4a. (Would require 5a for size)
Do.	Baboquivari (low-grade)	do.	1	2.5	-	-	12.9	65-mesh	1, 3a, 2d, 5c, 4a. (specifications)
					43.1	33.0	-	65-mesh	1, 2a, 2d, 5a.
Do.	Coyote (high-grade)	do.	1	21.3	53.3	-	-	200-mesh	1, 3a, 5a.
					-	47.4	-	35-mesh	1, 2a, 2d, 5a.
Do.	Coyote (low-grade)	do.	1	14.2	58.5	-	-	100-mesh	1, 3a, 5a.
Pinal.....	Pomeroy	Superior	1	21.0	62.9	-	-	3-mesh	1, 2a, 2c, 2d, 5b, 5a.
Santa Cruz.....	San Fernando group	Patagonia	1	23.0	-	-	58.8	65-mesh	1, 2a, 3a, 5a.
Do.	do.	do.		31.4(HCL) 32.7(HF)					No test work. Do.
Do.	Salvador claim	do.	1	24.6					Do.
Do.	do.	do.	1	16.3	-	-	42.5	1-inch	1, 2b, 2d, 5b, 5a.
Do.	do.	do.	1	23.0	-	-	55.3	65-mesh	1, 2a, 3a, 2d, 5b, 5a.

State and county	Property	Nearest town	Class of ore[1]	Grade Mn, percent	Recovery Mn, percent: At 35-40 Mn	At 44 Mn	At 48 Mn	Treatment: Size started	Method[2]
ARIZONA (Cont'd.):									
Yavapai.....	Burmeister mine	Mayer	1	32.3	-	-	91.0	65-mesh	1, 3a, 5a.
					100.0	-	-	-	5a.
Do.	do.	do.	1	32.8	-	-	95.2	4-mesh	1, 2c, 2a, 2d, 5a.
Do.	do.	do.	1	7.5	49.2	-	-	20-mesh	1, 2d, 3a, 5a.
Do.	do.	do.	1	12.9	-	-	80.4	4-mesh	1, 2c, 2a, 2d, 5a.
Yuma.....	S. J. Curtis	Bouse	5	19.2					Not amenable.
Do.	Sheeptanks mine	Vicksburg	1	5.4					Do.
Do.	do.	do.	1	2.8					Do.
Do.	do.	do.	1	6.3					Do.
Do.	do.	do.	1	5.9					Do.
Do.	Doyle-Smith	-	1	16.1	-	56.0	48.0	48-mesh	1, 2a, 2d, 5a.
					74.4	-	-	48-mesh	1, 2a, 2d, 5a.
Do.	Spring mine	-	1	11.7	86.6	-	-	1-inch	2a, 1, 2d, 5a.
Do.	do.	-	1	20.6	-	83.1	-	48-mesh	1, 2a, 2d, 5a.
-	Orchard	Parker Dam	1	10.2	46.3	-	-	100-mesh	1, 3a, 5a.
CALIFORNIA:									
Alameda.....	Murphy Mine	Livermore	1	42.5	-	-	85.5	48-mesh	1, 2a, 3c, 5a.
Imperial.....	Pacific Coast Mn Corp.	Midway Wells	1	39.3	-	-	92.7	3-mesh	1, 2c, 2d, 5a.
Do.	do.	do.	1	35.1	-	-	93.0	20-mesh	1, 2d, 5a.
Do.	Turtle Group	do.	1	28.8	-	-	87.6	3-mesh	1, 2c, 2d, 5a.
Inyo.....	Wingate Wash	Shoshone	1	39.0	-	-	-	-	No test work.
Do.	do.	do.	1	43.9	-	-	-	-	do.
Do.	do.	do.	1	15.4	-	-	66.7	20-mesh	1, 2d, 5a.
Do.	do.	do.	1	8.8	-	-	42.0	65-mesh	1, 2a, 2d, 5a.
Do.	do.	do.	1	6.6	-	-	-	-	No test work.
Do.	do.	do.	1	12.9	-	-	11.1	100-mesh	1, 2a, 2d, 5a.
Mendocino.....	Thomas Mine	Ukiah	9	19.4	55.0	-	35.6	200-mesh	1, 3a, 5a.
San Bernardino..	Proctor	Cronese Station	1	11.4	23.6	-	-	65-mesh	1, 2d, 3a, 5a.

State and county	Property	Nearest town	Class of ore[1]	Grade Mn, percent	Recovery Mn, percent: At 35-40 Mn	At 44 Mn	At 48 Mn	Treatment: Size started	Method[2]
CALIFORNIA (Cont'd.):									
San Bernardino..	McWhinney	Owl Hole Springs	1	42.4	-	-	100.0	-	5a.
					-	-	96.0	65-mesh	1, 3a, 5a.
Do.	Black Magic	Baker	1	35.0	88.0	-	48.3	48-mesh	1, 2a, 2d, 4b, 5a.
Do.	do.	do.	1	3.3	-	-	-	-	No test work.
Do.	do.	do.	1	26.5	-	-	-	-	Do.
Do.	do.	do.	1	4.9	-	-	-	-	Do.
Do.	do.	do.	1	32.2	80.6	-	50.5	100-mesh	1, 2a, 2d, 4b, 5a.
Do.	National Resources, Inc.	do.	1	34.0	-	-	91.3	48-mesh	1, 2d, 5a.
Do.	Lee Kim	Ludlow	1	16.1	56.0	24.9	4.5	100-mesh	1, 2a, 3a, 5a.
Do.	Big Reef Claims	Barstow	1	16.3					No testing.
Do.	do.	do.	1	24.3	-	-	81.2	28-mesh	1, 2c, 2d, 3a, 5a.
Do.	do.	do.	1	21.5					No testing.
Do.	do.	do.	1	31.9					Do.
Do.	do.(Comp.)	do.	1	23.2	-	-	88.3	100-mesh	1, 2c, 3a, 5a.
Do.	Huntington	Baker	1	10.6	-	-	63.0	1-inch	1, 2b, 2c, 2a, 2d, 5b, 5a.
					-	64.2	-	65-mesh	1, 2a, 3a, 5b, 5a.
Do.	do.	do.	1	11.2	-	-	52.5	1-inch	1, 2b, 2c, 2a, 2d, 5b, 5a.
Do.	Trans-Oceanic	Hector	1	12.1	82.1	-	77.7	65-mesh	1, 2a, 3a, 5a.
San Joaquin.....	Ladd Mine	Tracy	1	16.3	48.5	-	39.4	100-mesh	1, 2a, 2d, 3a, 5a.
Do.	do.	do.	1	28.5	-	-	-	-	No test work.
Do.	do.	do.	1	14.3	-	-	-	-	Do.
Do.	do.	do.	1	27.5	60.4	-	30.6	65-mesh	1, 2a, 2d, 5a.
Do.	do.	do.	1	15.3	-	-	10.4	200-mesh	1, 2a, 3c, 2d, 5a.
					41.2	-	-	200-mesh	1, 2a, 2d, 5a.
Do.	Buckeye Mine	do.	6	44.6	-	-	100.0	-	5a.
Do.	do.	do.	2	32.8	-	-	95.5	100-mesh	1, 2a, 3c, 5a.

State and county	Property	Nearest town	Class of ore[1]	Grade Mn, percent	Recovery Mn, percent: At 35-40 Mn	At 44 Mn	At 48 Mn	Treatment: Size started	Method[2]
CALIFORNIA (Cont'd.):									
San Joaquin	Buckeye Mine	Tracy	2	39.5	-	-	98.8	100-mesh	1, 2a, 3c, 5a.
Do.	do.	do.	2	36.9	-	-	85.2	100-mesh	1, 2a, 3c, 5a.
Siskiyou	Maryland Mining Co.	Sawyers	1	13.3 HCL					
				15.0 HF	68.6	-	-	100-mesh	1, 3c, 5a.
Do.	Fort Jones (Shattuck 50)	Yreka	1	25.1					Not treated separately.
Do.	(Shattuck 51)	do.	1	28.45	-	-	54.4	1/2-inch	1, 2c, 2d.
					-	-	85.3	1/2-inch	1, 2c, 2d, 4b, 5a.
Do.	(Composite)	do.	1	27.6	-	59.9	-	1/2-inch	1, 2c, 2d.
					-	-	84.8	1/2-inch	1, 2c, 2d, 4b, 5a.
Do.	(Barquist)	do.	1	24.8	54.7	-	-	1/2-inch	1, 2c, 2d.
COLORADO:									
Chaffee	Spartan	Salida	4	10.1					Not amenable.
Do.	Pershing	do.	1	25.8	-	-	83.2	3-mesh	1, 2c, 2d, 5a.
Do.	do.	do.	1	22.4	89.5	-	79.7	3-mesh	1, 2c, 2d, 5a.
Custer	Victory A & B	Westcliff	1	23.0	68.6	-	-	2-inch	2a, 1, 2d, 5a.
Douglas	Denver Basin (Leonard)	Franktown	1	11.3					Not treated separately.
Denver	(Buckley Field No. 1)	Denver	1	12.4					Do.
Do.	(Buckley Field No. 2)	do.	1	10.6					Do.
Do.	Composite	do.	1	11.4	-	-	80.7	48-mesh	1, 3a, 2d, 5a.
Lake	Leadville	Leadville	1	21.6					No test work.
Park	South Park (Mine)	-	1	6.0	-	-	68.9	1/2-inch	2a, 1, 2c.
Do.	South Park (Reject)	-	1	3.45	-	-	58.3	1/2-inch	2a, 1, 2c, 5a.
IDAHO:									
Bannock	Lava Manganese	Lava Hot Springs	1	38.7	100.0	-	-		Without treatment.
					-	63.0	-	20-mesh	1, 2d, 5a.
					-	-	44.7	1-inch	1, 2b.
Do.	McGregor	Cleveland	1	20.3	-	-	50.6	3-mesh	1, 2c, 2a, 2d, 5a.

State and county	Property	Nearest town	Class of ore[1]	Grade Mn, percent	Recovery Mn, percent: At 35-40 Mn	At 44 Mn	At 48 Mn	Treatment: Size started	Method[2]
IDAHO (Cont'd.):									
Bannock.....	Idaho Manganese Mining Co.	Cleveland	1	38.7	-	76.9	-	1-inch	1, 2a.
					-	-	88.1	1-inch	1, 2a, 5a.
Do.....	Hot Spot Claim	do.	1	28.3	-	-	67.5	6-mesh	1, 2a, 2c, 2d, 5a.
					79.4	-	-	1-inch	1, 2a.
MONTANA:									
Granite.....	Little Dandy	Philipsburg	1	35.0	-	-	68.8	48-mesh	1, 2a, 2d, 5a.
Do.	Philipsburg (oxide)	do.	1	24.5	-	-	65.5	28-mesh	1, 2d, 4b, 5b, 5a.
Do.	Philipsburg (carbonate)	do.	2	26.2	-	81.5	70.6	100-mesh	1, 3d, 3a, 5a.
					-	-	88.7	1 1/2 in.	2b, 1, 3d, 3a, 5a.
Do.	Philipsburg (oxide)	do.	1	23.2	57.7	-	-	3-mesh	1, 2c, 2d, 5a.
Do.	Philipsburg (mixed tailings)	do.	1	16.8	-	50.3	-	28-mesh	1, 2d, 3a, 5a.
Do.	Philipsburg (magnetic tailings)	do.	1	16.3	-	52.1	-	35-mesh	1, 2d, 5a.
Do.	Philipsburg (slime dump)	do.	1	27.4	76.8	-	46.9	14-mesh	1, 2d, 5a.
Do.	Philipsburg (Marie)	do.	1	32.1	-	89.1	60.9	35-mesh	1, 2a, 2d, 5a.
Jefferson.....	Horsefly	Wickes	5	34.9	100.0	-	-	150-mesh	5c. Would require 5a to meet size specifications.
Do.	do.	do.	5	34.7	100.0	-	-	48-mesh	Do.
Park.....	Irma Mines	Cooke City	2	15.6					Not amenable.
Silver Bow.....	Minnie Jane (stock pile)	Butte	2	24.5	-	-	83.2	100-mesh	1, 3d, 3a, 5a.
Do.	Minnie Jane (mine)	do.	2	16.6	-	-	82.9	28-mesh	1, 2d, 2a, 3d, 3a, 5a.
					-	-	71.3	200-mesh	1, 3d, 3a, 5a.
Do.	Minnie Jane (low-grade)	do.	2	10.8	-	-	68.6	28-mesh	1, 2d, 2a, 3d, 3a, 5a.
Do.	Tzarina	do.	2	6.1	69.5	-	-	100-mesh	1, 3d, 3a, 5a.
Do.	do.	do.	2	10.7	-	75.3	50.2	150-mesh	1, 3d, 3a, 5a.

State and county	Property	Nearest town	Class of ore[1]	Grade Mn, percent	Recovery Mn, percent: At 35-40 Mn	At 44 Mn	At 48 Mn	Treatment: Size started	Method[2]
NEVADA:									
Clark.....	Three Kids	Las Vegas	1	32.5	-	-	66.2	48-mesh	1, 2a, 3c, 5a.
Do.	do.	do.	1	25.5	-	-	61.3	48-mesh	1, 2a, 3c, 5a.
Do.	do.	do.	1	37.1					No test work.
Do.	do.	do.	1	26.5					Do.
Do.	Three Kids Annex (Bradt)	do.	1	29.3	-	-	66.0	48-mesh	1, 2a, 3c, 5a.
Do.	Three Kids Annex (stock pile)	do.	1	20.5					No test work.
Do.	Annex	do.	1	29.3	-	-	65.5	48-mesh	1, 2a, 3c, 5a.
Do.	Virgin River Deposit	do.	1	12.7	40.0	-	-	48-mesh	1, 2a, 3c, 5a.
					-	-	12.0	100-mesh	1, 2a, 3c, 5a.
Do.	Virgin River	do.	1	22.7	64.1	-	-	48-mesh	1, 2a, 2d, 3c, 5a.
Do.	Boulder City	do.	1	3.8					Not amenable.
Do.	do.	do.	1	2.2					Do.
Do.	Pan American (Three Kids)	do.	1	10.1					Test work discontinued.
Do.	Three Kids (low-grade)	do.	1	10.2					Not amenable.
Eureka.....	Gibelleni (Walker)	Eureka	1	33.7	-	54.4	23.4	20-mesh	1, 2a, 2d, 5a.
Elko.....	Berning	Carlin	1	15.5	84.8	-	78.0	65-mesh	1, 2a, 2d, 3a, 5a.
Do.	Darkey	Shafter	1	7.7					No test work.
Do.	Reed-Parker Prospect	Tuscarora	1	16.6	-	-	17.7	100-mesh	1, 3a, 2d, 5a. High SiO_2.
Humboldt.....	Victory Lode	Winnemucca	1	3.4					No test work.
Do.	do.	do.	1	7.4					Do.
Do.	do.	do.	1	1.5					Do.
Do.	do.	do.	1	0.5					Do.
Do.	do.	do.	1	8.4	-	37.5	-	48-mesh	1, 2a, 2d, 5a.
Do.	do.	do.	1	2.5					No test work.
Do.	do.	do.	1	1.9					Do.
Do.	do.	do.	1	1.7					Do.

State and county	Property	Nearest town	Class of ore1/	Grade Mn, percent	Recovery Mn, percent: At 35-40 Mn	At 44 Mn	At 48 Mn	Treatment: Size started	Method2/
NEVADA (Cont'd.):									
Humboldt	Tom Major	Golconda	1	23.5					Not amenable.
Do.	Pink Lady claims	Winnemucca	1	7.1					No test work.
Do.	do.	do.	3	9.8 HCL 14.8 HF					Not amenable.
Do.	do.	do.	7	7.1					No test work.
Do.	Black Hawk	Golconda	7	9.8					Do.
Do.	do.	do.	7	10.2					Do.
Do.	do.	do.	7	24.2					Not amenable.
Do.	Black Top Group	do.	9	14.6					Do.
Do.	do.	do.	9	1.9					No test work.
Do.	do.	do.	9	6.4					Do.
Do.	O'Leary	do.	1	19.7	26.7	-	-	48-mesh	1, 2a, 2d, 5a.
Do.	O'Leary (Jasper lense)	do.	1	0.7					No test work.
Do.	O'Leary (shale bed)	do.	1	5.7					Do.
Do.	O'Leary (chert zone)	do.	1	16.5					Do.
Do.	Pollard Canyon (composite)	Winnemucca	1	26.6	70.5	-	56.3	1/2-inch	1, 2c, 2a, 2d, 5a.
Do.	Pollard Canyon (low-grade)	do.	1	25.0	68.3	-	-	3-mesh	1, 2c, 2a, 2d, 5a.
Do.	Pollard Canyon (high-grade)	do.	1	46.8	-	-	100.0	-	5a.
Do.	Western Alloys	-	1	18.5	64.5	-	-	-	1, 2d.
Do.	Western Alloys (jig conct.)	-	1	29.4	86.4	-	-	-	1, 2c, 2d.
Do.	Western Alloys (jig tails)	-	1	11.3	32.6	-	-	28-mesh	1, 2d.
Lander	Battle Mountain (Black Eagle)	Battle Mtn.	1	27.9	-	80.5	46.7	100-mesh	1, 2a, 3c, 5a.
					84.0	-	-	20-mesh	1, 4d, 5a.
Do.	Black Eagle	Battle Mtn.	1	26.0	-	-	80.4	65-mesh	1, 2a, 3a, 5a.

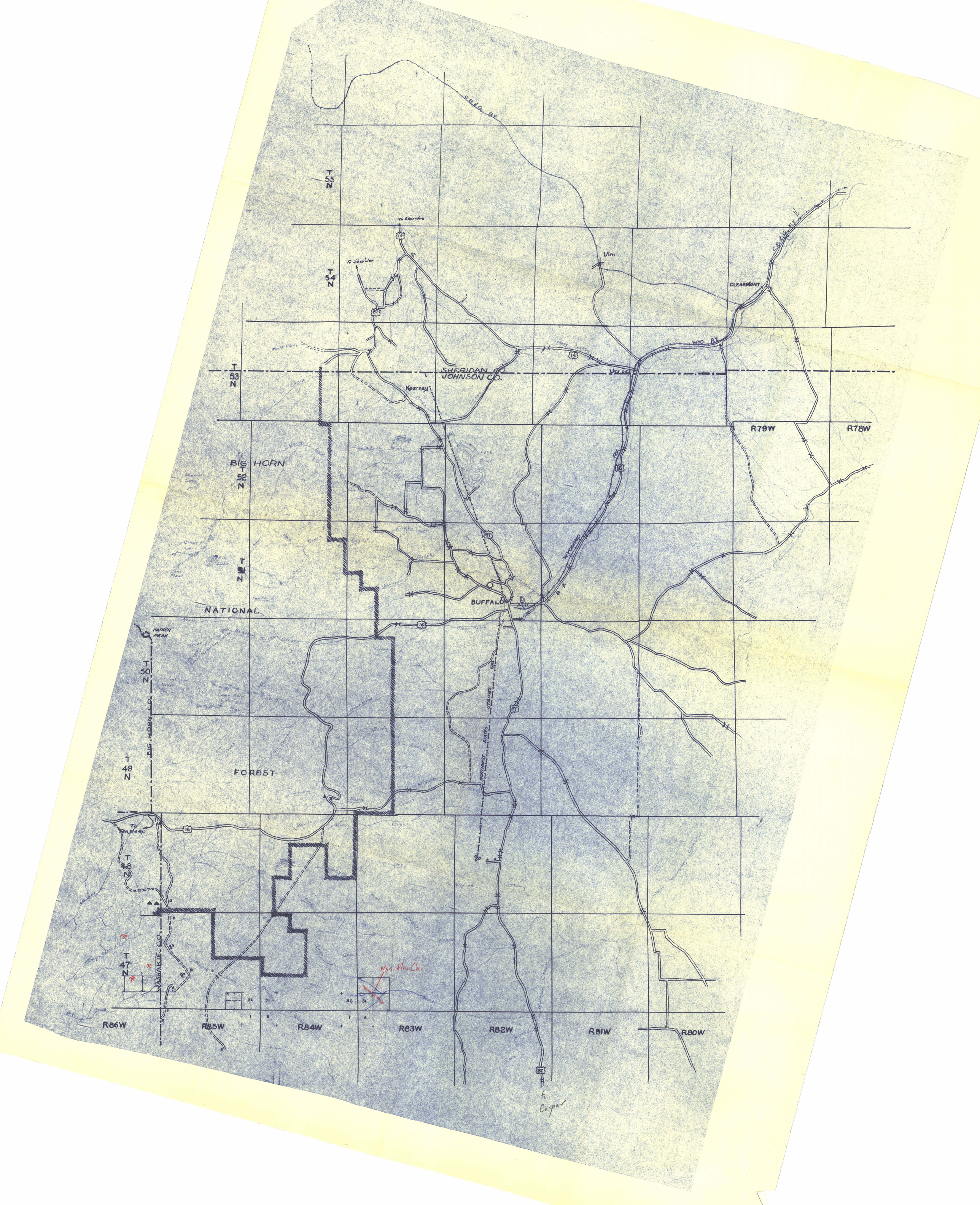
State and county	Property	Nearest town	Class of ore[1]	Grade Mn, percent	Recovery Mn, percent: At 35-40 Mn	At 44 Mn	At 48 Mn	Treatment: Size started	Method[2]
NEVADA (Cont'd.):									
Lander.....	Valmy (Black Rock)	Valmy	1	37.5	-	-	62.0	6-mesh	1, 2c.
Do.	Black Rock	Valmy	1	22.0	-	44.2	29.2	100-mesh	1, 2a, 2d, 3c, 5a.
Do.	do.	do.	1	22.2	-	-	25.8	100-mesh	1, 2a, 2d, 5a.
Do.	Walker	Austin	1	30.6	85.4	-	48.7	20-mesh	1, 2a, 2d, 5a.
Do.	Black Bird	Battle Mtn.	1	12.2	63.7	-	-	48-mesh	1, 2d, 3a, 5a.
Do.	Indian Springs	Austin	1	19.1	59.8	-	-	20-mesh	1, 2a, 2d, 5a.
Lincoln.....	Culverwell mine	Caliente	1	28.5	-	-	70.0	65-mesh	1, 2a, 2d, 5a.
Do.	Ely Valley mine	Pioche	5	17.2					Not amenable.
Do.	do.	do.	5	6.3					Do.
Do.	do.	do.	5	9.8					Do.
Do.	Zero Gap	do.	5	16.7	76.3	-	-	1-inch	1, 2b, 2c, 2d, 5b, 5a.
Do.	Golden Eagle Mines	do.	5	5.7					Not amenable.
Do.	Caselton Mine	do.	2	5.5					Do.
Do.	Prince Mine	do.	5	13.4					Do.
Do.	Black Prince (Wheeler)	do.	1	15.4					Do.
Pershing.....	Black Diablo	Golconda	1	27.4	-	-	60.8	100-mesh	1, 2a, 2d, 3c, 5a.
White Pine.....	Vietti Shaft	Ely	1	35.1	-	-	80.0	28-mesh	1, 2a, 2d, 5a.
Do.	Cariglia Shaft	do.	1	27.4	-	-	75.0	28-mesh	1, 2a, 2d, 5a.
NEW MEXICO:									
Sierra.....	Lake Valley	Deming	1	15.7	69.9	57.8	-	3/8-inch	1, 2c, 2d, 4b, 5a.
Do.	do.	do.	1	28.1	-	83.8	-	3-mesh	1, 2c, 2a, 2d, 5a.
Luna.....	Manganese Valley	do.	1	25.2	74.5	-	-	20-mesh	1, 4b, 5a.
OREGON:									
Jackson.....	Tyrell Mine	Medford	1	4.1					No test work.
Baker.....	Sheep Mountain (Durkee District)	Durkee	1	23.0	73.6	-	-	3/8-inch	1, 2a, 2c, 2d.
					81.0	-	-	do.	1, 2a, 2c, 2d, 5a.
SOUTH AMERICA:									
Chile.....	Atacama	-	1	30.2	100.0	-	-	-	5a.
					-	-	92.3	200-mesh	1, 3a, 5a.

State and county	Property	Nearest town	Class of ore[1]	Grade Mn, percent	Recovery Mn, percent: At 35-40 Mn	At 44 Mn	At 48 Mn	Treatment: Size started	Method[2]
SOUTH DAKOTA:									
Custer.....	Warneke	Custer	1						No test work.
Lawrence.....	Richmond Hill	Lead	1	23.6	73.8	-	-	3-mesh	1, 2c, 2d, 5b, 5a.
UTAH:									
Beaver.....	Susie Q Claim No. 1	Milford	1	8.5					Not amenable.
Do.	Steelville	Frisco	1	28.8	-	-	24.4	100-mesh	1, 2a, 2d, 5a.
					90.9	-	-	1-inch	1, 2a, 5a.
Daggett.....	Harris and Palleson	Manila	1	13.8	-	-	83.0	1-inch	1, 2a, 4b, 5a.
Do.	Daggett-Chief mine	do.	1	8.1	-	75.7	-	1-inch	1, 2c.
					-	-	85.0	1-inch	1, 2c, 2d, 3a, 5a.
Do.	do.	do.	5	7.7					Not amenable.
Emery.....	Stack-Snow	-	1	13.9	85.0	66.0	55.0	65-mesh	1, 2a, 3a, 5a.
Do.	Black Bird Claim No. 1	Green River	1	19.5	17.9	-	-	100-mesh	1, 2a, 2d, 5a.
Do.	Allen Claim	Emery	1	10.5	75.7	66.9	50.0	3-mesh	1, 2a, 2c, 2d, 5a.
Do.	Blackbird Claim	Cleveland	1	13.3	-	-	37.9	48-mesh	1, 2a, 2d, 5a.
Do.	Red Strike Claim	do.	1	21.8 HCL	59.9	-	-	100-mesh	1, 3a, 5a. High in
				22.4 HF	-	-	35.5	48-mesh	1, 2a, 2d, 5a. phosphorous.
Do.	Yellow Jacket	Greenriver	1	10.4	-	52.8	49.1	20-mesh	1, 2a, 2d, 5a.
Do.	Solitude	do.	1	21.7 HCL	-	43.1	-	48-mesh	1, 2a, 2d, 5a.
				22.6 HF	58.2	-	-	65-mesh	1, 3a, 2d, 5a.
Do.	Cedar Mt'n.	Huntington	1	28.1	-	-	71.5	3/8-inch	1, 2c, 5a. (Products
					-	81.0	-	65-mesh	1, 2a, 3a, 5a. high in phosphorous, but can be removed by leaching.)
Do.	Dry Wash	Ferron	1	19.9	58.2	-	-	3/8-inch	1, 2c, 5a.
Do.	Green River	Green River	1	25.6	89.6	-	-	1-inch	1, 2b.
Grand.....	San Rafael	do.	1	39.3	-	-	95.0	65-mesh	1, 2a, 2d, 5a.
Do.	Clyde Claim	Cisco	1	34.6	-	-	95.6	65-mesh	1, 3a, 5a.

State and county	Property	Nearest town	Class of ore[1]	Grade Mn, percent	Recovery Mn, percent: At 35-40 Mn	At 44 Mn	At 48 Mn	Treatment: Size started	Method[2]
UTAH (Cont'd.):									
Iron	Taylor Property	Newcastle	1-4	1.3					No test work.
Juab	Black Jack No. 1 (vein)	Levan	1	9.3	33.7	13.0	-	100-mesh	1, 3a, 2d, 5a.
Do.	Black Jack No. 2 (ledge)	do.	1	6.4	43.9	-	-	100-mesh	1, 3a, 5a.
Do.	Oxen No. 5974	Eureka	1	19.4	-	-	10.6	150-mesh	1, 2d, 5a.
					61.9	-	-	1-inch	2a, 1, 2c, 2d, 5a.
Do.	Fields Property	Eureka	1	22.2	41.3	-	-	100-mesh	1, 3a, 5a.
Do.	Morgan-Cromar	Jericho	1	25.7	79.4	-	65.6	1-inch	2a, 1, 2c, 2d, 5a.
Do.	do.	do.	1	39.3	-	-	100.0	1-inch	5b, 5a.
Do.	do.	do.	1	27.8	81.8	-	-	65-mesh	1, 3a, 2d, 5a.
					-	-	42.1	14-mesh	1, 2a, 2d, 5a.
Do.	do.	do.	1	23.4	81.4	-	48.9	1-inch	2a, 1, 2c, 2d, 5a.
Do.	Empire Mines Co. (Black Jack)	Mammoth	1	19.2					Not amenable.
Do.	Huber-Rydalch	Jericho	1	25.1	72.1	58.9	45.2	35-mesh	1, 2a, 2d, 5a.
Do.	do.	do.	1	31.5	86.9	55.2	44.3	35-mesh	1, 2a, 2d, 5a.
Do.	McFarlane	Nephi	1						No sample.
Kane	Black John Mine (Brown Lease)	Kanab	1	7.1	-	-	61.4	1-inch	1, 2b, 2d. (Would require 5a for size specifications.)
Millard	Drum Mountain (Staats)	Delta	2	33.8	-	-	96.6	10-mesh	1, 2a, 5a. (Four similar samples)
Do.	Drum Mountain (Ward Lease)	do.	1	28.3	-	-	63.1	65-mesh	1, 2a, 2d, 5a.
Do.	Drum Mountain (Composite)	do.	2	22.9	-	-	78.2	10-mesh	2a, 1, 3d, 3a, 5a.

State and county	Property	Nearest town	Class of ore[1]	Grade Mn, percent	Recovery Mn, percent: At 35-40 Mn	At 44 Mn	At 48 Mn	Treatment: Size started	Method[2]
UTAH (Cont'd.):									
Millard.....	Drum Mountain (Staats)	Delta	2	15.7	-	-	70.0	1 1/2-inch	2a, 1, 3d, 3a, 5a.) Treated as a composite assaying
Do.	do.	do.	2	14.3	-	-	70.0	1 1/2-inch	2a, 1, 3d, 3a, 5a.) 14.9% Mn.)
Do.	Drum Mountain (Ward lease)	do.	1	28.3	-	-	63.1	65-mesh	1, 2a, 2d, 5a.
Do.	do.	do.	2	12.4	-	-	55.0	100-mesh	1, 3a, 5a. (Exceptionally high in phosphorous.
Do.	do.	do.	6	34.7	-	-	89.6	3/8-inch	1, 2c, 2a, 2d, 5a.
Do.	Drum Mountain (Black Jack)	do.	1	22.9	80.7	72.9	70.4	28-mesh	1, 2a, 2d, 4b, 5a.
Do.	Black Jack Mines	do.	6	15.5					Not amenable.
Do.	Neilson-Overson	Leamington	5	0.6					No test work.
Piute.....	Blackbird	Marysvale	6	14.0	-	-	77.8	20-mesh	1, 2a, 2d, 5a.
Rich.....	Newcomb Property	Laketown	1	21.3	-	-	86.8	3-mesh	1, 2c, 2d, 5a.
Do.	do.	do.	1	20.7	-	-	85.1	3-mesh	1, 2c, 2d, 5a.
Salt Lake.....	Butterfield Canyon	Salt Lake	1	36.8	-	100.0	-	-	5b, 5a.
Tooele.....	Kramer	Eureka	1	30.9	61.8	-	-	3-mesh	1, 2c.
Do.	Empire Mines	Tintic	1	24.6					No test work.
Do.	Black Rock Nos. 1 & 2	Jericho	1	17.4	-	38.1	32.7	48-mesh	1, 2a, 2d, 5a.
Do.	Wildcat	Fairfield	1	25.7	-	-	91.6	1-inch	1, 2a, 2c, 2d. (Possibly need 5a to meet size specifications.
Do.	Sharp Mines (St. Joer lease)	Vernon	1	29.8	-	-	59.2	28-mesh	1, 2a, 2b, 5a.

State and county	Property	Nearest town	Class of ore1/	Grade Mn, percent	Recovery Mn, percent: At 35-40 Mn	At 44 Mn	At 48 Mn	Treatment: Size started	Method2/
UTAH (Cont'd.):									
Tooele.....	Ophir Hill Mines	Ophir	1	26.6	88.1	-	-	1-inch	2a, 2d.
					-	-	56.8	1-inch	2a, 1, 2d, 5a.
Do.	Black Crow	Vernon	1	32.1	-	77.0	-	10-mesh	1, 4b, 5a.
Utah.....	Tintic Standard	Dividend	1	27.5	88.9	-	-	3-mesh	1, 2a, 5a.
Do.	do.	do.	1	25.3	82.6	53.8	-	3-mesh	1, 2c, 2d, 5a.
					90.5	-	-	100-mesh	1, 3a, 5a.
Do.	do.	do.	5	13.5					Not amenable.
Do.	Aeronaut	Elberta	1	15.4					Do.
Wasatch.....	Haun Property	Wolf Creek	1	5.5	40.1	37.2	-	48-mesh	1, 2d, 5a.
Weber.....	Payday No. 1	Huntsville	1	39.5	-	-	94.0	20-mesh	1, 2a, 2d, 5a.
Utah.....	Rawlings	Elberta	1	15.3 to 27.2					No test work. (Microscopic examination only.)
WASHINGTON:									
Clallam.....	Barnes Creek (Lake View)	Lake Crescent	5	11.4					Not amenable.
Do.	Barnes Creek (Victory)	do.	5	26.0					Do.
Do.	Madeline Deposit	Hecklesville	3	25.7					Do.
WYOMING:									
Albany.....	J.B.C. Mining Co.	Rock River	1	28.7	93.6	-	-	3-mesh	1, 2b, 2a, 2d, 5a.
Crook.....	Caulkins-McGuckin	Sundance	5	31.6	85.2	-	-	20-mesh	2a, 2d, 5a.
Washakie.....	Gheen Nos. 1 & 2	Tensleep	1	13.8	30.7	-	-	48-mesh	1, 2a, 2d, 5a.


C.B.&Q. RY.
T 55 N
To Sheridan
14
To Sheridan
T 54 N
87
Ulm
CLEARMONT
C.B.&Q. RY.
WYO. RY.
14
T 53 N
SHERIDAN CO.
JOHNSON CO.
Kearney
R79W
R78W
BIG HORN
T 52 N
16
87
WYOMING
T 51 N
BUFFALO
NATIONAL
16
MATHER PEAK
T 50 N
BIG HORN CO.
UTAH
NORTHWEST
T 49 N
FOREST
To Tensleep
16
T 48 N
WASHAKIE CO.
T 47 N
Wyo. No. Co.
R86W
R85W
R84W
R83W
R82W
R81W
R80W
87
To Casper