RECONNAISSANCE OF IRON RESOURCES IN ARIZONA

By C. M. Harrer

information circular 8236

UNITED STATES DEPARTMENT OF THE INTERIOR Stewart L. Udall, Secretary

BUREAU OF MINES
Marling J. Ankeny, Director

This publication has been cataloged as follows:

Harrer, Clarence M

Reconnaissance of iron resources in Arizona. [Washington] U. S. Dept. of the Interior, Bureau of Mines [1964]

204 p. illus., tables. (U. S. Bureau of Mines. Information circular 8236)

I. Iron—Arizona. I. Title. (Series

TN23.U71 no. 8236 622.06173

U. S. Dept. of the Int. Library

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RECONNAISSANCE OF IRON RESOURCES IN ARIZONA

by

C. M Harrer [1]

ABSTRACT

Reconnaissance investigations were made of 129 iron occurrences in Arizona to determine their extent, attitude, and potential; character samples were analyzed to determine their quality and impurities; and pioneer metallurgical investigations were made on character samples to present their metallurgical problems. Some factors influencing past and potential western iron markets are discussed.

The location, features, qualities, extent, and potential of iron occurrences and some associative resources--limestone and dolomite, coal, petroleum and natural gas, power, and water are discussed.

The most abundant iron minerals are magnetite and hematite. The higher grade deposits are extensive contact-metamorphic or pyrometasomatic replacements of calcareous Paleozoic to Proterozoic rocks associated with intrusives.

Large low-grade deposits of great potential are present as Precambrian taconite, semitaconite-, and jaspilite-like iron formations of magnetite-hematite. Iron occurs also as low-grade concentrations of magnetite in extensive alluvial deposits. Nonferrous metallurgical slags, nearly 100 million tons, are considered a potential source of iron.

Various accessory elements are associated with the iron minerals and these pose metallurgical and economic problems.

INTRODUCTION

This paper, one of a series of Federal Bureau of Mines publications on the mineral resources of the Nation, presents information on the history, location, extent, and general features of Arizona iron resources, with an evaluation of their potential. Included also is general information on the selected

[1]Mining engineer, Bureau of Mines, Mineral Resource Office Area V, Denver, Colo.

Work on manuscript completed July 1963.

associative resources, limestone and dolomite flux; the sources of energy, coal, petroleum, natural gas and power; and water. Published information was used freely in preparing this report and proper credit has been given. All known or suspected occurrences of iron in Arizona were examined.

The investigation was begun in 1960 and was completed in 1963. Outcrops and exploration openings were examined; however, most of the deposits had been abandoned or inoperative for many years, and their underground workings had caved or were otherwise inaccessible. Character samples[2] of the iron minerals were analyzed in Bureau of Mines laboratories at Salt Lake City, Utah.

Pioneer metallurgical investigations of a few of the iron occurrences are described; however, much more research is necessary to develop the information needed for a full appraisal.

Occurrences of iron oxides are found scattered throughout the State; 129 of them have been investigated. The deposits are exposed in mountainous and rugged terrain. Alluvial concentrations occur in flat terrain and valleys.

The common iron minerals are magnetite and hematite. Higher grade deposits, in most cases, are contact metamorphic or pyrometasomatic replacements of calcareous Paleozoic to Proterozoic rocks associated with Tertiary to Precambrian intrusives. Extensive low-grade deposits of great potential are present as Precambrian taconite to semitaconite-like formations of magnetite-hematite. Iron occurs also as extensive concentrations of magnetite in alluvial deposits. Chemical and spectrographic analyses presented in the text indicate a variety of impurities, chiefly silica. However the many others noted in different deposits include varying but generally smaller amounts of lime, magnesia, alumina, phosphorus, sulfur, titania, manganese, copper, lead, zinc, vanadium, cobalt, nickel, zirconium, chromium, and arsenic.

Arizona reserves of 30 to 60 percent iron content were estimated in 1945 as more than 115 million tons. The resource potential, considering additional occurrences and the large low-grade sources of iron described in this report, is much greater.

As late as 1961, natural iron oxides were of little us in the raw materials economy of Arizona; production totaled only a few thousand tons. At that time Arizona had no metallurgical facilities to smelt or convert iron ores to salable products, and the nearest markets for iron were limited to the established metallurgical centers in California, Colorado, Texas, and Utah.

Iron oxides that can be classed as high-quality, direct-shipping ore are limited. The future of raw-material iron in Arizona will be largely associated with development of its million to multimillion ton deposits and its potentially large low-grade resources. Iron ore developments will probably be

[2]Character samples are grab- or chip-type samples taken off iron deposit in locality sampled. They are not to be considered more than a cursory indi-cation of quality. Long outcrops and deposits cannot be represented by a lone or a few character samples.

affiliated with the established domestic iron and steel industry; however, export markets and smaller local metallurgical developments are mentioned in this report. The future iron industry of Arizona will not be limited to intrastate developments but will be part of a much larger consideration comprising Western United States.

ACKNOWLEDGMENTS

Acknowledgments are due the many public-spirited Arizona residents who furnished directions, information, analyses, or served as guides to iron occurrences. Maps, publications, and general information of the U.S. Geological Survey, the Arizona Bureau of Mines at Tucson, and the Arizona Department of Mineral Resources at Phoenix were used in this work. Particular appreciation is expressed for the help of Frank P. Knight, Director, Arizona Department of Mineral Resources, and Chas. F. Willis, publisher Pay Dirt. The many other references consulted are listed in the bibliography.

HISTORICAL PRODUCTION AND USE

Local natural iron oxides have been of little use in the raw materials economy of Arizona. From 1900 through 1960 commercial production of natural iron oxides was limited to only 4 years totaling less than 3,000 tons. Production came from northern Yuma County in 1920, 1930, 1942, and 1943 and was shipped to California as iron ore and as a purifier for hydrogen gas.

The first industrial-scale research on reduction of iron oxides by re-formed natural gas was undertaken in 1931 at Clarkdale (5, 53)[3] by United Verde Copper Co. Granulated smelter slag was converted to sponge iron and was melted in an electric furnace. The resulting steel was satisfactorily rolled and forged.

The largest production of iron from Arizona ores, used locally, has been from the conversion of pyrite into sponge iron and sulfuric acid. The sponge iron plant at the Kennecott Copper Corp. Ray Mines Division at Hayden has a capacity (46) of 39 to 42 tons of sponge iron per day, containing 35 to 50 percent iron of minus 28-mesh size. The sponge iron and sulfuric acid are used in the leach-precipitation-flotation process of recovering nonsulfide copper from Ray ore.

Phelps Dodge Corp. has produced sponge iron from slag at its Douglas pilot plant.

A small quantity of iron oxides has been produced in various parts of the State for experimental purposes.

Mill tailings at Swansea, Yuma County, consisting of nearly pure specular ite, have been shipped to Victorville, Calif., for use in manufacturing cement.

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[3]Underlined numbers in parentheses refer to items in the bibliography at the end of this report. Page references refer to pages in the bibliographic references.

Alluvial magnetite has been mined in Pinal County between Oracle and Florence Junctions and has been concentrated for use at the Arkota Steel Corp. iron smelter at Coolidge (47, 64), now inactive. The smelter was operated experimentally for a short time during 1962--employing the Madaras direct-reduction process.

GEOGRAPHY

Iron occurrences are found in all 14 Arizona counties. The deposits described in this report are listed in table 1 and located on figure 1. All the known occurrences in the State are included without regard to size because even a small deposit may be useful locally. The deposits are generally in mountainous terrain at altitudes ranging from 1,000 feet at New Planet in Yuma County to more than 6, 000 feet at Mingus Mountain in Yavapai County. Their location relative to railroads and smelters, are shown on maps in figures 1 and 2.

TABLE 1. - Iron occurrences in Arizona

No.'	Name of Deposit	County
1	Lyman Reservoir (Red Cap) hematite	Apache.
2	Quartzite Creek hematite	Do.
3	Dos Cabezas Mountains magnetite	Cochise.
4	Dragoon Mountains (Black Diamond) magnetite-hematite.........	Do.
5	Gleeson Ridge (Courtland) magnetite-hematite	Do.
6	Spike Hills (Iron Door) hematite	Do.
7	Deadman-Lonesome Pockets (Sycamore Canyon) hematite..........	Coconino.
8	Long Valley-Iron Mine Draw hematite-limonite	Do.
9	Baker and Carr Mountain magnetite-hematite	Gila.
10	Bear Creek-Rock Creek hematite	Do.
11	Big Pig hematite	Do.
12	Black Mountain hematite	Do.
13	Bottle Spring (Hope-Lucky) hematite	Do.
14	Christmas Mine cupreous magnetite	Do.
15	Christopher Mountain hematite	Do.
16	Circle Ranch magnetite-hematite	Do.
17	Coon Creek (Baker-Willyerd) hematite	Do.
18	Delshay Basin magnetite-hematite	Do.
19	Dry Creek (Last Chance-Lucky Strike) hematite	Do.
20	Fern magnetite	Do.
21	Fourth of July magnetite	Do.
22	Gentry Creek (Frog Pond) hematite	Do.
23	Gentry Mesa hematite	Do.
24	Globe District hematite-limonite	Do.
25	Great View magnetite...	Do.
26	Griffin Wash (Walnut Spring) magnetite	Do.
27	Haigler and Gordon Creeks magnetite-hematite	Do.
28	Horse camp Creek-Rock house hematite	Do.
29	Howard magnetite	Do.
30	Iron Group hematite	Do.

'Numbers in this column refer to locations on figure 1.

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TABLE 1. - Iron occurrences in Arizona (Con.)

No.[1]	Name of Deposit	County
31	Iron King group titaniferous hematite......................	Gila.
32	Kennedy Ranch magnetite.................................	Do.
33	Last Chance (Last Time, Kennedy) magnetite	Do.
34	Limestone Ridge (V. O. Ranch) hematite	Do.
35	Nail Ranch (Iron Spike, Iron Prince) hematite	Do.
36	Pig Iron titaniferous hematite	Do.
37	Pine Ridge magnetite	Do.
38	Pittsburg-Tonto-Alder Creek magnetite-hematite	Do.
39	Pueblo-Lucky Strike magnetite	Do.
40	Seneca (Cienega) magnetite	Do.
41	Shell Mountain (Hematite 1-8 group) hematite	Do.
42	Twin Peaks hematite	Do.
43	White Tail (Horseshoe) magnetite..........................	Do.
44	Zimmerman-Asbestos Points magnetite	Do.
45	Bitter Spring magnetite	Graham.
46	Mount Turnbull-Stanley Butte District (Captain Jack, Brewer) magnetite-hematite.	Do.
47	Morenci-Metcalf District magnetite-hematite (East Yankee magnetite, Copper Mountain Magnetite-limonite, Gold Gulch magnetite, Shannon Mountain magnetite, hematite, and limonite).	Greenlee.
48	Big Boulder-Iron Ridge hematite-magnetite taconite	Maricopa.
49	Big Horn District (Fred Brown) magnetitic alluvium........	Do.
50	Hieroglyphic Mountains (Pikes Peak) hematite-magnetite taconite.	Do.
51	Miscellaneous hematite, goethite, turgite (Bilge Pump, New Year, Toro).	Do.
52	Phoenix Mountains magnetite	Do.
53	White Tank Mountains (Luck Lode) titaniferous magnetite...	Do.
54	Alamo Crossing hematite	Mohave.
55	Grand Wash Cliffs hematite	Do.
56	Hualapai District magnetitic alluvium	Do.
57	Yucca District magnetitic alluvium	Do.
58	Apache (Alsace-Lorraine) hematite	Navajo.
59	Chediski-Lost Tank Ridge hematite	Do.
60	Cow Creek hematite	Do.
61	Marley-Grasshopper hematite	Do.
62	Oak Creek (Grasshopper Ranch) hematite	Do.
63	Split Rock (Gentry-Rock Creek) hematite)	Do.
64	Ajo magnetite-hematite	Pima.
65	Quijotoa Mountains magnetite-hematite (Horseshoe Basin, Iron Dike, Duke, Knight, Iron Hill, Morgan Peak, Stepp-Laive).	Do.
66	Santa Rita and Sierrita Mountains magnetite	Do.
67	Sierrita Mountains magnetite	Do.
68	Mineral Hill and Daisy cupreous magnetite	Do.
69	Mammoth-Collins mine hematite	Pinal.

'Numbers in this column refer to locations on figure 1.

TABLE 1. - Iron occurrences in Arizona (Con.)

No.'	Name of Deposit	County
70	Omega-Owlhead Butte District titaniferous magnetite alluvium.	Pinal.
71	Red Rocks group titaniferous magnetite alluvium...........	Do.
72	Red Rocks-Midway titaniferous magnetite alluvium..........	Do.
73	Slate Mountains-Lake Shore mine magnetite	Do.
74	Superior (East Wind and Lime Cap) magnetite	Do.
75	Table Mountain (Swingle) manganiferous hematite...........	Do.
76	Troy magnetite-hematite	Do.
77	Copper Mountain hematite-limonite	Santa Cruz.
78	Line Boy magnetite-hematite	Do.
79	Ash Creek magnetite taconite	Yavapai.
80	Big Iron hematite	Do.
81	Big Buck-Three Points magnetite jaspilite	Do.
82	Black Chief (Warrior) magnetite jaspilite	Do.
83	Black Gold magnetite-hematite jaspilite	Do.
84	Blind Indian-Longfellow Ridge magnetite taconite..........	Do.
85	Blue Bell mine magnetite-hematite taconite	Do.
86	Blue Bell siding magnetite-hematite taconite	Do.
87	Boulder-Milholland Creeks titaniferous magnetite-hematite.	Do.
88	Cash Reserve magnetite jaspilite	Do.
89	Copper Mountain taconite-jaspilite	Do.
90	De Soto magnetite taconite	Do.
91	Goodwin magnetite-hematite taconite	Do.
92	Howard Copper mine magnetite taconite	Do.
93	Jerome and Bradshaw areas iron oxides	Do.
94	Los Felice (Townsend Butte) manganiferous magnetite-hematite.	Do.
95	Lynx Creek magnetite taconite	Do.
96	Mayer-Stoddard magnetite taconite	Do.
97	Pine Creek magnetite taconite	Do.
98	Santa Margarita District alluvial magnetite	Do.
99	Seligman (Juniper Mountains, Cowden) hematite	Do.
100	Stanton magnetite taconite	Do.
101	Wasson Peak-Oro Belle taconite	Do.
102	Yaeger (Vojnich) hematite-magnetite jaspilite	Do.
103	Black Chief manganiferous hematite-limonite	Yuma.
104	Black Diamond (Black Mesa) magnetite	Do.
105	Black Jack (Bird) group hematite	Do.
106	Black Mesa hematite	Do.
107	Black Mule hematite	Do.
108	Black Stud manganiferous hematite	Do.
109	Bouse Gold and Copper Co. (Paradise Ext., Dollie W., Llano) hematite.	Do.
110	Brown Mountain cupreous hematite	Do.
111	Dome Rock Mountains magnetite	Do.
112	Good Bet-Smokey hematite	Do.
113	Granite Wash Mountains cupreous magnetite	Do.

'Numbers in this column refer to locations on figure 1.

TABLE 1. - Iron occurrences in Arizona (Con.)

No.[1]	Name of Deposit	County
114	Harcuvar Mountains hematite	Yuma.
115	Highline hematite	Do.
116	Hope (Bauer-Kelly) alluvial magnetite	Do.
117	Iron Mine hematite	Do.
118	Knight Group hematite	Do.
119	Little Butte hematite	Do.
120	Mammoth (Corona Copper) hematite	Do.
121	Mineral Hill cupreous hematite	Do.
122	New Planet cupreous hematite	Do.
123	Phoenix-Yuma groups hematite	Do.
124	Planet Peak cupreous hematite	Do.
125	Ruthie-Linda groups hematite	Do.
126	Swansea cupreous hematite	Do.
127	Tank Mountains magnetite, hematite, limonite, jarosite	Do.
128	Trigo Mountains hematite-limonite	Do.
129	North Trigo Mountains hematite	Do.

[1]Numbers in this column refer to locations on figure 1.

Weather ranges widely from very mild winters in the desert areas to rigorous winters and heavy snows at the higher altitudes. Some of the iron occurrences are difficult to reach and from many of them long truck and rail-road hauls would be required to deliver the ores to markets. The high cost of transportation is one of the handicaps of development.

Other than the presently inactive Arkota Steel Corp., (64), Arizona has no established metallurgical facilities to smelt *iron* ores, and the nearest markets (fig. 2) are those represented by The Colorado Fuel and Iron Corp., at Pueblo, Colo.; the Lone Star Steel Co., at Daingerfield, Tex.; the Armco Steel Corp., Sheffield Steel Div., at Houston, Tex.; the Columbia-Geneva Steel Division, United States Steel Corp., at Provo, Utah; and the Kaiser Steel Corp., at Fontana, Calif.

Arizona, covering 113,575 square miles in southwestern United States, is served by a network of highways and transportation facilities. The northern part of the State is served by the Atchison, Topeka and Santa Fe Railway. The southern part of the State is served by the Southern Pacific Railroad. Many local buslines and two large interstate carriers, Southwest Greyhound lines and Continental Trailways, also serve the State. Major airlines, including American, Western, and TWA, and a number of feeder airlines provide passenger and freight service to the State.

IRON RESOURCES

General

Occurrences of iron in Arizona are in a variety of mineralogic and geologic forms. Deposits, although widespread (fig. 1, table 1), have not been developed for present markets because of their metallurgical and economic problems and their inaccessibility.

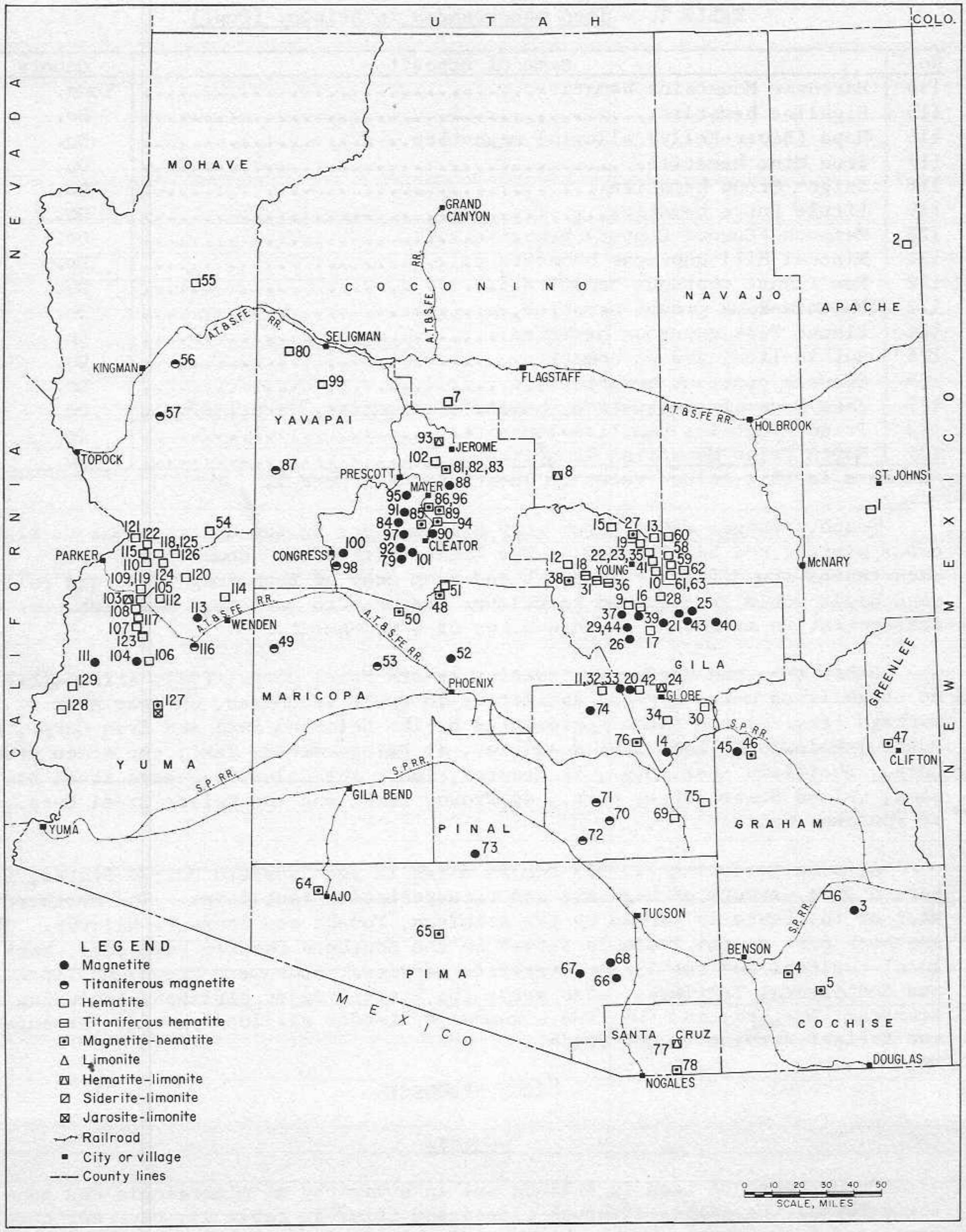

FIGURE 1. - Location of Iron Resources and Railroads in Arizona.

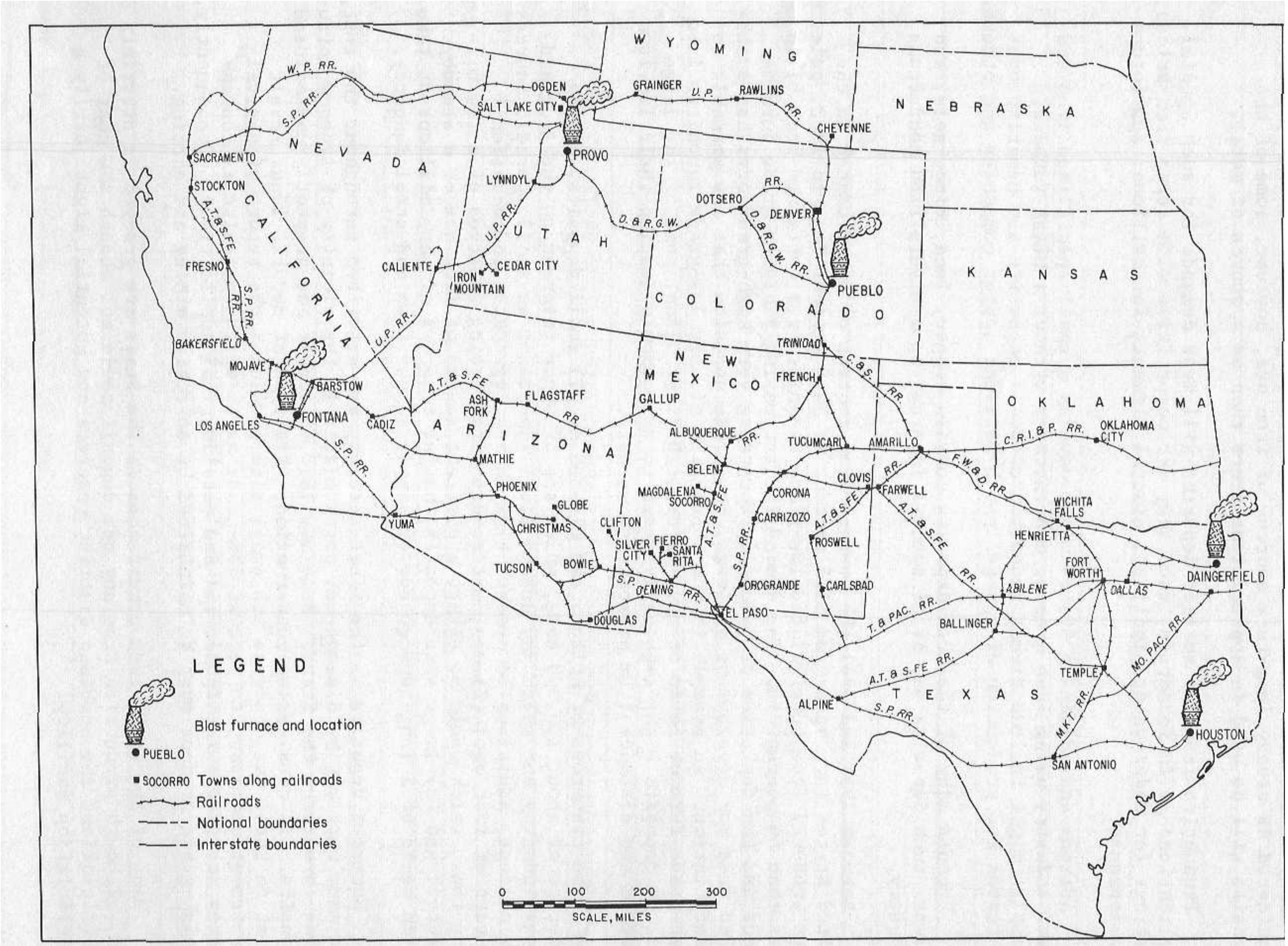

FIGURE 2. - Location of Blast Furnaces and Connecting Railroads in Western United States.

Many of the iron occurrences in the State (fig. 1) are too small to be considered as steady long-term sources of iron ore; however, some of the deposits will be used in applications other than as a source of metal.

Production from the smaller deposits will meet demands for such special applications as in foundries, when they are competitive with scrap iron prices; coatings for under-water pipelines; mineral pigment; ferrosilicon; and future developments.

Arizona and adjoining States might develop a small specialized iron and steel industry using iron ores or concentrates without a blast furnace. Examples might include direct reduction of local magnetite and hematite concentrates and production of sponge iron by Arizona copper companies and others.

Because many of the iron deposits contain copper, lead, zinc, gold, and silver, such deposits may be of special interest to a diversified nonferrous industry.

Between 1957 and 1961 the average iron content of ore produced in the United States increased from 51.3 percent to 54.5 percent Fe. In 1962, pellets produced from beneficiated low-grade taconite ores contained from 61 to more than 64 percent Fe. The demand for increasingly higher grade furnace feeds and the depletion of naturally occurring very high-grade ores has emphasized need for development of large, low-grade deposits that are amenable to beneficiation. An example is the conversion of very low-grade taconites into high-grade furnace feeds of optimum desirability. Thus, some of the large Arizona deposits might eventually prove to be economic despite their low iron content and distance from present day markets.

Iron resources of Arizona are classed as (1) small deposits, having reserves of about 100,000 tons, which are of minor interest to the iron and steel industry but which may assume local importance as small sporadic sources for pigment; additives in cement, flux, heavy aggregate; and occasional sources of iron ore; (2) medium-size deposits, having reserves of a few mil-lion tons, which could be either a contract source of iron ore or a standby reserve; and (3) large size deposits, having reserves of many millions of tons, which could be a long-term source of supply to the iron and steel industry.

Numerous deposits of the first category are described throughout the text, and many more may be discovered, particularly in the vicinity of igneous intrusions throughout the State. Some may lead to larger and presently undisclosed deposits. In considering conservation, this type of deposit lends itself least to total use, because its small size precludes the return of capital investment necessary to recover low-grade parts of the deposits as concentrates acceptable for industrial and metallurgical applications. Consequently, a high-grade product must be maintained by selective mining and sorting.

Many of the small iron occurrences in the State are grouped in districts and, although production from any one deposit could not absorb the cost of beneficiation, the combined district reserves and potential might justify a beneficiation facility.

Deposits in the second category involve greater exploration and development costs. Choices for this size of deposit are whether to sort out a small high-grade fraction, as in category 1, or to mine and beneficiate a larger tonnage of lower grade ore. In the first choice, a smaller portion of the deposit would be mined but the development costs would be lower. In the latter choice, beneficiation would require crushing and grinding to liberation size; magnetic, gravity, flotation, and/or other means of concentrating the iron and probably agglomeration. Some of the deposits contain sulfide minerals and base metals which might be worth recovering in auxiliary facilities. Deposits of this type include cupreous hematite of northern Yuma County; cupreous magnetite at Christmas, Gila County; and magnetite-bearing alluvial areas in Pinal and Yavapai Counties.

Deposits in the third category might require capital investment of mil-lions of dollars. Thorough exploration, a proven beneficiation procedure; assured long-term markets; and large-scale mine, mill, and transportation development would be needed. Deposits of this type include (1) potentially huge low-grade deposits like the Precambrian taconites of Maricopa and Yavapai Counties and the quartzitic hematite-magnetite (semitaconite) beds of the Gun Creek-Delshay area (T 8 N, Rs 11 and 12 E) in Gila County; and (2) a combination of high-grade hematite and magnetite deposits with large bodies of much lower grade; for example, the combination of extensive hematite replacements in Mescal limestone in Navajo and adjoining Gila Counties with magnetite-rich facies of the great diabase intrusives of the area.

Quality

Iron occurrences in Arizona contain various deleterious constituents. Chiefly, these may include silica, carbonate, silicate minerals, oxide and sulfide copper minerals, titania, phosphorus, and sulfur. Chemical and spec-trographic analyses reported in the text also indicate the presence of lime, magnesia, alumina, manganese, copper, lead, zinc, vanadium, cobalt, nickel, zirconium, chromium and arsenic in different deposits. The minable portions of iron deposits would require some beneficiation to remove these impurities and to increase their iron content. The quality of Arizona iron resources is indicated by Bureau of Mines analyses in table 2 and in the text.

Reserves

Arizona iron resources were investigated by the U.S. Geological Survey (10) in 1930 and the Federal Bureau of Mines (15, 20, 32, 65); during 1942-47. This work resulted in publications and partial estimates of iron reserves in the Hieroglyphic Mountains of Maricopa County, Buckskin Mountains of Yuma County, and Fort Apache Indian Reservation in Navajo County. Reserves developed by these explorations are reported by the Bureau (20, pp. 1, 23; 32, pp. 7, 10) and the U. S. Geological Survey (13, p. 97). They are summarized in table 3.

TABLE 2. - Arizona iron analyses

Location[s]	Chemical analyses, ?ercent										Remarks
	Fe	Mn	SiO_2	P	S	TiO_2	$Al_2 0_a$	Cu	Zn	Pb	
Apache County:											
Lyman Reservoir Red Cap (1).	16.0	0.04	66.4	0.01	0.11	0.53 to 1.6	-	-	-	-	Alluvial hematite in sandstone; in situ.
Do	63.1	-	-	-	-	-	3.0	-	-	-	Gravity concentrate of above.
Cochise County:											
Dos Cabezas (3).........	52.8	-	1.62	.11	.93	.2	-	0.54	-	-	Cupreous magnetite.
Black Diamond (4)	44.6	.20	20.4	.02	.25	.2	-	.44	-	-	Dragoon mountains magnetite-hematite.
Spike Hills (6)	56.2	-	16.4	.03	.30	.6	-	-	-	-	Hematite.
Coconino County:											
Sycamore Canyon (7).....	41.1 to 58.2	-	-	-	-	-	-	-	-	-	Lonesome and Deadman Pockets hematite.
Iron Mine Draw (8)	36.5	-	31.5	-	-	-	-	.37	3.5	-	Hematite replacements.
Gila County:											
Bottle Spring (13)......	51.8	.1	21.0	.34	.10	.4	-	-	-	-	Hematite replacing Mescal limestone.
Gentry Creek (22).......	35.4 to 64.1	.1 to .4	6.2 to 37.6	.1 to .48	.02 to .1	.1 to .5	-	-	-	-	Do.
Nail Ranch (35)	35.4	.4	37.6	.20	.08	.4	-	-	-	-	Do.
Shell Mountain (41).....	64.2	.1	7.2	.15	.08	.2	-	-	-	-	Do.
Haigler-Gordon Creek (27)	43.6	.2	5.4	.01	.05	.2	-	-	-	-	Do.
Dry Creek (19)..........	54.0	.1	21.4	.03	.08	.3	-	-	-	-	Do.
Pinto Creek Fern (20)....	65.7	.1	2.6	.04	.1	.1	-	-	-	-	Do.
Iron King (31)..........	39.0 to 42.0	.1 to .2	23.4 to 27.4	.06 to .10	.08 to .10	8.7 to 9.8	-	-	-	-	Precambrian titanifer-ous hematite quartzite
Pig Iron (36)	18.6 to 31.8	.5 to 1.5	37.8 to 57.1	.03 to .1	.05 to .11	2.6 to 7.6	8.2 to 10.0	-	-	-	Do.

Limestone Ridge (34)....	31.1 to 39.1										Hematite replacement.
Pine Ridge (37).........	68.4	.3	2.4	.02	.08	.4					Magnetite replacing Mescal limestone.
Pueblo-Lucky Strike (39).	51.0 to 58.7	.05 to .3	5.7 to 14.6	.01 to .03	.01 to .10	.09 to .30	.3	.01	.04	0.01	Do.
Twin Peaks (42).........	64.6	.1	12.3								Hematite replacing Mescal limestone.
Zimmerman and Asbestos Points (44).	50.8 to 60.4	.02 to .2	1.4 to 12.4	.03 to .06	.09 to .11	.05	2.72				Magnetite replacing Mescal limestone.
Graham County:........... Butte-Mount Turnbull (46).	20.96 to 65.35										Magnetite replacing Paleozoic limestone.
Greenlee County:											
Gold Creek (47).........	62.9	.2	8.0	.06	.11	.3					Do.
Shannon Mountain (47)....	17.4 to 50.9	1.0 to 7.6	5.0 to 28.4								Magnetite-limonite replacing Paleozoic limestone.
Maricopa County:											
Big Boulder-Iron Ridge (48).	25.5 to 33.1	1.04 to 2.5	31.8 to 51.8	0.12 to .194	0.10 to .12	0.15 to .4	8.49				Precambrian hematite-magnetite taconite.
Hieroglyphic Mountains (Pikes Peak).......... (50).	28.7 to 31.2	1.9 to 2.8	36.4 to 46.5	.13	.05	.1	4.1				Do.
Navajo County:											
Apache (58)	42.96 to 58.53	.04 to .05	12.14 to 30.60	.191 to .220	.018 to .054	.15	2.12 to 2.92				Hematite replacing Mescal limestone.
Chediski (59)..........	48.92	.10	23.02	.285	.055		2.26				Do.
Pima County:............ Quijotoa Mountains (65).	43.7 to 55.6	.1 to .3	13.2 to 24.4	.02 to .69	.08 to .11	.4 to 1.0					Magnetite-specularite replacing epidotized granite.

[1]Numbers in this column refer to locations on figure 1.

TABLE 2. - Arizona iron analyses (Con.)

Location[s]	Chemical analyses, percent										Remarks
	Fe	Mn	SiO_2	P	S	TiO_2	Al_2O_3	Cu	Zn	Pb	
Pinal County:											
Oracle Junction, Omega-Owlhead, Butte district...............(70).	20.8	0.5	49.0	0.26	0.4	2.1	-	-	-	-	Magnetitic alluvium between Oracle Junction and Florence.
Do	63.2	.15	4.5	.19	.06	2.3	-	-	-	-	Magnetitic concentrate from above.
	44.9		19.4								
Slate Mountains Lake Shore (73)..		-		.02	.15	.15	-	1.75	-	-	Cupreous magnetite replacing limestone and quartzite.
	62.3		2.8								
Superior (74)...........		.3		.03	.09	.2	-	-	-	-	Magnetite replacing Mescal limestone.
	35.8	19.9	2.2								
Table Mountain (75)				-	-	-	2.9	-	-	-	Manganiferous hematite replacing limestone.
	33.7	2.25	34.9								
Yavapai County:											
Black Hills, jaspilite (81,......... 102)..................				.27	.04	.20	-	-	-	-	BuMines composite metallurgical test sample--1962.
Black Hills, jaspilite (81).	37.26	2.93	25.32	.02	.05	.27	3.76	Trace	0.08	0.29	Precambrian jaspilite. Average of 3 locations (Courtesy Elwood Wright).
	36.2	1.9	52.0								
Lynx Creek (95)				.10	.08	.3	-	-	-	-	Precambrian taconite.
Mayer-Stoddard (96)	27.2	1.4	51.0	.10	.09	.2	-	-	-	-	Do.
Blue Bell siding (86)...	27.3 to 35.6	1.5 to 1.8	39.0 to 46.9	.15 to .17	.04 to .10	.2 to .33	-	-	-	-	Do.
Cleator, Los Felice (94).	27.2 to 38.88	1.3 to 10.91	35.2 to 51.2	.18 to .3	.08 to .25	.2 to .3	-	-	-	-	Do.
Goodwin (91)	20.8 to 27.3	.7 to .4	50.6 to 44.4	.12	.17 to .13	.6 to .45	-	-	-	-	Do.

Pine Creek (97).........	33.8 to 27.3	.1 to .4	38.2 to 44.4	.11 to .12	.08 to .13	.3 to .45	-	-	-	-	Do.
Stanton (100)	20.6 to 30.6	1.8 to 2.9	43.8 to 59.2	.11 to .27	.08 to .10	.2 to .4	-	-	-	-	Do.
Seligman (99)..........	55.5 to 68.4	.03 to .14	1.8 to 8.7	.0 to .03	.0 to .1	-	.1 to 3.19	-	-	-	Hematite replacing Paleozoic limestone.
Yuma County :											
Black Jack (105)	25.8 to 31.3	3.3 to 12.7	26.5 to 37.4	.06	.71	.33 to .6	-	-	-	-	Manganiferous hematite replacing Paleozoic limestone.
Black Mule (107)	21.4	1.3	43.6	.12	.22	.8	-	-	-	-	Do.
Black Stud (108)	41.8	.4	14.4	.02	1.24	.2	-	-	-	-	Do.
Iron Mine (117)	47.0	.3	19.4	.11	.36	.3	-	-	-	-	Do.
Phoenix-Yuma. (123).....	61.38	-	8.26	.094	.016	-	-	-	-	-	Do.
Black Diamond (104)	49.7	.3	9.6	.04	.13	.2	-	-	-	-	Do.
Mineral Hill (121)	24.5 to 63.2	.1 to .15	38.5 to 27.6	.06 to .07	.36 to .67	.1 to .29	-	2.51 and vari-able	-	-	Cupreous hematite replacing Paleozoic limestone.
New Planet (122)	57.9	-	4.0	-	.09	-	1.65	7.90	-	0.05	Do.
Granite Wash Mountains (113).	58.4	.3	12.2	.13	.14	.2	-	Vari-able	-	-	Cupreous magnetite replacing Precambrian rocks.

[1]Numbers in this column refer to locations on figure

TABLE 3. - Published Arizona iron reserves

Locality No.[1]	Area and county	Type of ore	Approximate percent Fe	Estimated millions reserves, of long tons Measured	Indicated	Inferred	References
58,.... 59..	Fort Apache Indian Reservation, Navajo County.	Hematite..	46	-	-	14.144	(13, p. 97; 32, pp. 7 and 10)
122 ...	Buckskin Mountains, Yuma County.	do.....	60	-	1.25	-	(13, p. 97; 32, pp. 7 and 10)
50.....	Hieroglyphic Mountains, Maricopa County.	Hematite and magnetite.	30	-	-	100.000	(13, p. 97; 20, pp. 1 and 23)
Total.			-	-	1.25	114.144	

'Keyed to figure 1.

Quantitative estimates of reserves for the many other iron occurrences in Arizona, based on a few character samples and reconnaissance, are not considered conclusive; however, an indication of the size and potential is implied in descriptions of the various deposits.

Results of this reconnaissance investigation indicate that the potential iron-oxide resources of Arizona may prove very large--several billion tons--if low-grade deposits, presently inferred, are considered.

Favorable Areas and Their Potential

Reconnaissance information indicates that iron resources in Arizona are much greater than the estimate presented in table 3. The following iron occurrences and areas appear particularly favorable for exploration and development:

1. Widespread occurrences of hematite and magnetite as contact metamorphic and pyrometasomatic replacements of Precambrian Mescal limestone associated with diabase intrusives are in Navajo and Gila Counties, and possibilities exist of extensions and similar occurrences in the area. These medium to high-quality hematite and magnetite replacements have been inferred (32) to be 14 million tons, averaging 46 percent iron. However, iron-rich material of lower grade crops out sporadically for many miles in the deeply dissected mesa-canyon terrain of Navajo and Gila Counties. The tonnage of concentrate that could be produced from this low-grade material might far exceed the above inferred reserve estimate.

2. Intrusive contacts with calcareous Paleozoic rocks in the State are the sites of many contact metamorphic and pyrometasomatic replacements containing iron minerals and sulfide base metals. They are typified by the cupreous magnetite at Christmas and the magnetites north of Globe in Gila

County, the magnetite-hematite in the Quijotoa Mountains, and many others described in the text. Many of the deposits are in the first category; how-ever, some appear large and may be of second category magnitude. Combined reserves from this type deposit could prove important locally, particularly with inclusion of low-grade material and recovery of accessory minerals.

3. Magnetite and hematite occur as low-grade taconite- and jaspilite-like iron formations, manganiferous in part, that crop out interruptedly more than 70 miles through Maricopa and Yavapai Counties as part of the great Precambrian Yavapai series in the Bradshaw-Hieroglyphic-Weaver Mountains and Black Hills areas. Iron reserves have been inferred (20) to be 100 million tons, averaging 30 percent iron. However, extensions traced for many miles indicate a much greater potential that merits more detailed investigation.

4. Low-grade titaniferous hematite-magnetite is prominent as a facies in the quartzite-schist-arkosic sandstone sequence of the Precambrian Yavapai series in the Delshay-Gun Creek-Clover Creek area. This formation extends for many miles in Gila County in widths more than 2,000 feet. The few character samples collected contained 18.6 to 42.0 percent iron and 2.6 to 9.8 percent titania. The iron resource potential of this low-grade formation could be tremendous; however, much more must be known about this deposit before a meaningful appraisal can be attempted.

5. Large areas, comprising many square miles of alluvium, in Arizona, contain 1 to 15 percent or more magnetite--usually titaniferous. Tests including screening, magnetic separation, and pelletizing indicate that concentrates containing more than 60 percent iron can be obtained. The great alluvial plain northwest of Tucson between Oracle Junction, Florence, Casa Grande, Red Rocks, and the Santa Margarita district, northwest of Wickenburg, are typical of this type of occurrence.

6. Hematite was known in southern Yuma County before 1865--particularly in the vicinity of Mineral Hill, Brown Mountain, New Planet, and Swansea; in the Buckskin Mountains; and along the east flank of the Plomosa Mountains. Iron reserves of hematite and cupreous hematite have been indicated (32) to be more than a million tons, averaging 60 percent iron, Lower grade material exposed interruptedly over large areas indicates a potential much greater than that estimated previously, assuming economic beneficiation and recovery of copper and/or manganese.

7. Intrusive contacts in the State have not been fully investigated. The extensive occurrence of magnetite and specularite in the Quijotoa Mountains of Pima County is typical of the type deposit that could occur at the contacts.

8. Nonferrous smelter slags of Arizona, approximately 100 million tons containing 30 to 50 percent iron, comprise a potential source of iron. The slags contain some copper, zinc, and traces of other metals.

GENERAL GEOLOGY

Iron oxides occur in numerous deposits and as accessory minerals in the rocks of Arizona and color many formations yellow, red, brown, and black. The oxides, hematite, and limonite occur as irregular ocherous masses in rocks of nearly all ages. Iron in the lower concentrations, as ocherous masses, may have some value as mineral pigments. In higher concentrations the oxides have value as sources or potential sources of iron. The common iron oxide minerals are magnetite, martite, hematite, and limonite. Pyrite may also be considered a possible byproduct source of iron when used under special situations like the joint production of sulfuric acid, synthetic hematite, and/or sponge iron.

The source of mined iron ore in Arizona has been hematite and magnetite from contact metamorphic or pyrometasomatic replacements. These deposits are replacements of Proterozoic to Paleozoic sediments associated with Precambrian to Tertiary intrusives. The intrusives vary greatly in size and shape and in many cases form the cores of mountain ranges, ridges, and mesas. The ore bodies are irregularly tabular, sheetlike, and lenticular.

They vary in attitude from horizontal to vertical. They commonly include branches or tongues that protrude from a main ore body. In many, as exemplified by deposits in the Precambrian Mescal limestone in Gila and Navajo Counties and the Paleozoic sediments of Yuma County, iron ore occurs massive or disseminated in bands parallel to the beds they replace. Some deposits like those in the Quijotoa Mountains, Pima County, appear distant from intrusive contacts and may be of hydrothermal origin.

Magnetite and hematite with some limonite occur in pegmatites within Precambrian rocks. They are generally accessory minerals and of little value as a source of iron.

Magnetite and hematite (specularite) and some ilmenite occur as abundant accessory minerals in many igneous rocks in Arizona. Characteristic occurrences are the great diabase areas of Sierra Ancha, Gila, and Navajo Counties.

Some iron deposits have been formed by atmospheric agencies and action of subsurface and near surface waters of external (meteoric) origin. The resulting deposits include replacements and enrichments of sandstone, siltstones, and limestones; filled cavities and breccia zones; and iron enriched gossans. Examples of these are the manganiferous hematites of Yuma County and the iron group hematite of Gila County.

Colluvial and alluvial deposits of iron, chiefly magnetite and hematite, occur along the slopes and drainage channels below many iron occurrences. In addition, placer deposits of heavy minerals, principally magnetite, form from erosion of many rocks, in which they are accessory minerals. Examples were noted in the Lyman Reservoir area of Apache County, the alluvial areas of Pinal and Yavapai Counties, and other places.

Taconite, semitaconite, and jaspilite-like deposits of magnetite-hematite are extensive in the metamorphosed Precambrian Yavapai series in Maricopa and

Yavapai Counties. An example is the Pikes Peak deposit in Hieroglyphic Mountains of Maricopa County.

IRON MINERALS, ROCKS, AND SLAGS

Magnetite

Magnetite (Fe_sO_1) is a hard, strongly magnetic, black to brownish-black mineral with a dull to metallic luster and a black streak; when pure it contains 72.4 percent iron. Magnetite alters to martite, hematite, and limonite-goethite. Magnetite occurs in small quantities in many rocks and as an accessory mineral, in pegmatites, gneisses, schists, and igneous rocks. It is an important iron mineral in many contact metamorphic and pyrometasomatic replacement type deposits, taconite-like iron formations, and alluvial deposits in Arizona.

Hematite

Hematite (Fe_20_3) is red to brownish red, steel gray, metallic, or black--occurring in micaceous, platy, columnar, fibrous, reniform, botryoidal, earthy, or ocherous form and frequently mixed with clay, sand, gravel, talus, host rock, or other impurities. It may be granular, porous, compact, or concretionary. Its streak is cherry red to reddish or purplish brown. As martite, it occurs in the upper parts of ore bodies as an oxidation pseudomorph after magnetite. It often hydrates to form limonite, goethite ($Fe_20_3 \bullet H_20$), and turgite ($2Fe_2O_3 \bullet H_2O$). When pure, hematite contains 70.0 percent iron. Hematite is the most important iron mineral in the replacement deposits of Gila and Yuma Counties.

Martite

Martite, a variety of hematite, occurs as isometric, octahedral, and dodecahedral crystals pseudomorphis after magnetite and possibly pyrite. It is nonmagnetic to feebly magnetic. Magnetism is due to inclusion of residual magnetite. Martite contains 70.0 percent iron; and it is usually iron black, having a reddish- to purplish-brown streak, an irridescent tarnish, and a dull to splendent submetallic luster. It is distinguished from magnetite by its reddish streak and lack of magnetism. Martite may contain enough residual magnetite to be recoverable in part by magnetic separation.

Limonite-Goethite

Limonite ($Fe_203 \bullet nH_2O$) occurs as a mixture of hydrated iron oxides, principally goethite (Fe_20_3-H_20) with some hematite (Fe_2O_3). Limonite-goethite is the common oxidation product of iron oxides, iron sulfides, iron carbonate, and rock forming minerals. Its streak is yellowish brown, and its hardness may vary considerably. Limonite varies widely in purity and may contain manganese and many foreign substances such as sulfur, phosphorus, lime, alumina, and silica. Limonite occurs as ocherous and crustlike masses at the outcrop of many iron and base-metal sulfide deposits where it has formed from the oxidation and hydration of magnetite and hematite and included sulfides. It contains 59.8 to 62.9 percent iron but is rarely pure.

Jarosite

Jarosite [$KFe,(OH)_6(SO_a)_2$], the basic iron sulfate, has been noted in gossan and oxidized zones of nonferrous sulfide and pyritic deposits. It is colored yellow to brown and contains about 33.5 percent iron.

Pyrite

Massive to disseminated pyrite (FeS_2) is a common constituent of many nonferrous metal deposits. Pyrite contains 46.5 percent iron and is brass . yellow in color.

Chamosite

Chamosite [$15(Fe, Mg)0 \cdot 5Al_20_3 . 11SiO_4 . l6H_20$] occurs compact to oolitic and colored black to greenish gray. At Limestone Ridge (72) in Gila County, it occurs as an associate iron mineral with oolitic hematite.

Taconite

Taconite has been defined (45) as "ferruginous chert or ferruginous slate in the form of compact, siliceous rock, in which the iron oxide is so finely disseminated that substantially all of the iron-bearing particles of merchant-able grade are smaller than 20-mesh. Taconite may be further defined as ore-bearing rock which is not merchantable as iron ore in its natural state, and which cannot be made merchantable by simple methods of beneficiation involving only crushing, screening, washing, jigging, drying or any combination thereof." The few character samples taken of Arizona taconite indicate a 20 to 40 percent iron content as magnetite-hematite.

Semitaconite also is defined as altered iron formation, altered taconite, ferruginous chert, or ferruginous slate which has been oxidized and partly leached, and in which iron oxide is so finely disseminated that substantially all of the iron-bearing particles of merchantable grade are smaller than 20-mesh. Thus it is not merchantable as iron ore in its natural state and cannot be made merchantable by simple methods of beneficiation involving only crushing, screening, washing, jigging, heavy-media separation, spirals, cyclones, drying, or any combination.

Geologically, taconite is fine-grained, cherty, jaspery, or siliceous and is bedded to sometimes slatelike iron formation similar to that in the Minnesota Mesabi iron range, where the term originated. Taconite is very low grade but is an enormous source of iron. The iron formations contain recoverable magnetic or nonmagnetic iron oxides (45).

Jaspilite

Jaspilite is a compact siliceous, very fine-grained rock composed of interbanded layers of hematite-magnetite and red to black chert, possibly formed from chemical sediments.

Impurities

Impurities in the many iron occurrences of Arizona are varied and comprise sulfides, carbonates, sulfates, silicates, and a group of minor accessory minerals.

Sulfides include pyrite (FeS_2) and chalcopyrite (CuFeS,,) and, less commonly, sphalerite (ZnS) and pyrrhotite ($FeS(S)_x$).

Carbonate impurities comprise calcite ($CaCO_3$), malachite [$Cu_2(OH)_2CO_3$], dolomite [$Ca(Mg, Fe)\ (CO_3)_2$], limestone ($CaCO_3$), and marble ($CaCO_3$).

Silicate minerals are principally quartz, garnet, actinolite, serpentine, tremolite, epidote, wollastonite, phlogopite, and pyroxene.

Other impurities may include very minor amounts of apatite, rutile, and ilmenite. In addition, spectrographic analyses of a few samples indicate the presence of minor amounts of cobalt, nickel, copper, vanadium, titanium, and zirconium.

Metallurgical Slags

Metallurgical slags at smelter sites in Arizona may some day be used as a source of iron. These complex silicates, nearly 100 million tons in aggregate, contain an estimated 33 to 50 percent total iron content with small amounts of copper, zinc, and other elements.

IRON OCCURRENCES BY COUNTIES Apache County

Lyman Reservoir (Red Cap) Hematite

A residual-type deposit of hematite (1, fig. 1) was located as the Red Cap group of claims in 1958. The deposit is in secs 6 through 9, T 11 N, R 28 E, Gila and Salt River meridian and baseline, along and east of the Lyman Reservoir road, 9.2 miles north of Springerville.

A flat lying, weakly cemented, kaolinitic white sandstone sequence of the Triassic Chinle formation in the area contains an abundance of hematite and some specularite. Erosion of this sequence has led to the formation of hematite alluvial deposits consisting of chips, pellets, and nodules of siliceous (sandy) to almost pure hematite by removal and transport of the sand content. Character samples of the alluvial material contain 11 to 16 percent iron as hematite; concentrates contain 52.8 percent iron, 0.52 percent titania, 18.6 percent silica, and negligible amounts of sulfur and phosphorus. A character sample taken by the Bureau in 1961 contained 16.0 percent iron, 0.11 percent sulfur, 0.01 percent phosphorus, 0.04 percent manganese, 66.4 percent silica, and 0.53 percent titania.

The hematite iron occurrences are small as a source of iron ore, however, they may be useful as a prepared mineral pigment or as a small local source of iron when concentrated. (Results of pioneer beneficiation testing for these and most of the following deposits are shown in the section on beneficiation and in table 28 accompanying that section.)

Quartzite Creek Hematite

Hematite occurs in Precambrian quartzite (2, fig. 1) dissected by Quartzite Creek, 2 miles northwest of Fort Defiance, in the center of T 1 N, R 6 W, Navajo meridian and baseline. The hematite, in a 1-square-mile area, is disseminated through the quartzite; streaks of bluish-black hematite less than 1/16-inch thick among the crossbedding laminae give the rock a banded appearance. Bluish-black films of hematite coat the many fractures. The hematite (28) represents original magnetite accumulated during deposition of the quartzite. The deposit is too low grade to be considered a source of iron ore.

Cochise County

Dos Cabezas Mountains Magnetite

The presence of abundant magnetite reported in Archean schists near Dos Cabezas (25) could not be verified, and the Precambrian Pinal schist of the area, where examined, contained very little to no magnetite; however, in the same area massive to disseminated magnetite with some chalcopyrite, cuprite, azurite, malachite, chrysocolla, epidote, and quartz was traced in slope widths of as much as 200 feet of a 3/4 mile. Magnetite was noted in outcrops, on mine dumps, and as float northwest and southeast of a pinnacle of siliceous magnetite-hematite known as Iron Tower (3, fig. 1) in secs 16 and 21, T 14 S, R 27 E, Gila and Salt River meridian and baseline, on the Mascot Consolidated Copper Co. property. This occurrence and others in the area, in secs 9, 22, 26, and 27, are irregular, contact metamorphic replacement deposits in fault blocks of Paleozoic limestone associated with granitic and dioritic intrusives. The deposits are 3 to 4 miles north of Dos Cabezas by road (14).

All mine workings were inaccessible during 1961, and consequently little is known of their extensions underground. The deposits were mined for copper and silver during 1908-28. A 1961 sample of the better magnetite ore exposed contained 52.8 percent iron, 0.54 percent copper, 0.2 percent titania, 0.11 percent phosphorus, 0.93 percent sulfur, and 1.62 percent silica.

Any production would require beneficiation to be a limited local source of iron.

Dragoon Mountains (Black Diamond) Magnetite-Hematite

Cupreous magnetite-hematite is prominent in the outcrops and dumps at Black Diamond mine (fig. 3), particularly on the Black Diamond and Englander claims (4, fig. 1), about 8 miles southwest of Pearce and 27 miles south-southeast of Dragoon, in the southern part of the Dragoon Mountains, in the Coronado National Forest. The property comprises part of secs 19, 20, 28, 29, and 30, T 18 S, R 24 E, Gila and Salt River meridian and baseline.

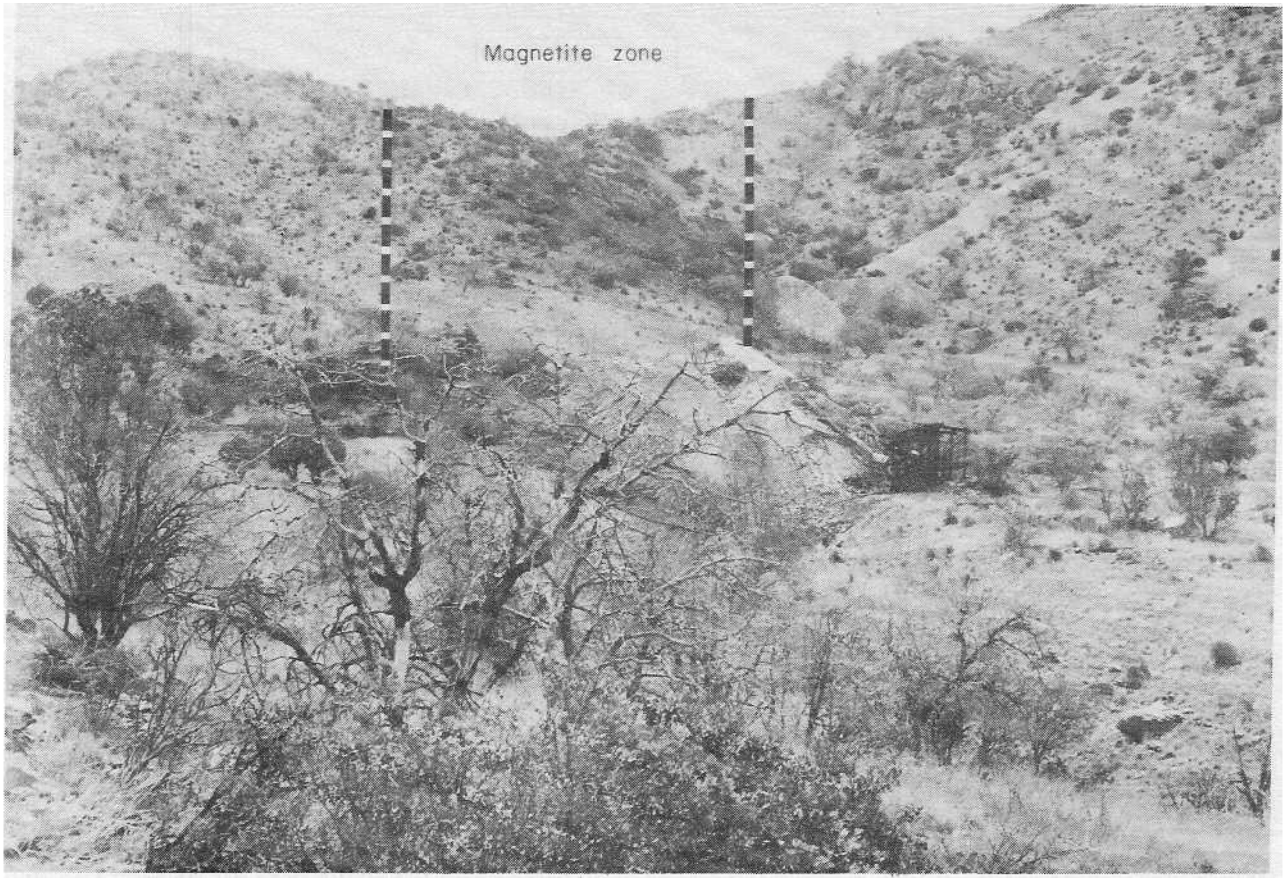

FIGURE 3. - Black Diamond Magnetite Outcrop, T 18 S, R 24 E, Cochise County, Ariz.

Magnetite with specular to earthy hematite and some oxidized copper minerals--malachite, azurite, and chrysocolla--and the sulfide chalcopyrite occur as irregular, tabular, contact metamorphic replacements of Paleozoic limestone associated with nearby granitic intrusives. The magnetite-hematite occurs massive to disseminated and in places constitutes a banded structure composed of layers of magnetite and limestone and quartz. The magnetite-hematite replacement body strikes northwest and dips 45° to 80° northeast.
It was noted in outcrops near the desert floor and was traced 600 feet steeply upslope to the top of the ridge. George Peverill of Benson, 1961 lessee, reported magnetite was in winze workings more than 300 feet below the bottom (Bagge) tunnel level.

The deposit had been mined for copper and silver since 1903. The ore was considered self fluxing, since it contained about 40 percent iron and 38 per-cent silica.

Underground workings were inaccessible during the investigation in 1961, and no estimate was possible of the quality and quantity of magnetite-hematitebearing rock remaining other than a statement that a favorable zone--about 2,000 feet long, 200 feet wide, and possibly more than 900 feet deep--contains magnetite-hematite-rich bodies that would require beneficiation to be of value as a local source of iron.

A character sample by the Bureau of Mines, taken in 1961, contained 44.6 percent iron, 0.44 percent copper, 0.2 percent titania, 0.02 percent phosphorus, 0.25 percent sulfur, and 20.4 percent silica. Samples taken by Fred A. Mattox, lessee, in 1947 contained about 40 percent iron and 38 percent silica. In 1947 Black Diamond mine was the property of Chas., Phillips of Yuma.

Gleeson Ridge (Courtland) Magnetite-Hematite

Disseminated magnetite, hematite, and limonite are associated with copper, lead, and zinc minerals and pyrite in the Turquoise mining district (73). Hematite and limonite are prominent in the oxidized zone at Tejon, Shannon, and Costello mines (5, fig. 1). The deposits are on Gleeson Ridge in the vicinity of the contact between Carboniferous limestone and a quartz monzonite intrusive in T 19 S, R 25 E, Gila and Salt River meridian and baseline.

Thickly disseminated magnetite, hematite, and limonite occur also as contact metamorphic-type occurrences in pyritic ores in the Cambrian Abrigo dolomitic limestones and shales west of the ghost towns of Courtland and North Courtland, T 19 S, R 25 E, Gila and Salt River meridian and baseline (5, fig. 1).

Magnetite occurs as an accessory mineral in Precambrian-Pinal schist at the foot of Reservoir Hill (5, fig. 1), about 1 mile northwest of Courtland; several square miles of similar Pinal schist crop out in the Dragoon Mountains about 5 miles west-northwest of Courtland and northwest of South Pass.

The deposits are not considered sources of iron ore.

Spike Hills (Iron Door) Hematite

Hematite is prominently exposed in Spike Hills (6, fig. 1) on the Iron Door claims in the NW 1/4 sec 17, T 13 S, R 25 E, Gila and Salt River meridian and baseline, north of Willcox. The property is reached by driving 6.5 miles northeast from Willcox on U.S. Highway 86 then 2 miles west. The Spike Hills (14) comprise a hogback of Precambrian quartzite and Pinal schist extending west-northwest about 0.5 mile and rising above the floor of Sulphur Springs valley about 150 feet.

Bluish-black films of hematite coat the many joint and fracture planes of the hard, white quartzite; almost pure, fine-grained, massive specular hematite is exposed in pocketlike concentrations as much as 4 feet thick in a bulldozer cut about 100 feet along the southwest slope. The deposit is indistinctly exposed in shallow prospect cuts and appears small. A character sample taken by the Bureau in 1961 contained 56.2 percent iron, 0.6 percent titania, 0.03 percent phosphorus, 0.30 percent sulfur, and 16.4 percent silica.

Coconino County

Deadman-Lonesome Pockets (Sycamore Canyon) Hematite

Hematite is prominent in Deadman and Lonesome Pockets Canyons, both (7, fig. 1) adjoining Sycamore Canyon. The hematite exposures, including the Iron, Iron King, and Mother Lode groups of claims were located during 1960 by A. Allen of Cottonwood, F. Schnitzler and Lydia Falkenhayn of Phoenix, and W. L. Hostetter of Black Canyon. Lonesome Pocket is a narrow steep-walled canyon in sec 29, T 19 N, R 3 E. Deadman Pocket is approximately in sec 27, T 19 N, R 3 E, Gila and Salt River meridian and baseline. The deposits are reached by driving 2 miles north from Perkinsville (Yavapai County) to a junction with the northeast trending road to Henderson Flats, NE4 sec 11, T 18 N, R 2 E, Yavapai County. From there proceed by difficult trails about 2 miles northeast to Lonesome Pocket and 7 miles farther to Bar Cross ranch and Deadman Pocket. The deposits are about 12 air miles north of Clarkdale.

Hematite is prominent in the rugged canyon walls as irregular, more or less bedded replacements in flat to gently dipping yellowish to red sandstone--probably Coconino sandstone of the Permian system--and can be traced for about 14 miles. The sandstone is overlain by Kaibab limestone and capped by Permian basalt. Part of the hematite is coated by caliche. The deposits range in quality from a dark red stained sandstone to almost pure bodies of specularite and hard, bluish-black hematite with weak malachite staining.

Assays of samples from the property are compiled in table 4.

TABLE 4. - Analyses of hematite samples from Deadman and Lonesome Pocket area, Coconino County, Ariz.

Sample	Fe, percent	Remarks
1.........	49.3	Surface sample by Frank Schnitzler, prospector, 1960.
2.........	55.3	Sample 3 feet below surface by Frank Schnitzler, 1960.
3.........	58.24	Sample below surface by Frank Schnitzler, 1960. Character
4.........	55.7	sample by Albert Allen, and other prospectors. Contains small amount of copper and gold.
5.........	41.1	Character sample by Albert Allen, and others. Contains small amount of gold and silver.

The deposits at this stage are prospects that require more exploration to establish their value. The general geology of the area is published (39).

Long Valley-Iron Mine Draw Hematite-Limonite

Small, irregular, replacement-type deposits of hematite-limonite in Tertiary, Kaibab limestone occur in the Long Valley-Iron Mine Draw District (8, fig. 1) in T 14 N, R 9 E. In places the clayey iron oxides are mixed with nodules and streaks of manganese oxides. A character sample of the red to brown iron oxides from the Last Chance property southwest of Clints Well and about 2 miles east of Iron Mine Draw contained 36.5 percent iron, 0.37 percent copper, 3.5 percent zinc, 31.5 percent silica, 7.82 percent alumina, 3.40 percent lime, and 1.73 percent magnesia. The deposits appear small, low grade, and irregular and are not considered an important source of iron.

Gila County

Introduction

Precambrian, Mescal limestone, a great host rock for magnetite and hematite in Gila County and the adjacent southwest part of Navajo County, extends interruptedly for many miles within an area 36 miles wide east-northeast by 90 miles long north-northwest, roughly delineated by Cristopher Mountain to the north, the Mescal Mountains to the south, Chediski Mountain to the east, and the west slope of the Sierra Ancha to the west. Mescal limestone varies widely in composition, appearing as much as 400 feet thick. It has been dilated, shattered, and metamorphosed into complex fault blocks by widespread intrusions of diabase as sills, stocks, and great local thickenings.

Magnetite and hematite occur as many, widely distributed, irregular pyrometasomatic and contact metamorphic replacements in the Mescal limestone; associated with great Precambrian to Tertiary diabase intrusives. The diabase itself contains as much as 30 percent magnetite in places; concentrations of magnetite were noted in the many stream beds and valleys below the readily erodable diabase. Prominent individual occurrences of magnetite and hematite are described separately. All locations in Gila County are made using the Gila and Salt River meridian and baseline as reference, and the Federal Bureau of Land Management protractions of June 23, 1960, for Arizona.

Baker and Carr Mountains Magnetite-Hematite

Magnetite and some hematite crops out along Baker and Carr Mountains (9, fig. 1) between Aztec Lodge and Workman Creek Falls, in the vicinity of Work-man Creek, in T 6 N, Rs 13 and 14 E. The deposits are accessible with difficulty on foot at 6,400 feet altitude and are poorly exposed.

A diabase sill, containing as much as 30 percent magnetite in its pegmatoid facies and nearly 1,000 feet thick, underlies the sedimentary rocks in this area of the Sierra Ancha. As a result of contact metamorphic processes, magnetite and some hematite have locally replaced certain calcareous and dolomitic beds of 250-foot-thick Precambrian, Mescal limestone. The magnetite-hematite deposits, where exposed, appear to be small and irregular replacements. A character sample on the La Ferra claims east of Aztec Lodge contained 67 percent iron. The deposits may prove to be a small local source of iron. There had been no production from the property from discovery of the iron until the investigation in 1961 (27, pp. 428, 435).

Bear Creek-Rock Creek Hematite

Hematite crops out in the steep west wall of Rock Creek canyon and around the canyon exposures (65, p. 23) between the confluence of Rock and Bear Creeks (10, fig. 1), approximately in secs 8, 9, and 17, T 8 N, R 15½ E. The hematite occurrence is about 4 miles southwest of the Chediski deposit. The deposit is reached by driving 16.5 miles northeast from Young post office towards Red Lake and the gate to the Fort Apache Indian Reservation and then about 10 miles south by jeep trails and across country.

Hematite, as contact-metamorphic replacements of flat to gently dipping Precambrian, Mescal limestone associated with thick diabase sill intrusives, can be traced intermittently more than a mile in the steep canyon walls of Rock and Bear Creeks. The hematite varies considerably in thickness and in quality. In much of the outcrop, high-grade hematite occurs in narrow discontinuous layers mixed with lower-grade earthy material, hematitic chert, and partly replaced limestone. The hematitic zone occurs just below a silicified and hematite stained algal member of Mescal limestone. This hematite is in the prospect stage and would require extensive exploration for evaluation. It is considered part of a broad areal hematite mineralization of the Precambrian, Mescal limestone by contact metamorphic processes, associated with widespread invasion by great diabase intrusions that have dilated and shattered it into complex fault blocks to form the deeply dissected Mesa-canyon terrain.

There was no production as of 1961.

Big Pig Magnetite

Magnetite occurs as irregular contact metamorphic and pyrometasomatic replacements in thin-bedded, gray dolomitic limestone (11, fig. 1) on the Big Pig group of claims, approximately in sec 4, T 1 N, R 12 E, in the Globe-Pinto Creek district, Pinal, and Gila Counties. The property is about 2 miles west of the Louis Horrell ranch, on the west fork of Pinto Creek. It is reached by driving 4 miles southwest from Miami on U.S. Highways 60-70, 2.4 miles north toward the Castle Dome mine, 9.4 miles northwest toward Pinto Creek and the Louis Horrell ranchhouse, and then about 2 miles west up the west fork of Pinto Creek. The deposit was located during 1958 as the Big Pig 1-3 claims by R. J. Edwards, J. D. and Fern Hughes, and W. C. Graham.

The magnetite occurs as nearly pure masses, as bands partially replacing Precambrian, Mescal limestone and as disseminations, associated with nearby diabase intrusives. Outcrops and float zones are exposed across an area extending about a thousand feet northwest in widths of as much as 200 feet. True dimensions were not obtainable without further exploration; the limestone dips as much as 30° variably.

A sample of the better magnetite ore contained 62.2 percent iron, 0.59 percent manganese, 0.03 percent copper, 0.05 percent lead, 0.30 percent zinc, 0.034 percent phosphorus, and 3.60 percent silica.

Individual bodies of magnetite appear small as a source of iron ore, however, others are known in the area and their aggregate along the contact of favored calcareous rocks with intrusives might prove large.

There had been no production from the property by 1961.

Black Mountain Hematite

Specular hematite (12, fig. 1) crops out in a dry wash northwest of the Black Mountain road along the south slope of the Black Mountain, approximately in secs 22 and 28, T 9 N, R 10 E. Black Mountain consists of an irregular mass of rhyolite and a pebble conglomerate. Films of specular hematite occur along the joints and fractures in the conglomerate, and veinlets of specularite as much as 2 inches thick are exposed in the dry wash. The hematite is exposed in small scattered outcrops in the dry wash and the occurrence is believed to be small. A 1961 character sample of the better hematite taken by the Bureau contained 55.9 percent iron, 1.9 percent titania, 0.1 percent manganese, 0.02 percent phosphorus, 0.07 percent sulfur, and 14.8 percent silica.

There had been no production from the property by 1961.

Bottle Spring (Hope-Lucky) Hematite

Hematite crops out (fig. 4) about 11/4 miles northeast of Bottle Spring (13, fig. 1), approximately in adjoining secs 29 and 32, T 10 N, R 15 E, on

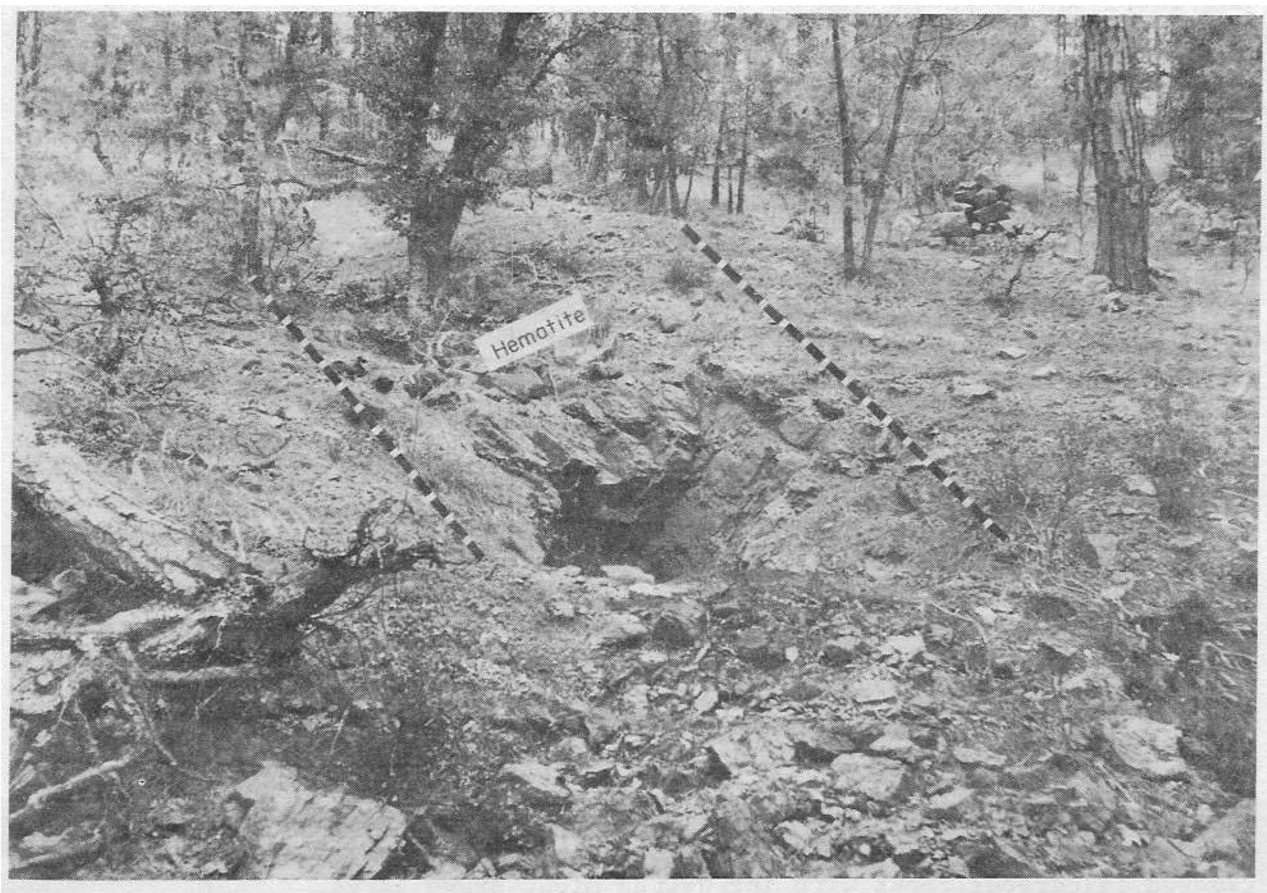

FIGURE 4. - Hematite Outcrop, Hope-Lucky Claims, Vicinity of Bottle Spring, T 10 N, R 15 E, Gila County, Ariz.

the Hope and Lucky groups of claims located by W. Henderson and D. Clark of Globe. The occurrence is reached by driving 10.9 miles northeast from Young post office towards Bottle Spring and then 2 miles north to the claims and outcrops.

The deposit occurs as a contact-metamorphic replacement of Precambrian, Mescal limestone, having a gentle 35° dip and trending northeast and west. It is associated with large granitic and diabase intrusives. Massive, bluish-black hematite as much as 20 feet thick can be traced about 300 feet east on the Hope claim No. 1; it is overlain by hard, hematite-stained, and siliceous limestone comprising an algal bed of the Mescal limestone. The hematite-stained silicified limestone and hematite crop out again on the Hope claims Nos. 2 to 4 and in Parallel Creek canyon to the north and west. Thus, hematite replacement of limestone can be traced intermittently more than a mile by outcrops, float, and hematite staining. In parts of the outcrop, replacement of the limestone beneath the silicified algal member of the Mescal limestone is incomplete and observable hematite may be mixed with impure, earthy hematite, hematitic chert, and limestone host rock; in other parts the hematite may be nearly pure. A character sample taken by the Bureau in 1961 contained 51.8 percent iron, 0.1 percent manganese, 0.4 percent titania, 0.34 percent phosphorus, 0.10 percent sulfur, and 21.0 percent silica. The deposit should be considered part of the hematite mineralization of a great area of the Precambrian, Mescal limestone by contact-metamorphic processes associated with widespread invasion by great diabase intrusions.

Hematite of variable quality is exposed also in a few shallow pits and cuts (fig. 4). There has been no production from the deposit to date (1961).

This hematite occurrence, like those mentioned under Navajo County, is considered part of a much larger hematite-rich area in northeastern Gila County and southwestern Navajo County and adds to the hematite resource potential of the area. The results of pioneer beneficiation testing are reported on pages 144-145 and in table 46.

Christmas Mine Cupreous Magnetite

Masses and disseminated bodies of magnetite are prominent in garnet zones at the Christmas mine (14, fig. 1) in the southeast Dripping Spring Mountains, Banner mining district. The Christmas mine is in T 4 S, R 16 E, and is reached by driving 29 miles south from Globe on U.S. Highway 70 and Arizona Highway 77 to the Christmas junction and then 1 mile west. The Christmas is a copper mine of the Inspiration Consolidated Copper Co.

Cupreous magnetite with some pyrite and pyrrhotite occurs as contact metamorphic and pyrometasomatic replacements in upper Paleozoic limestones along their contacts with Tertiary quartz diorite intrusives. The limestone dips about 10° southwest but varies considerably near the borders with intrusives. Paleozoic formations containing cupreous magnetite are the Naco, Escabrosa, and Martin limestones.

Principal primary minerals are chalcopyrite, bornite, magnetite, pyrite, sphalerite, and pyrrhotite. Magnetite and pyrite are most abundant close to the limestone-diorite contact and in narrow blocks of limestone between diorite dikes. Magnetite becomes increasingly abundant in depth, and much of the ore on and below the 800 level contains so much magnetite that it completely masks the copper minerals. Gangue consists of garnet, idocrase, epidote, diopside, tremolite, quartz, and partly replaced limestone. Reserves, reported[4] as copper ore, are more than 20 million tons, averaging 1.83 percent copper.

In the 1,000-foot-thick Pennsylvanian and Permian, Naco limestone the cupreous magnetite deposits, 5 to 12 feet thick and as much as 200 feet wide, occur in several favorable beds as gently dipping tabular replacements in garnetized zones between thin shale and shaly limestone beds. Magnetite and pyrite are most abundant near the limestone-diorite contacts.

In the massive, crystalline Mississippian, Escabrosa limestone, 550 feet thick, the cupreous magnetite occurs as irregular massive replacements near and along the limestone-quartz diorite contacts. Vertical dimensions of the deposit are usually greater than horizontal thicknesses. The deposits terminate abruptly into marbleized limestone away from the contacts. Other deposits occur in limestone blocks surrounded by diorite and in embayments between dikes that project from the main intrusive. Magnetite and pyrite commonly predominate near the contacts, while sphalerite is localized in the outer margins of the deposits. Sizeable ore bodies are indicated wherever the limestones are in contact with main intrusives.

The Devonian, Martin limestone, 265 feet thick, has been extensively replaced by cupreous magnetite. Development indicates an extensive replacement on the 1,300 to 1,400 levels, covering an area about 2,700 feet in width across intrusives and 5,000 feet in length (N-S) along intrusive contacts. Magnetite is predominant throughout, comprising as much as 25 percent of the deposits. The deposits are gently-dipping, massive, and tabular and are in thin-bedded, dolomitic, and shaly limestones along the limestone-diorite contacts.

Magnetite reserves in the area may prove large; however, their use as a source of iron would require beneficiation, agglomeration, and special metallurgical adaption (19, pp. 1-6; 51, p. 363; 57; 61; pp. 59-60; 69, p. 58).

Christopher Mountain Hematite

Hematite crops out on Christopher Mountain (15, fig. 1), approximately in sec 36, T 11 N, R 12 E, and is accessible with difficulty. The hematite is indistinctly exposed as float and sporadic outcrops, at the heavily timbered crest and down the north slope.

This hematite occurrence is one of many similar contact-metamorphic replacements of Precambrian, Mescal limestone associated with diabase intrusives.

[4] Inspiration Consolidated Copper Co. Annual Report. Dec. 31, 1961, p. 17.

The full extent of the deposit cannot be determined without more detailed exploration.

There was no production as of 1961.

Circle Ranch Magnetite-Hematite

A number of places are known in the Sierra Ancha region where magnetite and hematite have locally replaced Precambrian, Mescal limestone at or near contacts with diabase intrusives. The deposits (16, fig. 1) are often small or masked by rock debris. Outcrops occur on the Circle Ranch in the following areas:

1. Northwest of the Circle Ranch buildings in sec 1, T 6 N, R 13 E, Gila and Salt River meridian and baseline.

2. The SE ¼; sec 6, T 6 N, R 14 E.

3. The SW ¼ sec 18, T 6 N, R 14 E.

4. The south center of sec 29, T 6 N, R 14 E.

5. The NW ¼ sec 32, T 6 N, R 14 E.

6. Hematite float on the southwest slope of Center Mountain in sec 21, T 6 N, R 14 E.

7. Hematite similar to that at the Apache deposit in sec 15, T 6 N, R 14 E.

8. Hematite in sec 28, T 7 N, R 15 E, along Rock House Creek.

There had been no production by 1961.

Coon Creek (Willyerd-Baker) Hematite

Hematite crops out in mesa-canyon terrain between northwest trending Coon and Deep Creek canyons (17, fig. 1) of the Sierra Ancha, approximately in secs 13, 23, and 24, T 5 N, R 14 E, about 3 miles west along Bull Creek. The out-crops are on the Iron King, Baker, Willyerd, Jack, Jerry, Wilma, and other claims owned by Cletus Baker and Wayne Willerd of Phoenix and Tempe.

Rocks cropping out on the claims are flat to gently dipping, gray to tan, dense to finely crystalline limestone with thin lenses of brown to black chert, comprising the Precambrian, Mescal limestone, and overlying Troy quartzite.

Hematite occurs as irregular, contact-metamorphic replacements of Mescal limestone, associated with nearby diabase intrusives. The hematite is exposed as dark-red, hard to pulverulent replacement bodies; as bluish-black kidney-botryoidal masses; and as float. Three exposures in the upper Mescal lime-stone were examined. On the Iron King 1 claim, a channel sample along a thickness of 3 feet contained 46.42 percent iron. A second sample from a prospect pit 1,300 feet east of the first location contained 40.40 percent iron. A top-to-bottom section down the prospect pit included 8 inches of pink quartzite; 36 inches of red, slightly siliceous hematite; 11 inches of fine, slabby quartzite with some interbedded clay; and 36 inches of massive red hematite with abundant kidney-botryoidal hematite in the bottom portion. The bottom of the 7- by 6-foot excavation remained in identical material.

A third outcropping, 600 feet south of the second, on the eastern part of the Iron King 1 claim is poorly exposed but appears at least 3-feet thick.

Prospecting has revealed several good exposures of hematite, traceable northeast in widely distributed and unconnected outcrop and float areas for about 10,000 feet.

This hematite occurrence requires further prospecting and exploration to determine its true potential.

Delshay Basin Magnetite-Hematite

Beds of magnetite-ilmenite-hematite rich quartzite-semitaconite form part of an extensive Precambrian greenstone and schist sequence in Delshay Basin (18, fig. 1) and occupy an area approximately 1/4 mile wide and 1 mile long. Delshay Basin is approximately in S½ T 8 N, R 11 E, in very rugged terrain (fig. 5) at about 4, 500 feet altitude. The occurrence is reached from Tonto Basin (Punkin Center) post office by driving 12 miles north to the Seventy-Six ranch in sec 13, T 8 N, R 10 E, and 13.5 miles by jeep over steep and tortuous trails to the rim of Delshay Basin, then by walking about 5 miles down into the basin.

The magnetite-ilmenite-hematite occurrence crops out as lenticular and individual masses as much as 50 feet wide. There are gradations between nearly pure titaniferous magnetite and hematite, titaniferous hematite, and ferruginous quartzite. The material reportedly (54) was laid down in Precambrian time as a magnetitic sand and has been folded and squeezed with the other rocks of the schist complex. The iron formation trends northeast and dips steeply northwest (54, pp. 155-157).

This is a low-grade iron formation similar to that on the Iron King and Pig Iron groups of claims to the northeast and may be an extension of them.

Dry Creek (Last Chance-Lucky Strike) Hematite

Hematite crops out on the Last Chance 1 to 7 group of claims (19, fig. 1), approximately in secs 7, 8, 18, and 19, T 10 N, R 14 E. In 1961, the claims were the property of S. V. Gillette, E. H. Tallant, and H. H. Davis of Young. The claims may be reached by driving 4.4 miles north from Young post office, 13.5 miles northwest towards the Dry Creek access road, 2 miles east to the end of the road, and about a mile northeast on foot along Dry Creek. Abundant hematite float was noted along Dry Creek.

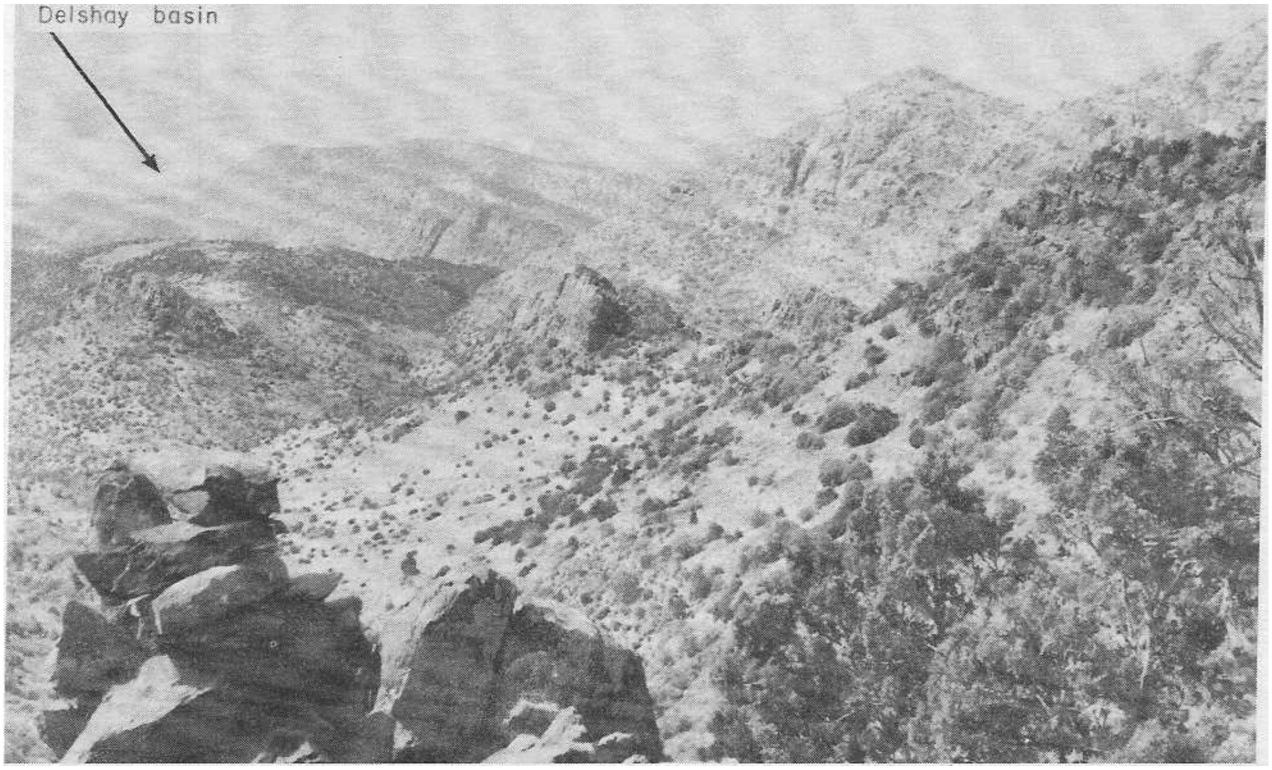

FIGURE 5. - Delshay Basin From Iron King Claims, T 8 N, R 11 E, Gila County, Ariz.

Hard blue-black to red hematite and specularite occur as irregular contact-metamorphic replacements in Mescal limestone that strikes northwest, dipping from 10° to 20° northeast. The limestone is associated with nearby diabase intrusives. Abundant high-grade hematite float is noted in Dry Creek and high on the steep slopes of the canyon. Outcrops are scanty and poorly exposed due to heavy overburden, brush, and timber. The hematite zone was traced by float for about a mile in widths of as much as 50 feet. A character sample of the hematite contained 54.0 percent iron, 0.1 percent manganese, 0.3 percent titania, 0.03 percent phosphorus, 0.08 percent sulfur, and 21.4 per-cent silica.

This hematite occurrence is in the prospect stage, and any further evaluation would require extensive exploration. It is considered to be part of the broad areal hematite mineralization of the Mescal limestone by contact-metamorphic processes during the time when the limestone was dilated and shattered by widespread diabase intrusions. There was no production as of 1961.

Magnetite occurs as irregular, pyrometasomatic replacements in a thin-bedded, crinkled, gray dolomitic limestone (20, fig. 1) on the Fern group of claims, approximately in sec 6, T 1 N, R 14 E, in the Globe-Pinto Creek district. The property is reached by driving 4 miles southwest from Miami on U.S. Highway 60-70, 2.4 miles north towards the Castle Dome mine, 9.4 miles northwest towards Pinto Creek and the L. Horrell ranchhouse, and then 2.3 miles east to the magnetite outcrops. The property was located as the Fern group of claims in 1958 by J. D. and Fern Hughes and R. J. Edwards. The claims have been developed by shallow pits.

The magnetite occurs as nearly pure masses, as bands partially replacing Mescal limestone, and as disseminations, associated with nearby diabase intrusives. The magnetite-rich zone was traced by outcrops and float over an area about 500 feet wide and 1,000 feet long, along the dissected slopes of an east trending ridge.

The deposit of predominantly banded and mixed magnetite and limestone is as much as 50 feet thick and dips about 25° north. Two character samples from the Fern claims are shown in table 5.

TABLE 5. - Analyses of Fern claims magnetite, Gila County, Ariz.

Sample	Chemical analyses, percent								Remarks
	Fe	TiO_2	Mn	P	S	Zn	MgO	SiO_2	
1.....	65.7	0.1	0.1	0.04	0.1	-	-	2.6	Bureau of Mines, 1959.
2.....	67.8	-	.79	.033	.22	Trace	0.07	1.76	Courtesy of one of locators. R. J. Edwards, 1961, Coolidge, Ariz.

Individual bodies appear small as a source of iron ore, however, others are known in the area and their aggregate along the contact of favored calcareous rocks with intrusives may prove potentially large.

There had been no production from the property as of 1961.

Fourth of July Magnetite

Magnetite occurs as irregular replacements below the algal member of the Mescal limestone, associated with a thick diabase sill intrusive, at the Fourth of July asbestos mine (21, fig. 1). The property included 13 claims in 1960 in the Seneca (chrysotile) mining district, approximately in sec 26, T 5 N, R 16 E;[5] it is controlled by Carley L. Moore (1960) of Globe.

[5]U.S. Bureau of Land Management. Protraction Diagram No. 57. June 23, 1960.

The property is reached from Seneca (Cienega) on U.S. Highway 60 by driving 6. 3 miles northwest over dirt roads towards the Regal asbestos mine and a road junction, then about 3.5 miles southwest to the Fourth of July mine.

A bulldozer cut and short drill holes partly expose 16 feet of magnetite replacing flat to gently dipping Mescal limestone beneath a diabase sill. The better portions of the deposit contain about 60 percent iron, 3 percent lime, and negligible amounts of sulfur, phosphorus, and titania. The magnetite is incompletely exposed but may prove extensive.

There had been no production by 1961.

Gentry Creek (Frog Pond) Hematite

Hematite estimated to be as much as 20 feet thick occurs as a contact metamorphic replacement in flat-lying Mescal limestone associated with diabase intrusives that contain considerable magnetite. Hematite outcrops (figs. 6, 7) were traced on the Lady Bug-Minnie groups of claims along Gentry Creek (Frog Pond) canyon (22, fig. 1) and along the slopes of the mesa between Gentry

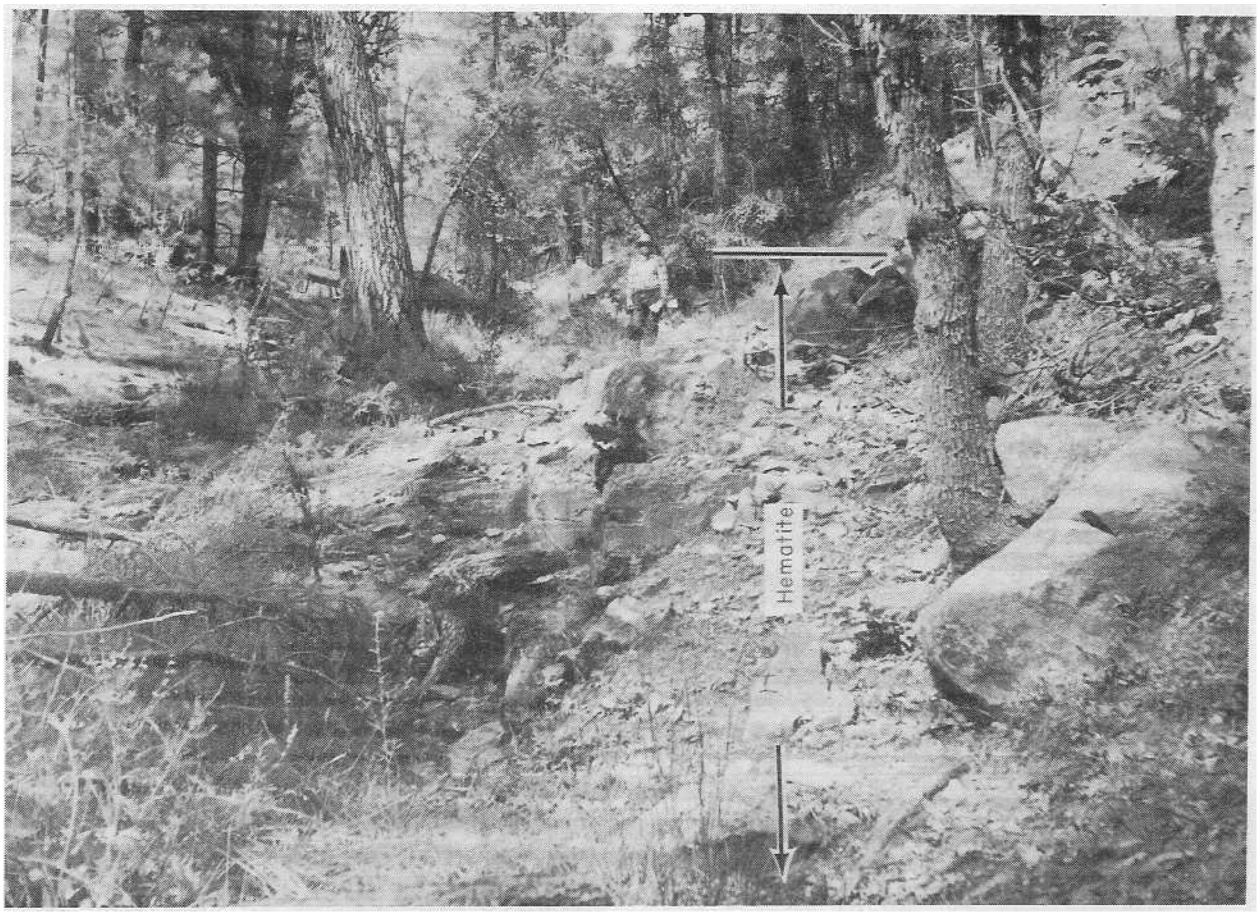

FIGURE 6. - Hematite Outcrop, Lady Bug No. 1 Claim, T 9 N, R 15 E, Gila County, Ariz.

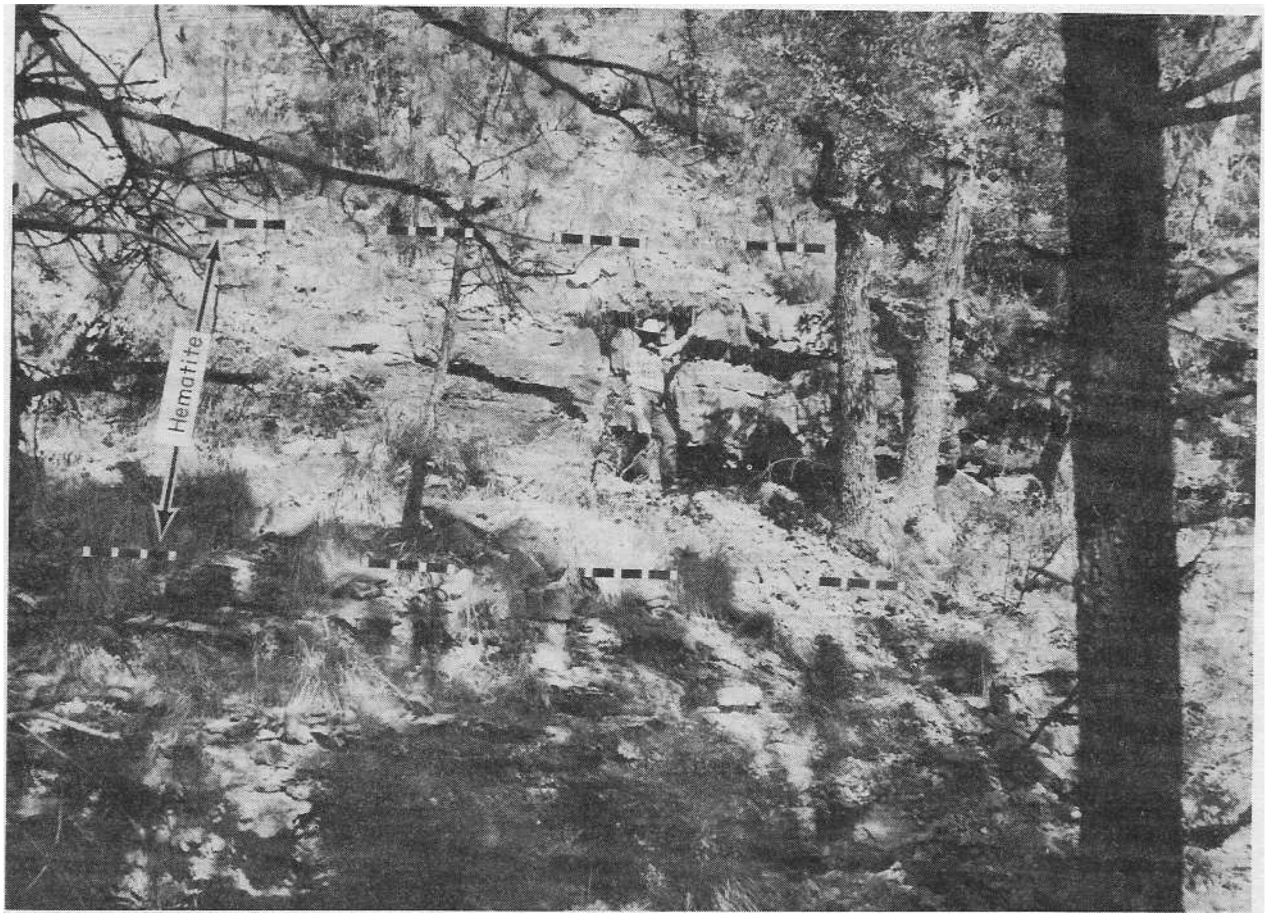

FIGURE 7. - Hematite Outcrop, Gentry Creek Canyon, T 9 N, R 15 E, Gila County, Ariz.

Creek and the old Nail ranch, approximately in secs 8, 16, 17, T 9 N, R 15 E. Outcrops and float can be traced interruptedly more than a mile in faulted and rugged mesa-canyon terrain below a capping of white Chediski sandstone.

The Lady Bug and Minnie groups of claims are the property of Alfred Haught, and others of Young and are reached by driving 12.1 miles north and east from Young post office over good dirt roads, and 1.0 mile south to Frog Pond and the head of Gentry Creek. Proceed on foot down Gentry Creek canyon south and east along Gentry Mesa for several miles.

Analyses of character samples by the Bureau during 1959-61 are included in table 6.

Semi-quantitative spectrographic analysis of sample 2 indicates the presence of 0.01 to 0.1 percent cobalt, copper, and nickel and 0.001 to 0.01 per-cent vanadium.

The deposit is one of many similar hematite occurrences in this part of Gila County and part of Navajo County (fig. 1), it should be considered as part of the broad, contact-metamorphic replacement of the Mescal limestone that has been dilated and shattered into a complex of fault blocks by wide-spread intrusions of diabase. There had been no production as of 1961.

TABLE 6. - Analyses of hematite samples from Frog Pond (Lady Bug-Minnie) hematite deposit, Gila County Ariz.

Sample	Chemical analyses, percent						Remarks
	Fe	TiO_2	Mn	S	P	SiO_2	
1.....	63.7	0.1	0.1	0.1	0.31	6.2	Mesa outcrop between Gentry Creek (Frog Pond) and old Nail ranch, sec 16, T 9 N, R 15 E.
2.....	35.4	.4	.4	.08	.20	37.6	Outcrop near confluence Gentry and Shell Creeks, sec 16, T 9 N, R 15 E.
3.....	52.4	.5	.2	.05	.48	19.8	Outcrop in bottom of Gentry Creek approximately in sec 17, T 9 N, R 15 E, Lady Bug No. 1_claim._

Gentry Mesa Hematite

Hematite (65, p. 23) crops out along the south slope of Gentry Mesa and canyon {23, fig. 1), opposite Shell Mountain, approximately in secs 21, 22, 27, and 28, T. 9 N, R 15 E. It is reached by driving 11 miles north and east from Young post office and 4 miles south on the Q-ranch road along Gentry Creek, then on foot about 3/4 mile east to the outcrops (fig. 8).

Hematite crops out intermittently 2,000 feet eastward in a zone as much as 50 feet thick. The zone comprises high-grade bodies of hematite, observed as much as 10 feet thick interlayered with lower-grade ferruginous material, as a contact-metamorphic replacement of gently dipping Mescal limestone in complexly faulted mesa-canyon terrain. Hematite occurs just below a silicified and hematite stained algal member of the Mescal limestone and above a thick diabase intrusion.

This occurrence could not be delineated without detailed exploration and geologic mapping.

A sample of the better hematite-rich outcrop taken by the Bureau in 1961 contained 64.1 percent iron, 0.1 percent manganese, 0.2 percent titania, 0.15 percent phosphorus, 0.08 percent sulfur, and 7.2 percent silica. A semiquantitative spectrographic analysis indicated the presence of 0.001 to 0.01 percent vanadium, and 0.01 to 0.1 percent copper, cobalt, and nickel.

This hematite occurrence, like those mentioned under Navajo County, is considered part of a much larger hematite-rich area and adds to the resource potential.

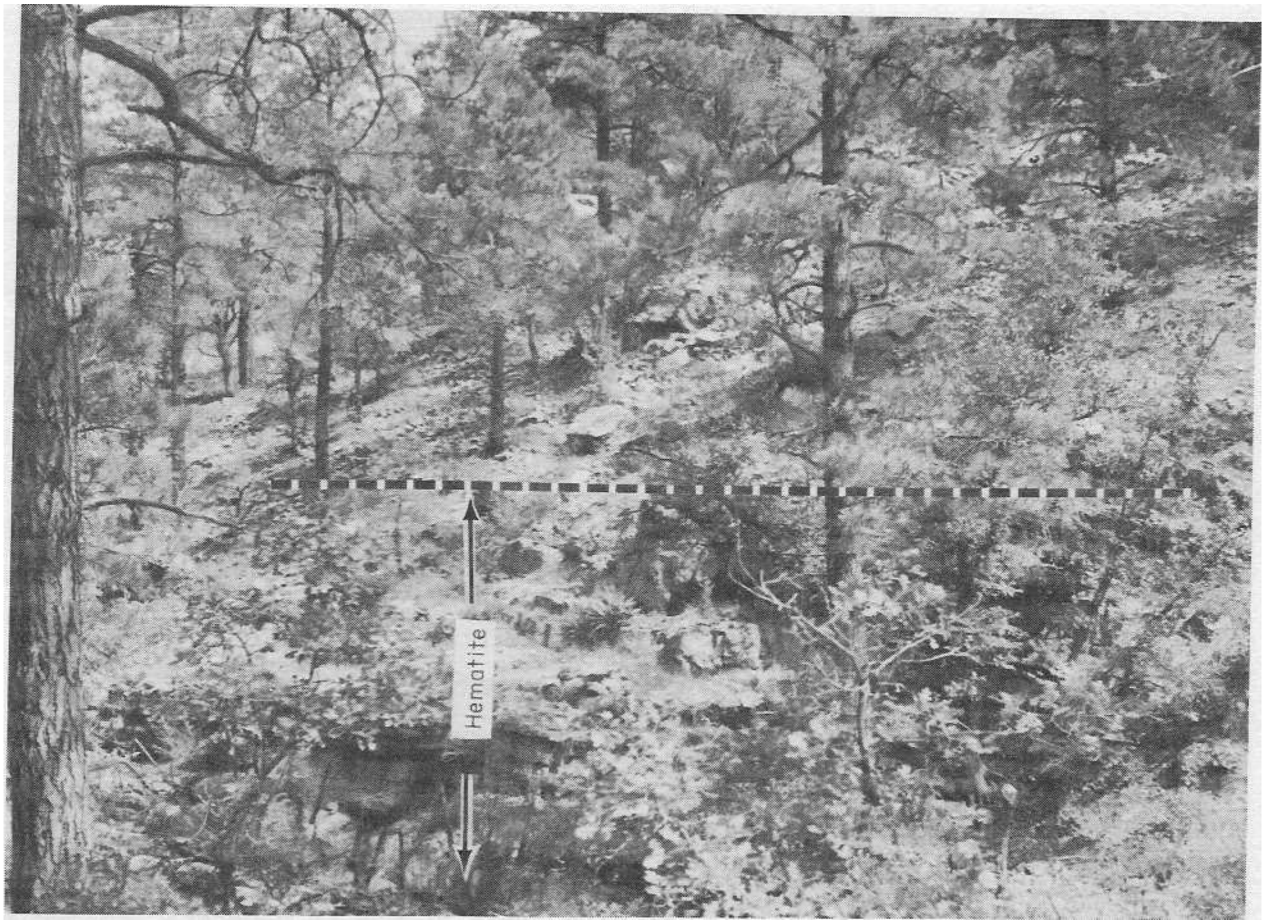

FIGURE 8. - Hematite Outcrop, Gentry Mesa, T 9 N, R 15 E, Gila County, Ariz.

Globe District Hematite-Limonite

Hematite and limonite with oxidized copper minerals are widespread in the Globe mining district (24, fig. 1). Specularite is common in quartzite and limestone, with limonite grading into ocher common in limestone. Hematite occurs usually as an envelop between copper ore and the surrounding limestone (58, 59).

Great View Magnetite

Magnetite as contact-metamorphic and pyrometasomatic replacements associated with diabase intrusions crops out at various places in the algal member of the Mescal limestone on the Great View group of asbestos claims (25, fig. 1) in the NE4 sec 35, T 5 N, R 17 E. The claims are on the San Carlos Indian Reservation, about half a mile east of the southern extremity of Mule Hoof Bend on the Salt River and west of U.S. Highway 60.

The deposit appears small but additional exploration of the area seems justified. The property was developed as a source of chrysotile asbestos (67, pp. 62-63).

Griffin Wash (Walnut Spring) Magnetite

Magnetite in rounded to angular particles, ranging in size from sand to boulders, is concentrated in alluvial deposits of unknown extent in the Griffin Wash (Walnut Springs) drainage (26, fig. 1). The deposits occur on the dissected slopes of the Sierra Ancha between Zimmerman Point and Asbestos Peak (fig. 9) in Tps 4 and 5 N, R 14 E, east of the Globe-Young highway and 8 miles north of the Salt River crossing. The deposits originated from the extensive magnetite occurrences high on the west slope of the Sierra Ancha Mountains between Zimmerman Point and Asbestos Peak.

A character sample of the better magnetite taken in 1959 contained 68.4 percent iron, less than 0.1 percent titania, 0.2 percent manganese, 0.06 percent phosphorus, 0.11 percent sulfur, and 1.4 percent silica.

There had been no production from the property as of 1961.

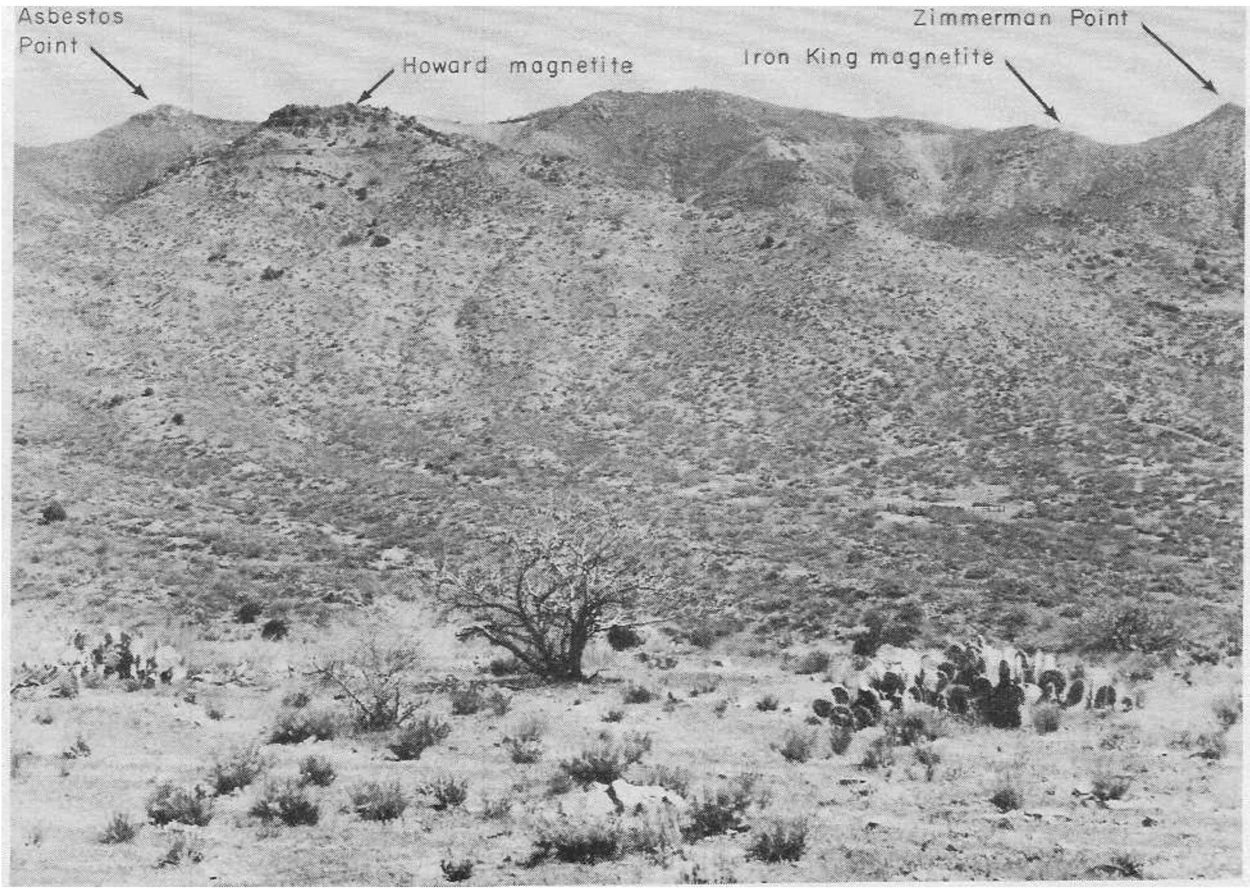

FIGURE 9. - Howard and Iron King Magnetite Deposits, T 5 N, R 10 E, Gila County, Ariz.

Haigler and Gordon Creeks Magnetite-Hematite

Magnetite and hematite occur along the Haigler Creek drainage (27, fig. 1) on the El Paso, Escondido, La Paloma, and Log Cabin claims (fig. 10), approximately in secs 6 and 7, T 10 N, R 14 E. The claims are the property of S. V. Gillette and others, of Globe and Young. The deposit is reached by driving 4.3 miles north of the Young post office, 10 miles north-northwest on the Payson road and 2.5 miles east to the Escondido claim magnetite outcrop.

Magnetite occurs as replacements (fig. 10) in Mescal limestone associated with local intrusives, probably diabase. The limestone trends northwest and dips 20° northeast. Magnetite observed as much as 40 feet thick can be traced by outcrop and float for more than 1,000 feet along a ridge in rugged and heavily forested terrain on the Escondido claims. A prospect shaft penetrated 10 feet of hard white limestone and 35 feet of magnetite. The bottom was in magnetite. To the west-northwest, along the general strike, magnetite crops out on the la Paloma claim. Steel-like, hard specularite and red hematite was noted as float in the heavy soil-timber cover. Because of the overburden, no dimensions could be determined. Hard, specular hematite and magnetite in

FIGURE 10. - Magnetite Outcrop, Escondido Claims, T 10 N, R 14 E, Gila County, Ariz.

angular masses as much as 2 feet thick were noted in Walnut Springs Canyon about 0.5 mile above its junction with Gordon Canyon. About 3 miles north, magnetite replaces Mescal limestone in a road cut in sec 29, T 10 1/2 N, R 14 E.

Analyses of samples of the magnetite are included as table 7.

TABLE 7. - Sampling data, Escondido, El Paso, La Paloma, and Log Cabin iron deposit, Gila County, Ariz.

Sample	Chemical analyses, percent						Remarks
	Fe	Mn	TiO_2	P	S	SiO_2	
1......	41.50	0.11	-	-	-	-	Dark, fine-grained magnetite from 45-foot shaft dump, Escondido claims; Bureau of Mines, 1942.
2......	44.05	.03	-	-	-	-	8-foot vertical chip sample down side of an opencut, Escondido claim; Bureau of Mines, 1942.
3......	43.6	.2	0.2	0.01	0.05	5.4	Character sample of magnetite. General grab, Escondido, El Paso La Paloma and Log Cabin claims; Bureau of Mines, 1961.

No clear picture of the extent and general quality of the iron present could be obtained, however, more detailed exploration of the area may prove extensive reserves.

Other occurrences of magnetite and hematite reportedly occur as scattered outcrop and float areas between Haigler and Gordon canyons (16, p. 230; 65, p. 23) . There was no production as of 1961.

Horse Camp Creek-Rock House Hematite

Hard and soft hematite crops out in the Precambrian, Mescal limestone 2 miles south of the Rock House, on the Q-Ranch (28, fig. 1) near the head of Horse Camp Canyon and about a mile west of Brushy Top Mountain, approximately in sec 28, T 7 N, R 15 E. The deposit was located as the Crater group by Robert Le Tourno of Young. The hematite crops out in 5 to 20 foot thicknesses of variable quality on the northwest side of Horse Camp Creek Canyon about 3 miles above its confluence with Cherry Creek (65, p. 23).

There had been no production by 1961,

Howard Magnetite

Magnetite was noted on the Howard 1 to 5 group of claims, located by W. W. Cline and H. M. Seitz of Tempe, Ariz. The deposit (29, fig. 1) is about 38 miles north of Miami, approximately in secs 29 and 30, T 5 N, R 14 E, in the same general area as the Zimmerman Point deposits (fig. 9) and about 3/4 mile south from American Ores Co., asbestos mine. The deposit occurs as a contact metamorphic or pyrometasomatic replacement of Mescal limestone, associated with diabase intrusives. Magnetite is indistinctly exposed as a bed more than

6 feet thick, dipping 10° north, and it can be traced by outcrop and float for more than 1,000 feet along its east strike. A character sample by the Bureau in 1961 contained 56.7 percent iron, 0.2 percent titania, 0.1 percent manganese, 0.02 percent phosphorus, 0.08 percent sulfur, and 10.0 percent silica. Another analysis reported 57.9 percent iron, 0.19 percent titania, 0.12 per-cent manganese, 0.005 percent phosphorus, 0.010 percent sulfur, 4.95 percent silica, 2.48 percent magnesia, 0.59 percent alumina, 0.070 percent lime, and 0,01 percent arsenic. Other samplings contained as much as 63.4 percent iron. Random shovel samples averaged 83 percent magnetite. The deposit is one of many similar occurrences in the area that in aggregate comprise a large potential source of iron.

Development in 1961 included construction of 1.5 miles of access road and a concrete pad, near Arizona Highway 288, sufficient for storage of several hundred tons of ore. Further, small shipments of magnetite were made to the iron industry in the Phoenix area,

Iron Group Hematite

Masses of hematite occur on the Iron group of claims (30, fig. 1), about half a mile south of the Southern Pacific Railroad tracks in the SW 1/4 sec 16, T 1 S, R 18 E, in the southwestern part of the San Carlos Indian Reservation, in Gila County. The hematite occurs as large irregular masses within a fault zone between Paleozoic and Tertiary limestone-siltstone formations. The hematite crops out northwest about 150 feet, dipping 60° northeast. Red soil col-orations indicate extensions for an additional 250 feet. The hematite appears to be partly a replacement of limestone breccia and partly a filling of fractures. In places, large masses of unreplaced limestone-chert breccia are in contact with massive hematite; in other places the contact is gradational. Some of the hematite masses contain unreplaced chert fragments. The hematite is colored black to red but is commonly red. Its texture grades from compact to pulverulent and it varies in quality from nearly pure hematite (± 60 per-cent iron) to impure earthy hematite, fracture fillings, and coatings averaging less than 30 percent iron.

The deposit has been developed by a vertical shaft, reportedly 100 feet deep but now inaccessible; two short adits; and several shallow cuts and pits on the northwest slope of a hill. Depth of the deposit could not be deter-mined; however, indications are that it is 20 to 100 feet deep (9, p. 638).

The deposit is considered small. There had been no production by 1961.

Iron King Group Titaniferous Hematite

Hematite with some magnetite, ilmenite, and limonite (31, fig. 1) occurs as a large low-grade deposit within a thick schist-quartzite-arkosic sandstone sequence in the Yavapai series of the Precambrian age as a taconite or semitaconite-like iron formation.

The deposit was located during 1958 as the Iron King group of 31 lode claims by W. H. and E. M. Stockman, L. L. Elsworth, and H. Hunt of Globe. It is reached from Tonto Basin post office by driving 12 miles north to the 76 ranch in sec 13, T 8 N, R 10 E, 10.8 miles east and south by jeep across steep and tortuous access roads beyond Turkey Flat to where the outcrop parallels the road, and about 3 miles farther, southwest, along the road and outcrop to the rim of Delshay Basin. The property is in a remote northern area of the Sierra Ancha, in the Tonto National Forest. It is roughly parallel to a similar iron formation known as the Pig Iron group of claims (36, fig. 1) a mile southeast; it may be a parallel structure or a repetition of the same structure due to folding and/or faulting. The iron formation strikes N 50° to 60° E, and dips 60° NW to vertical, passing approximately through unsurveyed sec 19, T 8 N, R 12 E, and secs 24, 25, and 26, T 8 N, R 11 E, in the Spring Creek District. The terrain is deeply dissected and rugged (fig. 11). The Iron King group of claims follows along the outcrop (fig. 11) and southwest about 2.5 miles paralleling Skunk Tank Ridge and Sorrel Horse Canyon, to the rim of Delshay Basin (fig. 5). The iron formation continues further, into Delshay Basin (54).

Cursory and reconnaissance investigations have indicated that the Precambrian iron formation is 1,000 feet or more wide, more than 2.5 miles long, and

FIGURE 11. - Titaniferous Hematite Outcrop, Iron King Claims, T 8 N, R 11 E, 1 Mile Southwest of Delshay Basin, Gila County, Ariz.

of varying iron content. Iron in the outcrops of the formation consists chiefly of hematite with some magnetite, specularite, and limonite. The magnetite is probably residual. Titania is present as ilmenite. Results of reconnaissance sampling are shown in table 8.

TABLE 8. - Results of reconnaissance sampling, Iron King group of claims, secs 24-26, T 8 N, R 11 E, Gila County, Ariz.

Sample	Chemical analyses, percent						Remarks
	Fe	TiO_2	Mn	P	S	SiO_2	
1......	42.0	8.7	0.2	0.10	0.10	23.4	Grab sample of high-grade hematite along outcrop; Bureau of Mines, March 1961.
2......	39.0	9.8	.1	.06	.08	27.4	Grab sample of hematite along outcrop; Bureau of Mines, August 1961.
3......	40.5	9.3	.15	.08	.09	25.4	Metallurgical chip sample; Bureau of Mines, August 1961.

Spectrographic analysis of sample 1 indicates the presence of more than 10 percent iron, titanium, and silicon, 1 to 10 percent aluminum, 0.1 to 1.0 percent calcium and magnesium, and 0.01 to 0.1 percent, respectively, of cobalt, chromium, copper, nickel, vanadium, and zirconium.

The calculated mineral content of sample 1 was 51 percent hematite and 16.5 percent ilmenite.

Fractures in the iron formation are filled with white quartz, ranging from 1/16 inch to several feet thick. Some of the iron formation is a very hard quartzite; part is a softer sandstone and schist.

No attempt was made in 1961 to map or systematically sample and explore the iron formation because of its inaccessibility and its titania content. However, this deposit may be a very large low-grade resource for the future, when its relations to other large and nearby iron formation extensions (18, 36, fig. 1) are established.

Kennedy Ranch Magnetite

Magnetite occurs as irregular contact metamorphic and pyrometasomatic replacements of thin-bedded, gray, dolomitic limestone (32, fig. 1) on the Kennedy Ranch group of claims in the Globe-Pinto Creek District, approximately in sec 12, T 1 N, R 12 E, and sec 7, T 1 N, R 13 E. The deposit is 6 miles west of the Louis Horrel ranchhouse and 4 miles west of the Big Pig magnetite deposit on the west fork of Pinto Creek. It is reached by driving 4 miles southwest of Miami on U.S. Highway 60-70, 2.4 miles north towards the Castle Dome mine, 9.4 miles northwest towards Pinto Creek and the Louis Horrel ranch-house, then about 6 miles west along the west fork of Pinto Creek--4 miles beyond the Big Pig magnetite--to the Kennedy ranch. An alternate route follows the Haunted Canyon road west 9 miles and northwest 7 miles to the Kennedy ranch. There has been no production from the property.

Magnetite occurs as nearly pure masses, as bands partially replacing Mescal limestone, and as disseminations, associated with nearby diabase intrusives. The deposit is sketchily delineated by small outcroppings and by irregular float zones. True dimensions were not obtainable without further, more detailed exploration. The deposit is identical to the Fern and the Big Pig deposits and many other replacements of Mescal limestone in the county.

The magnetite deposit as an individual and irregular replacement appears small; however, the proximity of other deposits in the area indicates more widespread replacement, and their aggregate and possible extensions along the contact of favored calcareous rocks and intrusives may prove potentially large.

Last Chance (Last Time, Kennedy) Magnetite

Magnetite occurs as an irregular contact metamorphic and metasomatic replacement {33, fig. 1) of thin-bedded, gray, dolomitic Mescal limestone, approximately in sec 19, T 1 N, R 12 E, unsurveyed. The deposit is reached by 0.5 mile of truck trail south starting 0.9 mile east of the Kennedy ranch-house. The deposit was located by V. H. Kennedy and J. Sanders for chrysotile asbestos as the Last Chance group of three claims.

A 3- to 5-foot-thick bed of granular magnetite is exposed in a 400-footlong bench cut for asbestos. The magnetite is exposed about 150 feet along the nearly horizontal contact between Mescal limestone and a diabase sill. Overlying the magnetite is a 3-foot-thick bed of garnetized limestone, containing epidote, tremolite, antigorite, serpentine, and other alteration minerals. The magnetite contains some copper as evidenced by green copper oxide stains. A 30-foot-long lens of chrysotile asbestos is included within the magnetite near the top of the bed.

The deposit appears small; however, its proximity to other similar deposits in the area indicates more widespread replacement of the Mescal limestone that, in aggregate and extensions, may prove important (67, p. 112).

Limestone Ridge (V. O. Ranch) Hematite

Hematite was noted as replacements in the upper part of the Devonian Martin limestone during 1959 (72). The occurrence (34, fig. 1) is in the EZ sec 19, T 2 S, R 16 E, adjacent to the San Carlos Indian Reservation. It is reached by driving 6 miles east-southeast from Globe on U.S. Highway 70, 10 miles south on Arizona Highway 77 to the Capitan School, then 2 miles east to the V. O. ranch, Limestone Ridge, and the deposit.

A 5- to 7-foot-thick bed of oolitic hematite and chamosite in a matrix of calcite, dolomite, and quartz silt occurs at the base of a widespread shale unit that is the top of the Martin formation in much of the area and is under-lain by a buff to yellowish brown silty limestone. The oolitic hematite bed can be traced for 2,150 feet along its strike on the north side of Limestone Ridge, where it dips 40° to 50° southwest. The result of sampling by the U.S. Geological Survey is shown in table 9.

The deposit has been estimated to contain 1,250 tons of iron-rich rock per foot of thickness and appears small, but its existence could be an indication of much larger replacement deposits elsewhere in the Martin formation, particularly since hematite occurs also at approximately the same strati-graphic position in much of the northern part of the Christmas quadrangle as nodules in limestone and cement in poorly sorted sandstone.

There was no production from the property as of 1961.

TABLE 9. - Results of sampling oolitic hematite, Limestone Ridge, Christmas Quadrangle, Gila County, Ariz.

Sample	Width, feet	Fe, percent	Remarks
1......	6	39.3	About 210 feet west of contact between Martin limestone and alluvial cover and about 600 feet west of San Carlos Apache Indian Reservation.
2......	1	31.1	Do.
3......	7	38.1	Weighted average of samples 1 and 2.
4......	6.2	39.1	540 feet west of sample 1.
5......	3.0	35.3	360 feet west of sample 4. Only 3 feet of bed accessible. Bed probably 6 feet thick.
6......	5.0	35.6	1,040 feet west of sample 5.
7......	1.2	34.3	325 feet west of sample 6.

Nail Ranch (Iron Spike, Iron Prince) Hematite

Hematite was noted on the Nail ranch (35, fig. 1) in the Gentry Creek-Mountain District in secs 8, 9, 15, 16, and 17, T 9 N, R 15 E, southwest of the ranch buildings. The deposit was known before 1930; during 1960 it was located as the Iron Spike, Iron Prince, and Extension groups.

The property is reached by driving 12.1 miles north from Young post office on good dirt roads, 3.0 miles southeast to the Nail ranch buildings and start of outcroppings, then 1.5 miles southwest along the road parallel to the hematite outcrop high on the steep slope northwest of the road.

Hematite (fig. 12) crops out as a contact-metamorphic replacement just under the iron-stained, and silicified algal zone in the Mescal limestone, near the top of a ridge in heavy pine forest.

The hematite zone, consisting of sporadic outcrops and high-grade float about 70-feet thick, was traced for more than 1,000 feet southwest along the steep slope above Gentry Creek from the discovery on the Iron Spike No. 7 claim. From the Nail ranch buildings the hematite zone was traced southwest intermittently for 1.5 miles.

A character sample taken of the hematite in 1961 contained 35.4 percent iron, 0.4 percent manganese, 0.4 percent titania, 0.20 percent phosphorus, 0.08 percent sulfur, and 37.6 percent silica. A spectrographic analysis indicated the presence of 0.01 to 0.1 percent cobalt, copper, and nickel, and

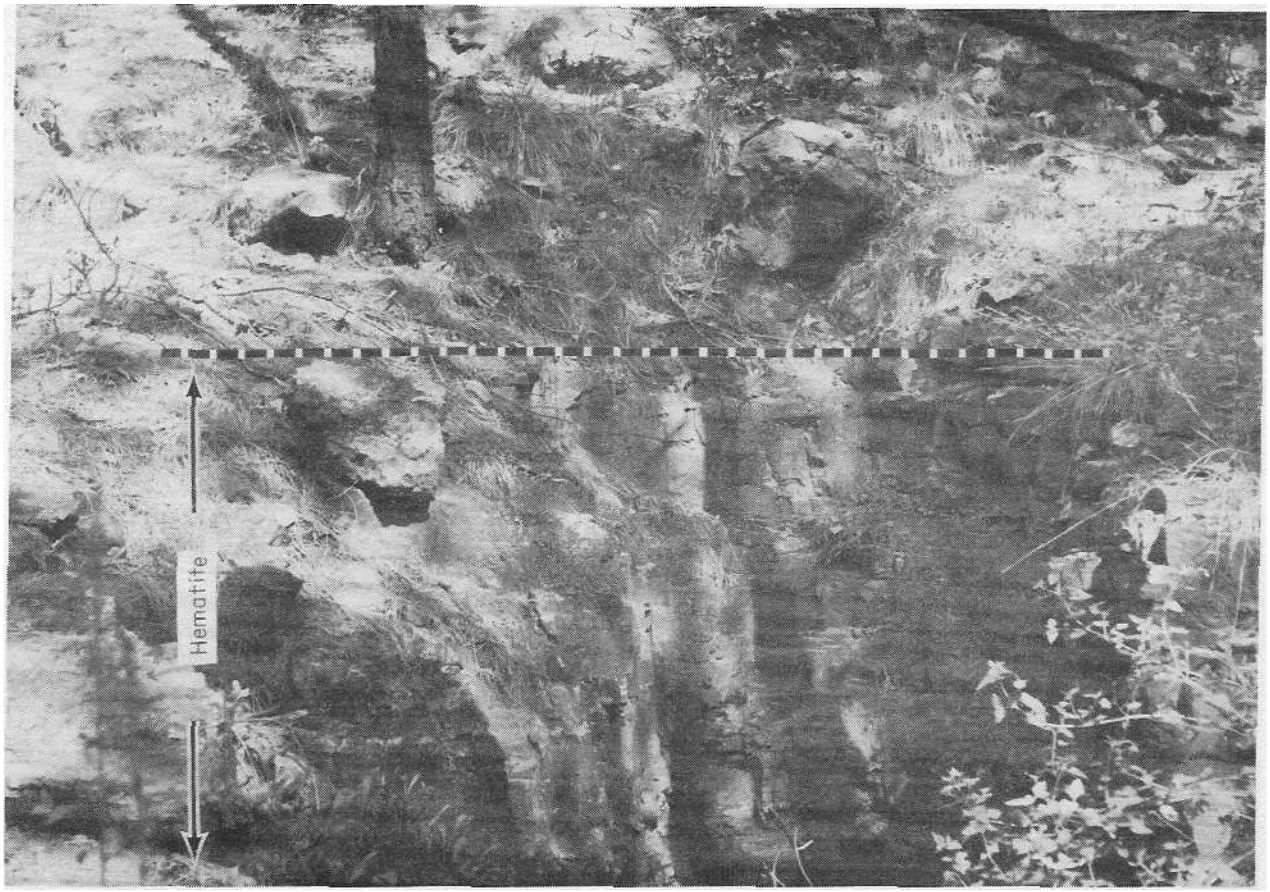

FIGURE 12. - Hematite Outcrop, Nail Ranch, Iron Spike Claims, T 9 N, R 15 E, Gila County, Ariz.

0.001 to 0.01 percent vanadium. Other samples contained as much as 57 percent iron.

The deposit is one of many similar hematite occurrences in this part of Gila and Navajo Counties (fig. 1) and is considered part of the broad contact-metamorphic replacement of the Mescal limestone that has been dilated and shattered into a complex of fault blocks by widespread intrusions of diabase. There had been no production by 1961 (10, p. 75; 65, p. 23).

Pig Iron Titaniferous Hematite

A large low-grade taconite or semitaconite-like iron formation (36, fig. 1) within the thick schist-quartzite-arkosic sandstone sequence of the Yavapai series contains hematite, with some magnetite, ilmenite, and limonite. The deposit was located during 1957 as the Pig Iron group of 40 lode claims by G. E. Toot, W. H. Stockman, and L. Kline, of Tonto Basin. It is reached by driving 6.8 miles east from Tonto Basin post office along the Greenback road, 10.1 miles northeast along the Juniper Spring road, then 4 miles northwest on the Chalk Mountain road and a poorly defined trail to the rim of Gun Creek

Canyon and the Pig Iron No. 11 claim approximately in sec 30, T 8 N, R 12 E. The property is in a remote northern area of the Sierra Ancha and the Tonto National Forest. It parallels a similar iron formation a mile northeast, known as the Iron King group of claims (31, fig. 1) and may be a parallel structure or a repetition of the same structure due to folding and faulting.

The iron formation strikes N 55° E and dips 75° NW to vertical, passing approximately through secs 20, 29, 30, and 31, T 8 N, R 12 E, and sec 36, T 8 N, R 11 E. The terrain is very rugged (fig. 13) with outcrops ranging from 5, 000 feet altitude in the steep-walled Gun Creek Canyon to 6,000 feet altitude on the high ridges. At the higher altitudes the iron formation is over-lain unconformably by nearly horizontal beds of Cambrian quartzite and lime-stone (54). The Precambrian ferruginous quartzite iron formation and schist sequence is exposed in depth in crosscutting and thousand-foot-deep Gun Creek Canyon (fig. 13) and a 700-foot-deep canyon mile northeast. Reconnaissance investigations indicate that the iron formation is more than 2,000 feet wide and is exposed for more than 3 miles along the strike. At both ends the iron formation is under a thin cover of horizontal Cambrian quartzite. The iron

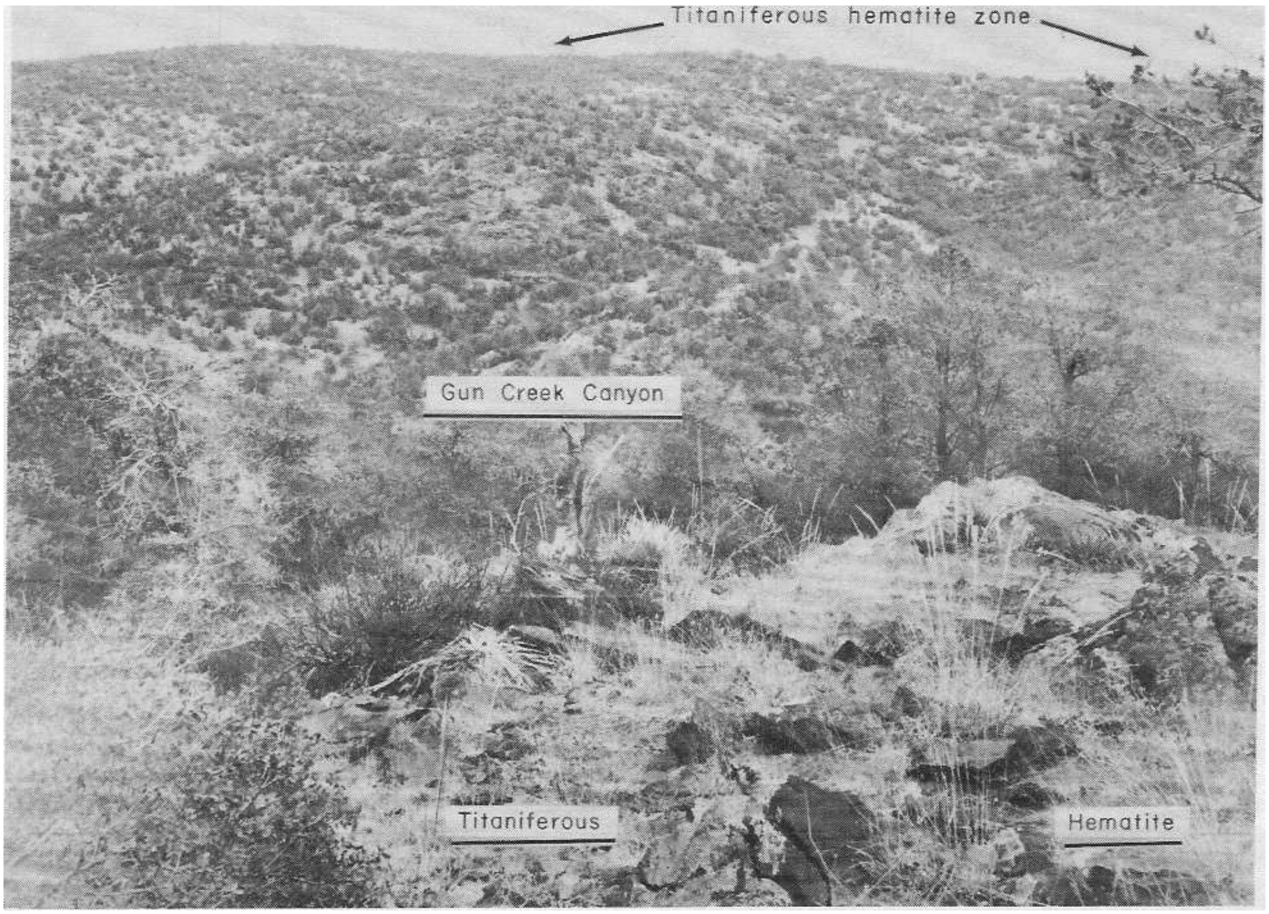

FIGURE 13. - Titaniferous Hematite Crossing Gun Creek Canyon Northeast, 1,000 Feet Deep, T 8 N, R 12 E, Pig Iron Claims, Gila County, Ariz.

formation reportedly crops out again in Clover Creek Canyon about 1.5 miles farther northeast. The formation is inferred to be continuous more than 6 miles between Clover Creek Canyon and Delshay Basin.

Iron in the outcrops of the formation consists chiefly of hematite with some magnetite, specularite, and limonite. The magnetite is probably residual. Iron content examined in cross section, as exposed in the steep-walled Gun Creek Canyon, appears most concentrated near the footwall of the formation and becomes leaner away from it. At 1,500 feet from the footwall it appears very low grade, and the last 500 feet of the quartzite-sandstone iron formation appears only iron stained. It must be remembered, however, that this is only a cursory observation. Results of reconnaissance sampling are shown in table 10.

A Bureau of Mines semiquantitative spectrographic analysis of sample 12, in table 10, on the Pig Iron No. 11 claim--believed representative of the Pig Iron group--indicates the presence of more than 10 percent iron, titanium, and silicon; 1 to 10 percent aluminum, 0.1 to 1.0 percent calcium and magnesium; 0.01 to 0.1 percent each vanadium, zirconium, nickel, cobalt, chromium, and manganese; and 0.001 to 0.01 percent copper.

The calculated mineral content of sample 12 was 38 percent hematite and 14.5 percent ilmenite.

Samples of the hard, quartzite-sandstone iron formation consisted of subangular to rounded particles of quartz, sericite, hematite, and a little magnetite. Limonite appeared to be the main cementing material with occasional quartz and sericite. Quartz grains ranged in size from 14- to 200-mesh, aver-aging 35-mesh. Hematite grains ranged in size from 28- to 150-mesh, averaging 48-mesh. Limonite cement particles ranged in size from 200- to minus-1,600-mesh. Sericite ranged in size from 14- to minus-300-mesh, averaging 48-mesh. Included in the sericite grains were numerous particles of hematite, ranging in size from 800- to minus-1,600-mesh. Titania, as ilmenite, is present as an intergrowth with hematite.

A few thin lenses of schist, probably less than 1 percent, are inter-bedded in the iron formation. The iron content of these lenses is much lower.

Fractures in the iron formation are parallel and transverse to the strike and are filled with white quartz. Occasional quartz inclusions are as much as 10-feet long and 1-foot thick. The white quartz content of the iron formation appears small totally. Cleavage faces in the white quartz are coated with specularite.

Faulting is evident in the area although no marked displacement of the iron formation was noted along the outcrop examined. Recemented boulders of fault debris containing inclusions of iron-bearing quartzite were noted along stream channels.

TABLE 10. - Results of reconnaissance sampling, Pig Iron group of claims, T 8 N, R 12 E, Gila County, Ariz.

Sample	Width, feet	Chemical analyses, percent									Remarks
		Fe	TiO_2	Mn	P	S	CaO	MgO	SiO_8	Al_aO_3	
1....	500	18.6	3.82	-	-	-	-	-	57.1	-	60 pound chip sample; Bureau of Mines, April 1957.
2....	-	36.7	-	-	-	-	-	-	-	-	Grab sample of stockpile at Tonto Basin; Bureau of Mines, April 1957.
3....	500	19.5	2.6	0.05	0.03	0.05	0.3	0.3	54.6	8.6	Chip sample across 500 feet, starting at the footwall at top of Gun Creek canyon, 300 pound metallurgical sample; Bureau of Mines, 1957.
4....	500	26.4	4.1	.15	.04	.09	.4	.4	41.6	8.8	Chip sample across 500 feet, starting at the footwall at the bottom of Gun Creek canyon, 1,000 feet below above sample 3; metallurgical sample, Bureau of Mines, 1957.
5....	100	22.6	5.3	-	.05	.11	.1	.3	47.0	10.0	Chip sample, bottom of Gun Creek canyon, 0- to 100-feet from footwall; Bureau of Mines, March 1958.
6....	100	24.3	6.2	-	.07	.08	.1	.4	44.6	10.0	Chip sample, bottom of Gun Creek canyon, 100- to 200-feet from footwall, continuation from sample 5; Bureau of Mines, March 1958.
7....	100	22.8	6.1	-	.08	.08	.1	.2	46.8	10.0	Chip sample, bottom of Gun Creek canyon, 200- to 300-feet from footwall, continuation from sample 6; Bureau of Mines, March 1958.
8....	100	25.2	6.1	-	.09	.08	.1	.2	43.6	9.6	Chip sample, bottom of Gun Creek canyon, 300- to 400-feet from footwall, continuation from sample 7; Bureau of Mines, March 1958
9....	100	25.4	5.9	-	.07	.08	.1	.2	45.0	8.8	Chip sample, bottom of Gun Creek canyon, 400- to 500-feet from footwall, continuation of sample 8; Bureau of Mines, March 1958.
10....	50	28.2	7.6	-	.04	.06	.1	.2	39.6	8.2	Chip sample, bottom of Gun Creek canyon, best iron in sight near footwall; Bureau of Mines, 1958.
11....	-	20.1	3.1	.1	.10	.10	-	-	56.4	-	Character sample along outcrop; Bureau of Mines, 1959.
12....	-	31.8	7.5	.1	.04	.10	-	-	37.8	-	Grab sample of best appearing iron along outcrop on Pig Iron No. 11 claim; Bureau of Mines, 1961.

No attempt had been made to map or systematically to sample and to explore the iron formation as of 1961 because of inaccessibility, size, and titania; however, the deposit is inferred to be a tremendous low-grade resource for the future, and there is a possibility that higher-grade, iron-bearing units may exist.

Pine Ridge Magnetite

Magnetite (27) crops out extensively as replacements in a 100-foot thick and mile-long, north-northeast trending lens of Mescal limestone (37, fig. 1), crossed by Workman Creek, ¼ mile west of Aztec Lodge, approximately in secs 24 and 25, T 6 N, R 13 E. The deposit is readily accessible from Arizona State Highway 288 by access roads.

Massive to disseminated magnetite, observes as much as 6 feet thick, replaces soft white limestone along Pine Ridge at the confluence of Rose and Workman Creeks interruptedly for about a mile. The magnetite is exposed in outcrops, in access road cuts, and in test pits. The limestone lens is under-lain by a thick sill of diabase (fig, 14) of Devonian age or older.

FIGURE 14. - Contact Between Precambrian Mescal Limestone and Diabase, Pine Ridge Magnetite, T 6 N, R 13 E, Gila County, Ariz.

The magnetite has been located as the Pine Ridge group of claims by W. W. Kline, H. Seitz, and W. N. Arney.

The deposit should prove a small local source of iron. Part of the magnetite would require beneficiation. A character sample of the magnetite exposed in 1961 contained 68.4 percent iron, 0.3 percent manganese, 0.4 per-cent titania, 0.02 percent phosphorus, 0.08 percent sulfur, and 2.4 percent silica.

There had been no production from the property as of 1961.

Pittsburg-Tonto Magnetite-Hematite

Hematite and magnetite rich quartzite float covers the southwest slope of a prominent northwest trending ridge (38, fig. 1) in Precambrian metamorphosed sediments and volcanic rocks northeast of the road to the Pittsburg-Tonto mine, approximately in the south center of sec 26, T 8 N, R 10 E. No hematite-magnetite outcrops were noted, and the structure was indistinct and covered; how-ever, judging from the float, the iron minerals occur as thin lenticular streaks less than 6 inches thick in a Precambrian quartzite-schist. Magnetite and hematite are present also as small alluvial deposits in the adjacent Tonto Creek.

The deposit appears small; however, it is in the same Precambrian structure that includes the extensive, low-grade titaniferous hematite on the Iron King and Pig Iron claims to the east in T 8 N, Rs 11 and 12 E.

Small, lenticular bodies of magnetite and hematite occur also to the east towards the Pittsburg-Tonto mine (38, fig. 1), which is approximately in the northwest corner of sec 36, T 8 N, R 10 E. The iron formation is part of a large Precambrian sequence of metamorphosed sediments and volcanics, having a northeasterly strike and a nearly vertical dip. Where observed, the iron-rich bodies were not more than 10 feet thick; however, a more detailed investigation may indicate a low-grade taconitelike area.

Alder Creek Magnetite-Hematite

On Alder Creek, about mile northeast of the Sunflower mine, approximately in sec 12, T 7 N, R 8 E, and southeast below a lenticular mass of yellowish, dolomitic limestone, several 10- to 20-foot-thick bands of hematitic and slightly pyritic iron formation were noted in the steeply dipping Yavapai quartzite slate.

This occurrence is about 6 miles southwest of the Pittsburg-Tonto outcrop (38, fig. 1). The iron formation trends northeast and is poorly exposed.

Pueblo-Lucky Strike Magnetite

Beds containing magnetite were noted on Roger Kyle's Pueblo and Lucky Strike groups of asbestos claims (39, fig. 1) along the rugged and steep west wall of Cherry Creek Canyon at about 6,000 feet altitude. The deposits are in the Sierra Ancha and the Tonto National Forest, secs 22 and 15, T 6 N, R 14 E, and are reached by driving 4 miles west from Globe on U.S. Highway 60-70 to its junction with Arizona State Highway 88 (Apache Trail), north 43 miles on Arizona State Highways 88 and 288 to Reynolds Creek, then 8 miles east-southeast over difficult access roads to the Lucky Strike and Pueblo asbestos mines. The claims were the property of Roger Kyle, Kyle Asbestos Mines of Arizona, Globe, Ariz, in 1961.

Magnetite crops out as irregular, flat-lying, contact metamorphic replacements of Mescal limestone, associated with nearby diabase intrusives. At the Pueblo mine the limestone dips 10° east and strikes north. The diabase-limestone contact dips 40° north and strikes east. At the Pueblo mine, three beds containing massive to disseminated magnetite 2- to as much as 18-feet thick locally, are separated by about 10 feet of altered and serpentinized limestone and asbestos. Individual magnetite beds (fig. 15) were traced intermittently with difficulty in the steep canyon walls for about a mile; they may be prevalent in other places in the area. Analyses of samples from various sources are compiled as table 11.

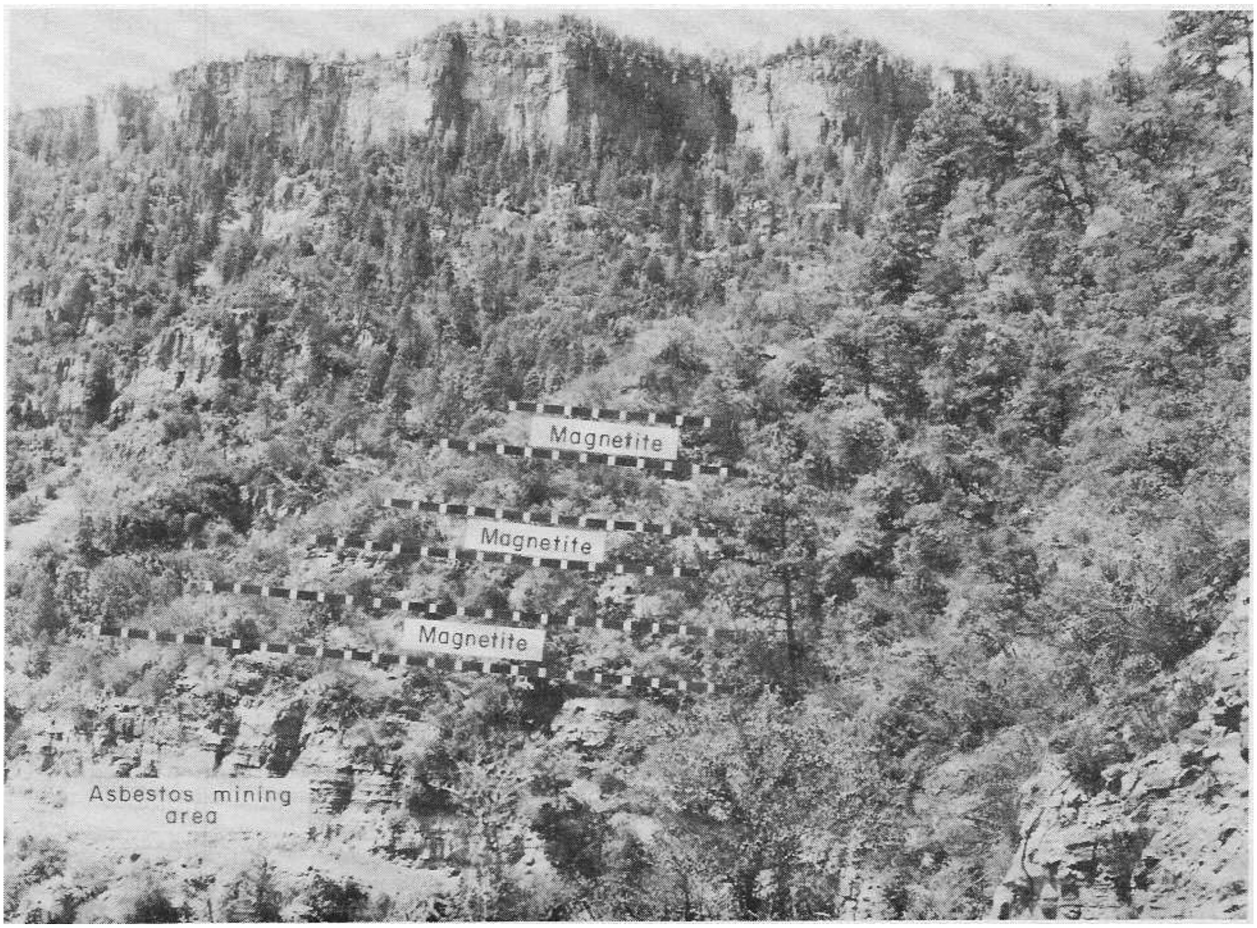

FIGURE 15. - Magnetite and Asbestos Outcrops in Precambrian Mescal Limestone, Pueblo Mine, T 6 N, R 14 E, Gila County, Ariz.

TABLE 11. - Analyses of magnetite samples, Pueblo-Lucky Strike asbestos mines area, Gila County, Ariz.

Sample	Chemical analyses, percent												Remarks
	Fe	Mn	SiO	Al_2O_3	P	S	As	Cu	Ni	Pb	Zn	TiO_2	
1[1]....	51.0	0.05	14.6	0.3	0.01	0.01	-	-	-	-	-		Courtesy Roger Kyle, owner, Globe, Ariz. Analyzed by C. F. & I Corp., Dec. 5, 1958.
2 ..	58.7 55.2	.12	5.70 8.2	-	.02	.015	0.02	0.01	0.01	0.01	0.04	0.09	Courtesy Roger Kyle, Globe, Ariz. Analyzed by U.S. Steel Corp.
3 ..		.3		-	.03	.10	-	-	-	-	-	.03	Bureau of Mines character sample Aug. 17, 1961.

[1]Semiquantitative spectrographic analysis indicated presence of 0.003 percent copper and 0.005 percent gallium and titanium.

The magnetite occurs massive to disseminated, and outcrops are indistinct, few, and scattered. Magnetite, where present, will be deeply buried in most of the area. No estimate of the size and volume of the deposits was possible (66, p. 11; 67, p. 78).

Seneca (Cienega) Magnetite

Four lenticular bodies of magnetite occur in Mescal limestone (40, fig. 1), approximately in the *center* of sec 19, T 4½ N, R 18 E, about 0.5 mile north of Seneca (Cienega) on U.S. Highway 60 and 0.7 mile west by dirt access road. The occurrence is in the north-west corner of the San Carlos Indian Reservation in Gila County (9).

Mescal limestone in the area, as much as 350 feet thick, has been dilated and shattered by widespread intrusions of diabase. The magnetite deposits are contact metamorphic replacements of Mescal limestone along the limestone-intrusive contacts. The magnetite occurs as irregular lenticular bodies, 2 to 10 feet thick, exposed for 100 to 400 feet along their northwest outcrops, and dipping 5° to 10° northeast. There are no prospect or exploration developments. The deposits appear small, however, there is a possibility that other similar deposits of magnetite exist along the Mescal limestone-diabase intrusives contacts in the area. Character samples of deposits indicate a 50- to 60-percent iron content when sorted.

There had been no production as of 1961.

Shell Mountain (Hematite 1 to 8 Group) Hematite

A hematite-rich formation (41, fig. 1) crops out on the Hematite 1 to 8 group of claims located by Tobe Haught and Stanley Turner of Young. The iron occurrence (fig. 16) is about two-thirds of the way up the slope of Shell Mountain, above Gentry Creek, approximately in secs 27 and 28, T 9 N, R 15 E. It is reached by driving 11 miles north and east from Young post office on good dirt roads and 4 miles south on the Q-ranch road along Gentry Creek, then by walking about 0.5 mile east to the outcrops.

The hematite-rich formation crops out intermittently in a zone about 0.5 mile in length northwest, 1,000 feet in width northeast, and 20 to 50 feet in thickness as a contact-metamorphic replacement of gently dipping Mescal limestone, underlain by a thick diabase intrusive. The limestone dips as much as 20° north in the complexly faulted mesa-canyon terrain. Along Gentry Creek Canyon opposite Shell Mountain, Mescal limestone and hematite are exposed on the Gentry Mesa side near the canyon bottom; whereas, on the south

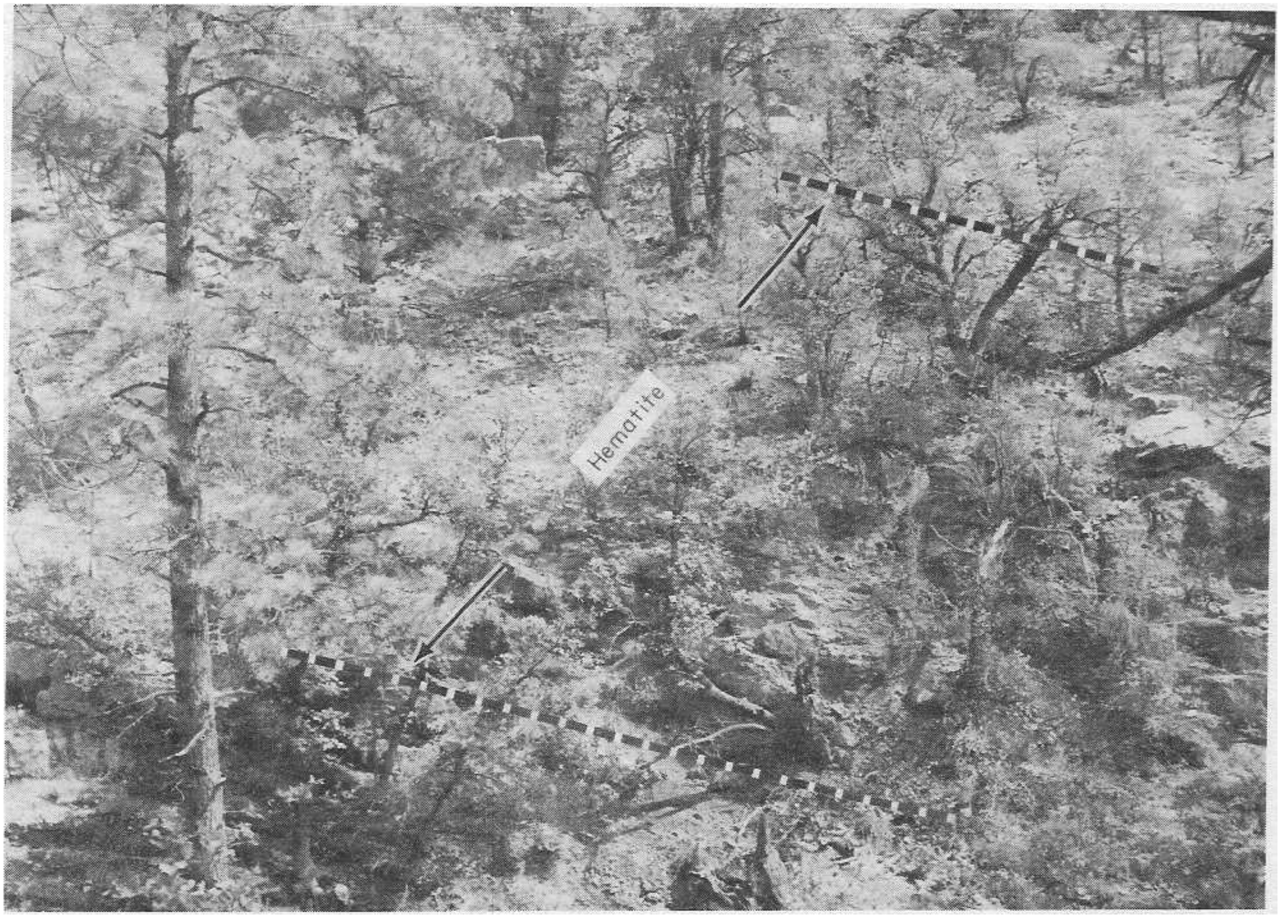

FIGURE 16. - Shell Mountain Hematite Outcrop in Precambrian Mescal Limestone, T 9 N, R 15 E, Gila County, Ariz.

side of the canyon, the lower two-thirds of Shell Mountain is diabase. Above the diabase, almost pure to mixed hematite occurs as irregular deposits just beneath the silicified and hematite stained algal member of the Mescal lime-stone formation. Magnetite is abundant in the diabase of the area and is prominent as placer sand in the Gentry Creek drainage bottoms of the area.

A character sample of the hematite taken by the Bureau during 1961 contained 64.2 percent iron, 0.1 percent manganese, 0.2 percent titania, 0.15 per-cent phosphorus, 0.08 percent sulfur, and 7.2 percent silica. A Bureau semi-quantitative spectrographic analysis indicated the presence of 0.001 to 0.01 percent vanadium and 0.01 to 0.1 percent cobalt, copper, and nickel.

The deposit is one of many similar hematite occurrences in this part of Gila and Navajo Counties (fig. 1) and is considered as part of the broad, contact-metamorphic replacement of the Mescal limestone that has been dilated and shattered into a complex of fault blocks by widespread intrusions of diabase. There had been no production as of 1961.

Twin Peaks Hematite

Hematite was noted on the Twin Peaks (Wayne Hansen) property (42, fig. 1), approximately in sec 12, T 1 N, R 13 E, about 12 miles northeast of Superior in 1949.

The hematite crops out around a ridge in a flat to southeast dipping exposure 1 to 6 feet thick, 100 feet wide, and 700 feet long. The deposit is a contact-metamorphic replacement of Mescal limestone 20 to 30 feet above the contact with a diabase intrusive. It rests on iron-stained sandstone and is overlain by 20 feet of thin-bedded impure carbonate rock containing seams of chert and shale partings. A thin red to brown sandstone and conglomerate caps the top of the ridge. Other outcrops reportedly occur in the area. A character sample of the better hematite taken by the Bureau in 1949 contained 64.6 percent iron, 0.10 percent manganese, and 12.3 percent insoluble.

The deposit is small, however, other occurrences in the area may prove important in the aggregate. There had been no production as of 1961.

White Tail (Horseshoe) Magnetite

Magnetite in heavy concentrations is reported on the White Tail--formerly Horseshoe--group of asbestos claims (43, fig. 1), approximately in sec 24, T 5 N, R 17 E, unsurveyed. It is reached by driving 5.4 miles north of the Salt River bridge on U.S. Highway 60, then 5.5 miles west on a rough access road. The property is on the cliffside of Salt River canyon on the Fort Apache Indian Reservation.

Magnetite, as contact-metamorphic and pyrometasomatic replacements, occurs in the algal and upper half of the 150-foot-thick Mescal limestone. The limestone is sandwiched between thick diabase sills.

The deposit appears small, however, it is one of several similar occurrences in the area. The aggregate potential is not estimable without more detailed exploration.

The claims have been developed for chrysotile asbestos only (67, pp. 45-46).

Zimmerman-Asbestos Points Magnetite

Magnetite occurs extensively between and beyond Zimmerman and Asbestos Points (44, fig. 1) in the Sierra Ancha (fig, 9), in secs 20, 21, and 29, T 5 N, R 14 E. The deposits comprise the Howard group of claims, previously mentioned, and the Zimmerman Point deposits, comprising the Iron King 1 to 14 claims, the Ferro 1 to 34 claims, the Ferrous 1 to 34 claims, and the Ferric 1 to 4 claims that are the property of the Arizona Mines, Inc., controlled by Chas. Jonas and Robert Peugh of Phoenix and Chas. S. Older of Los Angeles. The Zimmerman Point deposits are reached by driving 4 miles northwest from Globe on U.S. Highway 60-70 to its junction with the Apache Trail (Arizona Highway 88), 15 miles northwest on the Apache Trail to its junction with the

Young road (Arizona Highway 288), then north 15.7 miles on Arizona Highway 288 to the junction with access roads leading northeast towards Zimmerman Point and the property.

Magnetite occurs in irregular contact-metamorphic and pyrometasomatic replacements of serpentinized, chloritized, and silicified Mescal limestone that is 100 to 300 feet thick and is sandwiched between 2 large diabase sills; the upper sill being about 500 feet thick and the lower about 1,000 feet thick. The magnetite (figs. 9, 17) occurs as massive and high-grade bodies separated by disseminated and low-grade areas. The magnetite zone is as much as 100 feet thick and can be traced intermittently more than 2 miles northeast and southwest in the vicinity of Zimmerman Point along the steep western flank of the Sierra Ancha. Table 12 gives chemical analyses of character samples of the better magnetite.

TABLE 12. - Analyses of samples,Iron King Magnetite, Gila County, Ariz.

Sample	Chemical analyses, percent									Source
	Fe	Mn	TiO_2	P	S	SiO_2	Al_2O_3	CaO	MgO	
1	50.8	0.02	0.05	0.03	0.09	12.4	2.72	0.04	9.87	Cerro de Pasco Corp., November 1959.
2	68.4	.2	<.1	.06	.11	1.4	-	-	-	Bureau of Mines, December 1959.

In addition, spectrographic analyses indicate traces of lead, zinc, and copper. Crushing to minus 100-mesh liberates 75 percent of the magnetite. There had been no production from the property as of 1961.

The potential of the deposit is inferred to be several million tons of 30- to 68-percent iron content. The deposit[6] has an expectancy of 2-million gross tons of 65-percent Fe concentrates.

Magnetite of similar origin crops out on the Globe asbestos claims on the steep west slope of Asbestos Peak. The outcrops are poorly defined, and the deposit appears small.

Graham County

Bitter Spring Magnetite

Magnetite crops out on the Bitter Spring prospect (45, fig. 1) on the northwest slope of Mt. Turnbull, NE¼, sec 17, T 4 S, R 20 E, Gila and Salt River meridian and baseline, on the San Carlos Indian Reservation near its southwest border. It is 38.5 miles by difficult access road south-southeast of San Carlos at 4,650 feet altitude. Two small limestone outcrops show replacement bodies of magnetite with some pyrite and malachite. One outcrop

[6]Charles H. Jonas, vice-president, Arizona Iron Mine, Inc., Phoenix, Ariz., Oct. 8, 1961,

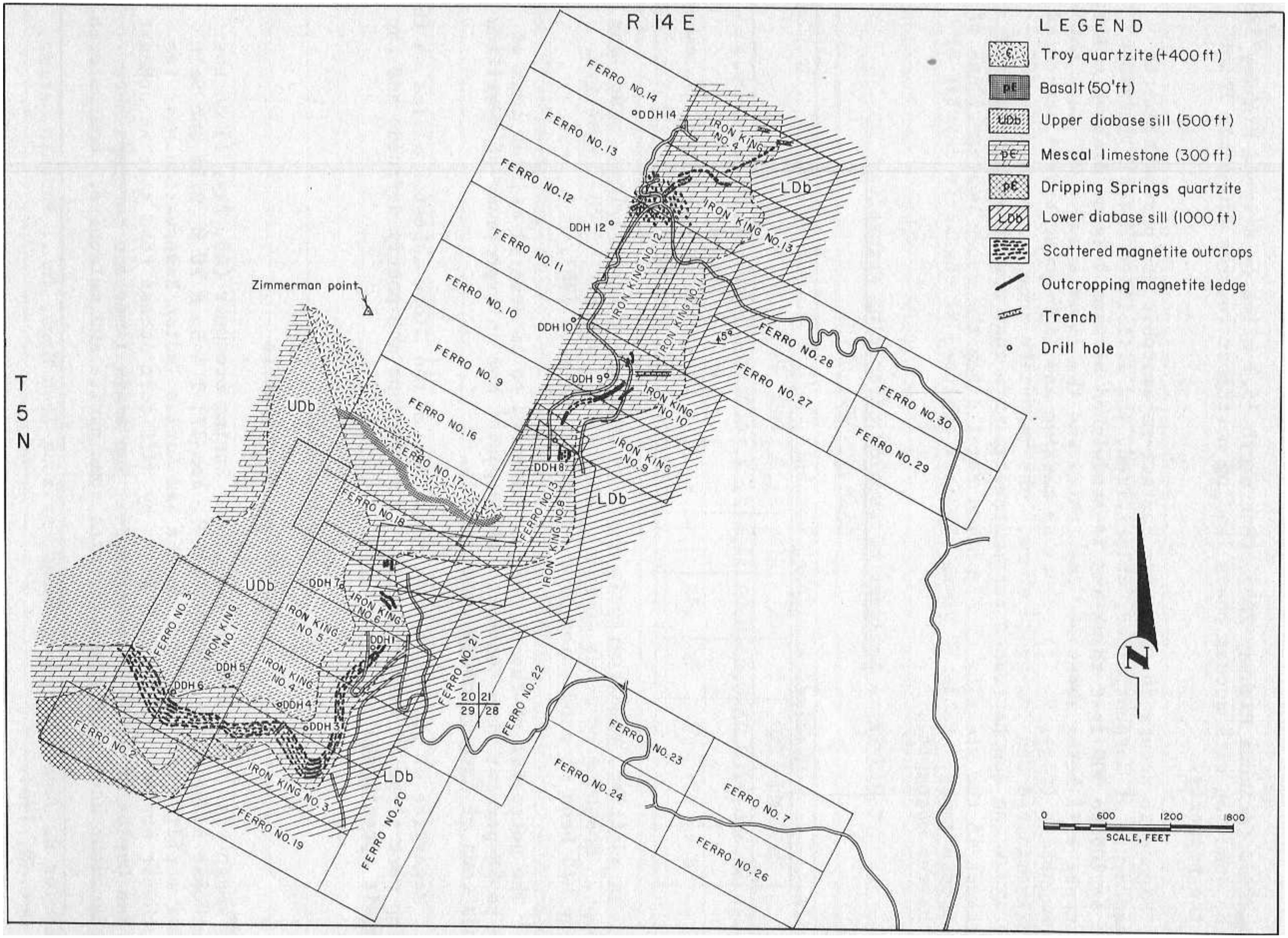

FIGURE 17. - Iron King-Ferro Magnetite Deposit, Gila County, Ariz.

above Bitter Spring trap is explored by a shallow shaft along a limestone and rhyolite contact. The outcrop can be followed for only 10 feet. The second outcrop is a few hundred feet south of the first and is explored by a shallow adit. The magnetite-pyrite-zone is as much as 10 feet wide and float is scattered as much as 150 feet up slope. Soil cover obscures most of the outcrop and contact between the limestone and andesite-rhyolite rocks of the area. The deposits are believed small. There was no attempt at production as of 1961 (9, pp. 634-635).

Mt. Turnbull-Stanley Butte District Magnetite-Hematite

Magnetite and hematite are found at or near contacts of the various intrusives with calcareous sedimentary rocks of the Mt. Turnbull district (46, fig. 1), which is partly on the San Carlos Indian Reservation. The iron minerals occur as more or less scattered and isolated replacement bodies of contact metamorphic origin in Paleozoic limestone, associated with rhyolite, dacite, diorite, and granite rocks. They were noted in an interrupted pattern across a length of about 12 miles at Mt. Turnbull, approximately in secs 13 and 24, T 4 S, R 20 E, and in secs 20, 21, 28, and 29, T 4 S, R 21 E, and in Stanley Butte district in T 4 S, Rs 19 and 20 E, unsurveyed, Gila and Salt River meridian and baseline.

Captain Jack Magnetite-Hematite

At the Captain Jack group of 5 claims, sec 26, T 4 S, R 19 E, in the Stanley Butte district, magnetite and specularite are found in limestone along a diabase intrusive contact. Several magnetite-specularite bodies are found within a mile, The largest appears 10 to 30 feet thick and about 200 feet long. The contact outcrop trends north, dipping 70° east. The property, comprising the Captain Jack group of claims as of 1946, has been explored by 2 shallow shafts, a 50-foot adit, and numerous small cuts and pits.

There has been no production from the property. It has been located several times for gold and silver. Two character samples by the Bureau (table 13) gave the following results.

TABLE 13. - Results of sampling at the Captain Jack property, Graham County, Ariz.

Sample	Thickness, feet	Fe, percent	Remarks
1	20.0	65.35	Taken from large outcrop near center of property; middle shaft, location monument of Captain Jack No. 1 claim. Outcrop 10 to 30 feet thick and 200 feet long.
2	5.0	57.81	Taken in adit about 2,000 feet north of sample 1.

The Captain Jack property is reached by taking the Stanley Butte road from U.S. Highway 70 south for 10 miles, then 2 miles southeast over a rough mountain access road.

Brewer Magnetite

Additional magnetite deposits in the Mt. Turnbull area were brought to the attention of the Bureau and were investigated during 1943. These included (1) a magnetite deposit associated with rhyolite on the north slope of Mt. Turnbull, approximately in sec 24, T 4 S, R 20 E; (2) a magnetite outcrop about 100 feet in diameter associated with diorite, approximately in sec 21, T 4 S, R 21 E; and (3) a magnetite-specularite deposit associated with diorite, approximately in sec 20, T 4 S, R 21 E, exposed for a length of 100 feet and having thicknesses of 20 to 30 feet. Results of sampling by the Bureau are shown in table 14.

TABLE 14. - Results of sampling three magnetite deposits, Mt. Turnbull district, Graham County, Ariz.

Sample	Width, feet	Fe, percent	Location
1	14	64.78	Approximately in sec 24, T 4 S, R 20 E.
2	100	44.16	Approximately in sec 21, T 4 S, R 21 E.
3	15	20.96	Approximately in sec 20, T 4 S, R 21 E.

Individual deposits appear small, however, their aggregate and extensions may prove a significant potential.

Greenlee County
Morenci-Metcalf District Magnetite-Hematite

Magnetite is abundant in the metamorphosed limestone of the Clifton-Morenci-Metcalf district (47, fig. 1), associated with garnet, amphibolite, pyroxene, and sulfides. Some magnetite was mined as flux from the Manganese Blue and old Arizona Central mines. Large masses of magnetite have been altered to limonite at the Manganese Blue mine.

Metasomatic replacements of magnetite in limestone were reportedly observed in almost countless localities at Morenci and Metcalf in T 4 S, R 29 E, Gila and Salt River meridian. At Morenci they occur as much as half a mile away from intrusive contacts (40, pp. 156, 248, 288).

East Yankee Magnetite

Large masses of magnetite, garnet, and epidote were formed on both sides of the north dike at the old East Yankee mine, T 4 S, R 29 E. At the bottom level (alt 4,688 ft) of the Montezuma mine, hard masses of magnetite, garnet, and pyrite was exposed (41, p. 156).

Copper Mountain Magnetite-Limonite

Large masses of magnetite were altered to limonite at the Copper Mountain mines in T 4 S, R 29 E.

<u>Gold Gulch Magnetite</u>

An extensive area of coarsely crystalline garnet-epidote rock with large masses of magnetite is exposed in an easterly trend across the approximate center of T 4 S, R 29 E, and it is well exposed along the road and in Gold Gulch (fig. 18) south from Morenci towards Eagle Creek. A sample of the better magnetite taken in 1961 contained 62.9 percent iron, 0.2 percent manganese, 0.3 percent titania, 0.06 percent phosphorus, 0.11 percent sulfur, and 8.0 percent silica. Spectrographic analysis indicated the presence of 0.1 to 1.0 percent each of aluminum, calcium, magnesium, copper, and manganese; 0.01 to 0.1 percent each of cobalt, nickel, and titanium; and 0.001 to 0.01 percent each of silver and vanadium (41, p. 102).

<u>Shannon Mountain Magnetite, Hematite, Limonite</u>

Detached areas of metamorphosed Mississippian sediments in the granite porphyry on the south side of Shannon Mountain form rough, black, siliceous outcrops of magnetite, hematite, and limonite. The most westerly area is at the Shirley or Little Giant adit about 1,000 feet northeast of Metcalf. The

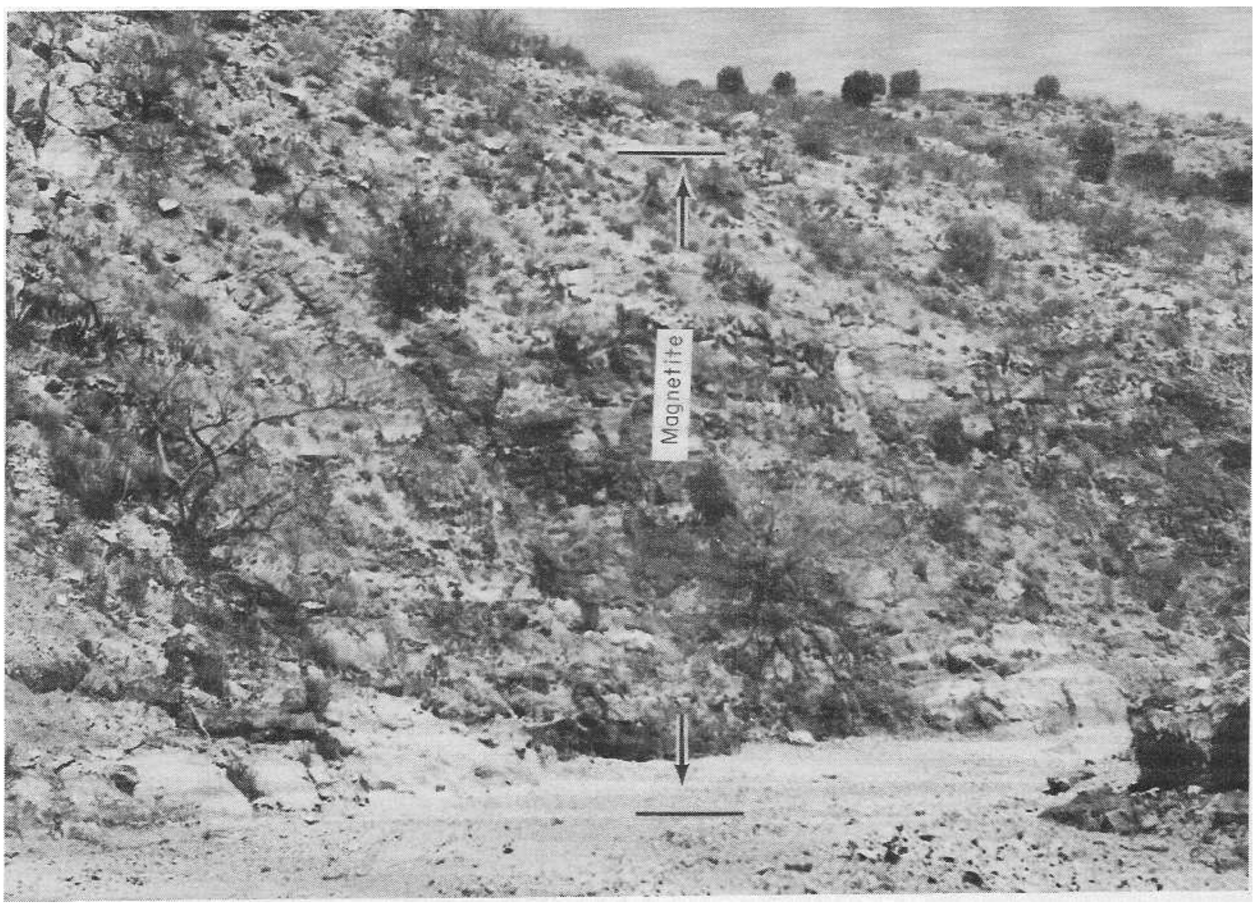

FIGURE 18. - Magnetite Outcrop Along Gold Creek, Sec 19, T 4 S, R 29 E, Between Morenci and Eagle Creek, Greenlee County, Ariz. Dark bands are magnetite.

overall area of metamorphosed and iron-rich rocks extends north from Metcalf about a mile, where it is cut off by a fault; the area is about 0.5 mile wide (41).

The Modoc limestone of Shannon Mountain is about 130 feet thick and has been highly metamorphosed with the development of magnetite and limonite. The resulting iron-rich rock includes garnet, quartz, some calcite, and is stained by malachite and azurite. Assays of samples by the Shannon Copper Co. are compiled in table 15 (41, pp. 313, 314).

Miscellaneous

Gold placer-mining operations in the Morenci district indicate the presence of abundant magnetite, and some hematite and ilmenite in alluvium of the area (17, pp. 1180-1181).

TABLE 15. - Analyses of Shannon Mountain iron, Greenlee County, Ariz. (41, pp. 310-314)

Sample	Chemical analyses, percent									Remarks
	Fe	Mn	Cu	Zn	S	SiO_2	MgO	CaO	Al_2O_3	
1....	43.2	7.6	1.9	14.5	None	5.2	None	Trace	21.8	Above lime quarry.
2 ...	17.4	1.0	6.5	20.4	do	28.4	do	do	17.7	Do.
3....	25.9	2.9	1.7	17.8	do	20.4	do	do	10.8	Do.
4....	50.9	1.0	1.2	2.2	do	9.3	do	do	4.5	Above Brown tunnel.
5....	49.46	2.92	2.88	-	do	5.02	-	-	1.68	Do.
6....	37.30	-	1.20	2.60	do	21.30	-	2.65	11.50	Cave near Mitchell tunnel.

Maricopa County

Precambrian Taconite-Like Iron Formations, Maricopa and Yavapai Counties

Introduction

Magnetite and some hematite were noted in low-grade taconite, semitaconite, and Jaspilite-like iron formations traced interruptedly more than 70 miles through Maricopa and Yavapai Counties (fig. 19) as part of the Precambrian, Yavapai schist or series. Geographically, the observable iron formations center around Cleator-Crown King. They extend south into the Hieroglyphic Mountains in T 6 N, Rs 1 and 2 W, and north beyond Lynx Creek into Tps 16 and 17 N, Rs 1 and 2 W, Gila and Salt River meridian and baseline.

The Yavapai series consists of metamorphosed volcanic and sedimentary rocks, including diorite, rhyolite, greenstone, quartzite, phyllite, argillite, graywacke, mica schist, hornblende schist, and amphibolites.

The iron occurrences investigated varied from jaspilite beds to predominantly taconite-like formations. The area, approximately 35 miles wide and 70 miles long (fig. 19), was too great for comprehensive evaluation without

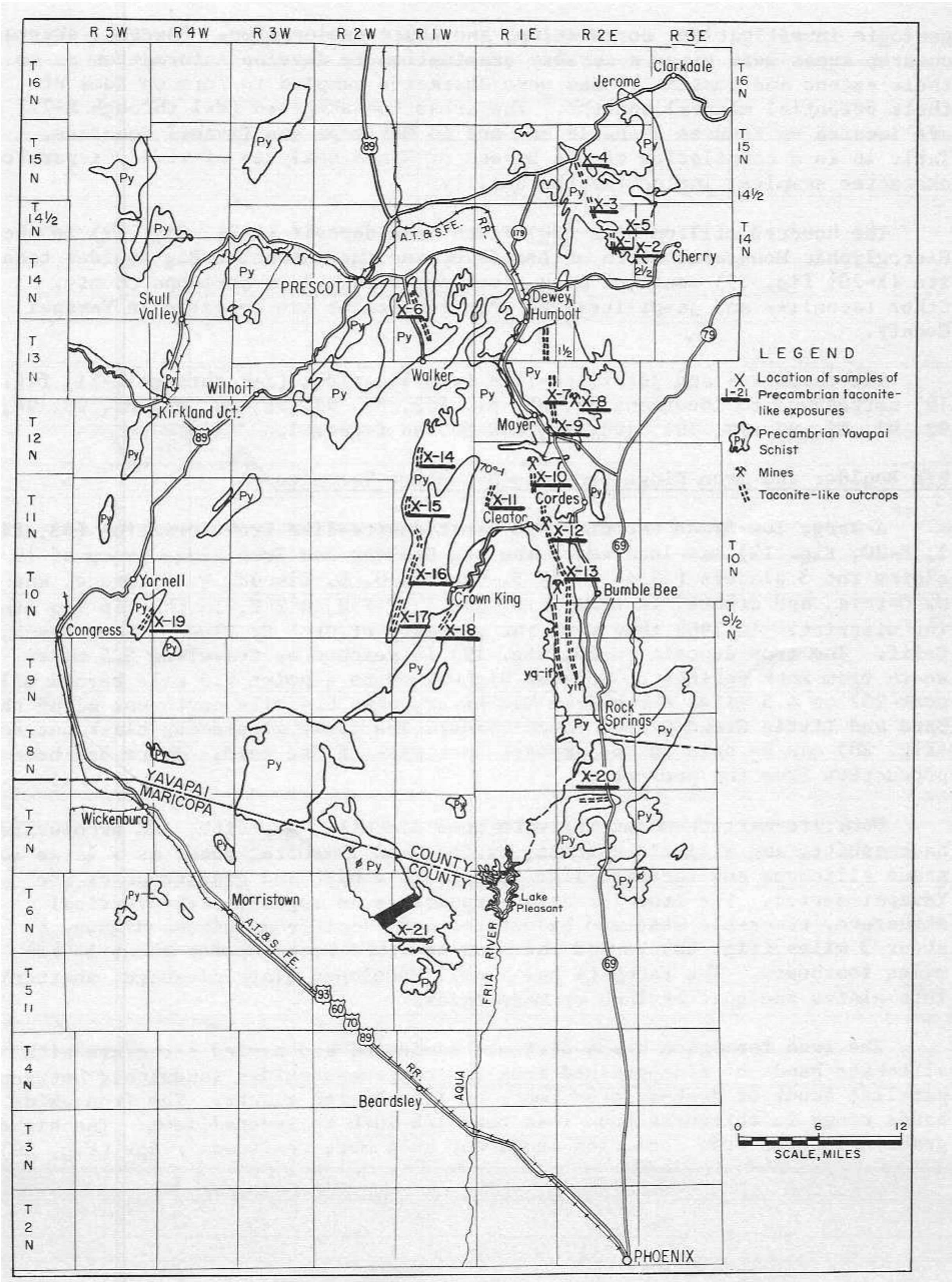

FIGURE 19. - Taconite-Like Iron Formations, Maricopa and Yavapai Counties, Ariz.

geologic investigation, correlation, and basic exploration. However, several outcrop areas were given a cursory examination to develop information as to their extent and continuity and were character sampled to form an idea of their potential mineral content. The areas investigated (X-1 through X-21) are located on figures 1 and 19 and are in Maricopa and Yavapai Counties. Table 16 is a compilation of the Bureau of Mines analyses of widely separated character samples, indicating the quality.

The hundred million tons (20) Pikes Peak deposit (X-21, fig. 19) in the Hieroglyphic Mountains north of Beardsley and the extensive Big Boulder taconite (X-20, fig. 19) south of Rock River are reported in Maricopa County. Other taconite- and jaspilite-like iron formations are reported in Yavapai County.

The taconite- and jaspilite-like iron locations (X-1 through X-21, fig. 19) correspond to locations 83, 88, 81, 102, 82, 95, 96, 89, 86, 85, 90, 94, 92, 91, 84, 97, 79, 101, 100, 48, and 50, on figure 1.

Big Boulder and Iron Ridge Hematite-Magnetite Taconite

A large low-grade taconite and semitaconite-like iron formation (48, fig. 1; X-20, fig. 19) was located as the Big Boulder and Iron Ridge group of 19 claims and 3 placers (1954-56) by D. Gordon, O. E. Elwood, W. E. Bruce, and M. Garcia, and others, in secs 3, 4, and 5, T 7 N, R 2 E, in the Tip Top mining district. In 1962 they were the property of Otto E. Elwert, Long Beach, Calif. The iron deposit (X-20, fig. 19) is reached by traveling 5.5 miles south from Rock Springs on Arizona Highway 69 to a point 0.5 mile beyond milepost 237 or 4.5 miles north from New River, then 0.4 mile northwest along the Bard and Little Grand Canyon ranch roads. The first glistening black outcrops (fig. 20) can be seen in the drywash just west of the road. There has been no production from the property.

Hematite-martite-magnetite with some limonite, goethite, and pyrolusite-hausmannite, and a little apatite, pyrite, and ilmenite, occur as a large low-grade siliceous and taconite-like deposit in schist and greenstone of the Yavapai series. The iron-formation appears as an approximately vertical structure, traceable westward by outcrop and float from Arizona Highway 69 about 3 miles (fig. 20) toward the similar Pikes Peak deposit about 14 air miles southwest. The taconite has a well developed slaty cleavage, shattering into plates one-quarter inch or more thick.

The iron formation has a distinct laminated and banded structure with alternate bands of fine-grained iron and manganese oxides sandwiched between parallel bands of dark-colored, more or less barren quartz. The iron oxide bands range in thickness from less than 1/8 inch to several feet. The higher grade siliceous iron formation crops out as a more resistant ridge (fig. 20).

TABLE 16. - Analyses of taconite and jaspilite-like iron formations, Yavapai and Maricopa Counties, Ariz.

Location		Name and county	Chemical analyses, percent						Remarks
Fig. 1	Fig. 19		Fe	Mn	SiO_2	TiO_2	P	S	
83	X-1	Black Gold, Yavapai.	33.5, 33.6.	4.5, 3.4.	28.5, 35.1	-	-	-	Magnetite-hematite jaspilite; two samples.
88	X-2	Cash Reserve, Yavapai.	36.2	2.9	37.4	0.3	0.21	0.12	Magnetite-hematite jaspilite; spectrographic analysis indicated presence of Co, Ni, Cu and V.
81	X-3	Big Buck, Three Points group, Yavapai.	37.1 to 37.4	2.9 to 3.0	25.2 to 25.5	.22 to .32	.02	.04 to .07	Hematite-magnetite jaspilite; also contains some Pb, Zn, and a trace of Cu; three samples.
102	X-4	Yaeger (Vojnich), Yavapai.	26.9, 34.6.	1.1, .9.	53.0, 36.6.	.4 -	.15, .30.	.11 -	Hematite jasper-jaspilite; some magnetite and ilmenite; two samples.
82	X-5	Black Chief (Warrior), Yavapai.	37.2	4.1	32.6	.3	.42	.09	Magnetite-hematite jaspilite; spectrographic analysis indicated presence of Co, Ni, and Cu.
95	X-6	Lynx Creek, Yavapai.	36.2	1.9	52.0	.3	.10	.08	Magnetite taconite. Spectrographic analysis indicated presence of Co, Cu, Ni, V, and Zr.
96	X-7	Mayer-Stoddard, Yavapai.	27.2	1.4	51.0	.2	.10	.09	Magnetite-hematite taconite.
86	X-9	Blue Bell Siding, Yavapai.	27.3 to 35.6	1.9 to 1.8	39.0	.2 to .3	.17	.10	Magnetite-hematite taconite; two samples. Spectrographic analyses indicated presence of Co, Ni, Cu, V, and Zr.
85	X-10	Blue Bell mine, Yavapai.	29.0	.9	52.4	.6	.10	.11	Magnetite-hematite taconite. Spectrographic analysis indicated presence of Co, Ni, Cu, V, and Zr.
90	X-11	De Soto mine, Yavapai.	28.3	.9	-	.2	-	-	Magnetite-hematite taconite.
94	X-12	Los Felice (Townsend Butte), Yavapai.	29.1 to 38.88	1.3 to 10.91	35.0 to 51.2	.2 to .3	.2 to .3	.1 to .25	Magnetite-hematite iron formation. Maxima-minima of 11 samples. Spectrographic analysis indicated presence of Co, Ni, Cu, and V.
91	X-14	Goodwin, Yavapai.	20.8	.7	50.6	.6	.12	.17	Magnetite-hematite taconite.
84	X-15	Blind Indian-Arrastra Creek-Longfellow Ridge, Yavapai.	34.0	.1	39.0	.3	.1	.1	Do.
97	X-16	Pine Creek, Yavapai.	33.8	.1	38.2	.3	.11	.08	Magnetite taconite. Spectrographic analysis indicated presence of Co, Ni, Cu, V, and Zr.
100	X-19	Stanton, Yavapai.	20.6, 30.6.	1.8, 2.9.	59.2, 43.8.	.2, .4.	.11, .27.	.10, .08.	Magnetite-hematite taconite; two samples. Spectrographic analysis indicated presence of Co, Ni, Cu, and V.
48	X-20	Big Boulder-Iron Ridge, Maricopa.	24.6 to 33.1	1.04 to 2.5	31.8 to 51.8	.15 to .4	.12 to .194	.10 to .12	Magnetite-hematite taconite. Maxima-minima of 4 samples. Spectrographic and other analyses indicated presence of Co, Ni, Cu, V, As, Pb, and Zn.
50	X-21	Hieroglyphic Mts. (Pikes Peak), Maricopa.	29.74	2.81	37.6	-	.126	.04	Magnetite-hematite taconite; average 165 surface samples.
		do.	31.2	2.8	36.4	-	.13	.05	Average of more than 200 samples; 1/3 surface, 2/3 underground.
		do.	28.7	1.9	-	.1	-	-	Character sample, 1961. Spectrographic analysis indicated presence of Co, Ni, Cu, and V.

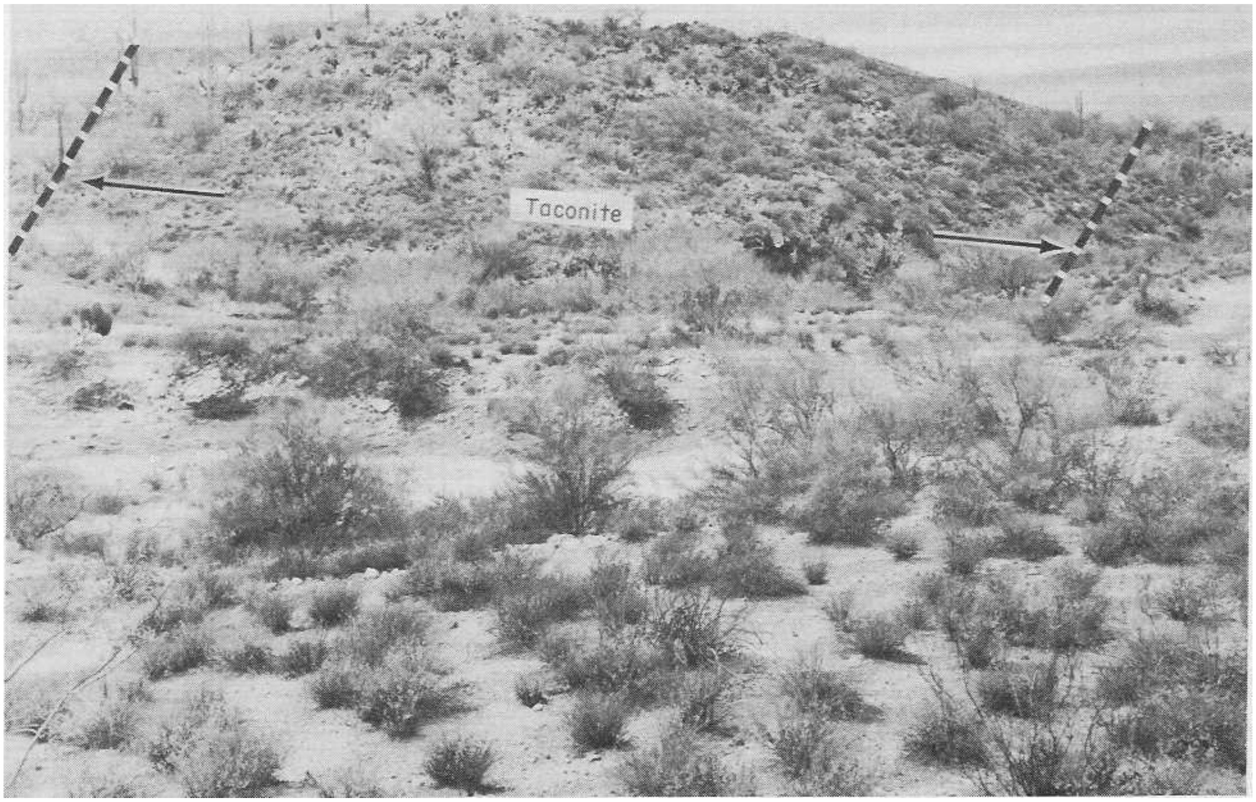

FIGURE 20. - Big Boulder-Iron Ridge Hematite-Magnetite Taconite, Sec 3, T 7 N, R 2 E, Maricopa County, Ariz.

From reconnaissance only, the east end of the deposit is inferred to be 200 to 500 feet wide. The Big Boulder group of claims extend along the westerly strike about 2 miles, following a hogback structure (fig. 20) as much as 200 feet above a drywash. The west end of the iron formation appears divided, with the north limb about 350 feet wide and the south limb about 150 feet wide. Beyond the outcrops and under volcanics and alluvium overburden a heavy float zone indicates further extensions of 4 or more miles.

Results of character sampling are compiled in table 17. The mineral con-tent of samples 2 and 3 were calculated as 24 and 20 percent magnetite, 11 and 18 percent hematite, and 0.05 percent ilmenite, respectively.

This iron formation, including schist and greenstone, is part of a great exposure of the Yavapai series traceable intermittently for many miles in Maricopa and Yavapai Counties.

This outcropping iron formation and its possible extensions, when considered with the similar Pikes Peak occurrence 14 air miles southwest, and others (fig. 19) is a large potential source of low-grade iron.

TABLE 17. - Results of character sampling, Big Boulder-Iron Ridge taconite iron formation, Maricopa County, Ariz.

Sample	Chemical analyses, percent									Source
	Fe	Mn	TiO_2	P	S	SiO_3	CaO	Al_2O_3	MgO	
1[1]....	33.1	1.04	0.15	0.194	-	33.78	0.32	8.48	0.58	Courtesy E. W. Fredell, P. E. consultant Webb & Knapp, Inc., Mar. 20, 1961; P. L. Rupard, Sr., representing the owner. (Analysis by U.S. Steel, Geneva, Utah, Apr. 12, 1954.)
2[2]....	25.4	2.5	.2	.14	0.11	51.8	-	-	-	Grab character sample; sec 3, T 7 N, R 2 E; Bureau of Mines Mar. 23, 1961.
3[2]....	26.6	1.9	.2	.12	.12	50.8	-	-	-	Do.
4......	24.6	2.5	.4	.18	.10	36.2	-	-	-	Grab sample; Bureau of Mines, Sept. 14, 1961.
5......	25.5	2.3	.26	.15	.11	46.3	-	-	-	Metallurgical chip sample composite; Bureau of Mines, 1961.

[1]Sample 1 also contained 0.01 percent As and Cu, 0.02 percent Ni, and U.U4 percent Pb and Zn.

[2]Spectrographic analysis of composite of samples 2-3 indicated presence of 1-10 percent manganese; 0.01-0.1 percent Co, Cu, Ni; and 0.001-0.01 percent V.

Hieroglyphic Mountains (Pikes Peak) Hematite-Magnetite Taconite-Semitaconite

A large low-grade taconite and semitaconite-like iron formation (50, fig. 1, X-21, fig. 19) on the south slope of the Hieroglyphic Mountains in the Pikes Peak mining district of north-central Maricopa County was known before 1906. The deposit is covered by 72 mining claims known as the Iron Age, Pig Iron, and Bessemer groups in parts of secs 8, 17, 18, 19, T 6 N, R 1 W, and secs 13, 23, 24, 25, T 6 N, R 2 W. The property (fig. 21) is reached by driving 2.6 miles northwest from Beardsley to the entrance of the Costello T T ranches, then 13 miles north to the southwestern end of the deposit. The nearest contact by railroad is Wittman, about 7.5 miles southeast on the Atchison, Topeka & Santa Fe Railroad. Altitudes range from 2,100 feet in the deeper drywashes to 2,800 feet at the highest peak.

The Pikes Peak deposit (X-21, fig. 19; fig. 22) was investigated by Kaiser Steel Corp. in 1942-43, and by the Bureau of Mines (20) during 1942. There was no further activity as of 1961.

Hematite-martite-magnetite with some limonite; goethite and pyrolusite-hausmannite; and a little pyrite, apatite, and ilmenite occur as a large low-grade siliceous and taconite-like deposit in schist and greenstone of the Yavapai series. The deposit includes many parallel and overlapping bands and lenses (fig. 21) within an outcrop area as much as 2,000 feet wide and 18,000 feet long, exposed through a topographic relief of 50 to 400 feet. Within this area are 10 large bodies and many more of lesser extent (fig. 21). Outcrops of the larger occurrences range from about 400 feet to more than 5,000 feet in length and from 50 to 300 feet in width. The iron formation has a distinct laminated and banded structure (fig. 22) with alternate bands of fine-grained iron and manganese oxides sandwiched between

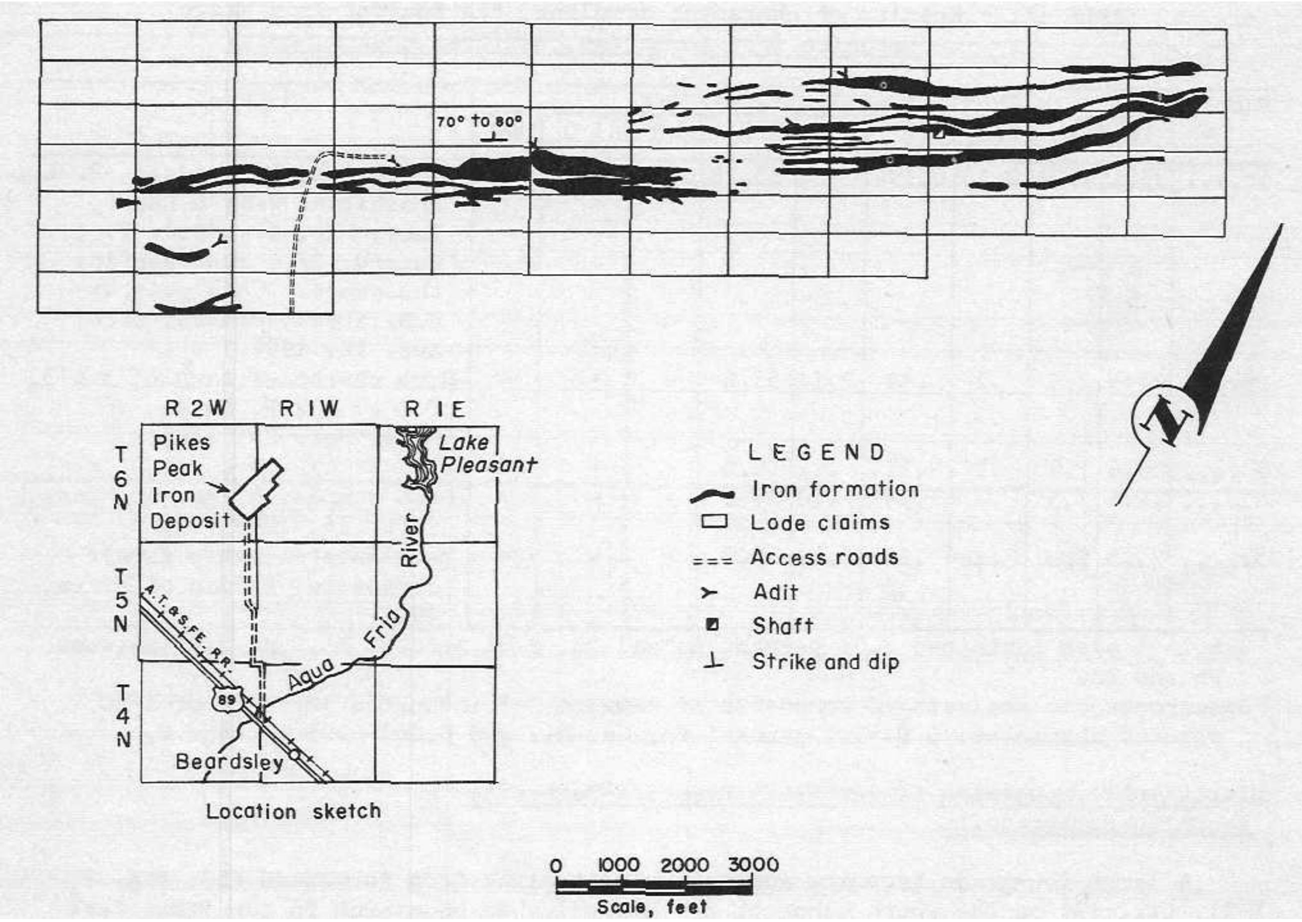

FIGURE 21. - Pikes Peak Taconite Deposit, T 6 N, Rs 1 and 2 W, Maricopa County, Ariz.

parallel bands of dark-colored, more or less barren quartz. The iron oxide bands vary in thickness from less than 1/8 inch to several feet. The higher grade siliceous iron formation crops out as more resistant hogbacks (fig. 23) that strike N 60° E, and dip 70° to 80° NW, concordant with regional schistocity. Many of the bodies of iron have no distinct walls but grade outward into leaner material. Depth is established to be more than 400 feet by topographic relief, one core drill hole, and observations at similar deposits.

In the part explored, hematite-martite, and magnetite are the principal iron minerals. Magnetite, only partly replaced by hematite, makes much of the iron formation magnetic. Magnetite particles appear so small (1- to 20-microns) and uniformly distributed that practically all of the crushed ore will contain more or less magnetite. Much of the magnetite occurs also in clusters one-quarter inch or larger in diameter that also include martite-hematite. Associated with the iron minerals are minor amounts of manganese as pyrolusite and hausmannite and a little titania as ilmenite. Gangue is mainly fine-grained quartz with a little apatite, pyrite, feldspar, and mica.

FIGURE 22. - Taconite-Like Hematite-Magnetite Iron Formation, Hieroglyphic Mountains, T 6 N, Rs 1 and 2 W, Maricopa County, Ariz. Note banded, laminated structure.

The average of 165 samples (20) taken in 35 trenches across outcrops averaged 29.74 percent iron, 2.81 percent manganese, and 0.126 percent phosphorus. The average of more than 200 samples (1/3 surface and 2/3 underground) used in Bureau metallurgical investigations (table 16) contained 31.2 percent iron, 2.8 percent manganese, 36.4 percent silica, 4.1 percent alumina, 1.1 percent lime, 0.13 percent phosphorus, and 0.05 percent sulfur.

Results of underground sampling (20) by Kaiser Steel Corp, to a depth of 100 feet on the Pig Iron No. 9 claim averaged 30 percent iron and 2.8 percent manganese. Underground channel samples on the Bessemer No. 5 claim averaged 34.3 percent iron and 2.6 percent manganese.

An out crop character sample taken by the Bureau in 1961 contained 28.7 percent iron, 0.1 percent titania, 0.13 percent phosphorus, 0.05 percent sulfur, 46.5 percent silica, and 1.9 percent manganese; a spectrographic analysis of this sample indicated the presence of 0.01 to 0.1 percent cobalt, nickel, titanium, and copper and 0.001 to 0.01 percent vanadium. The mineral content of the sample was calculated to be 21 percent hematite, 20 percent magnetite, and 0.5 percent ilmenite.

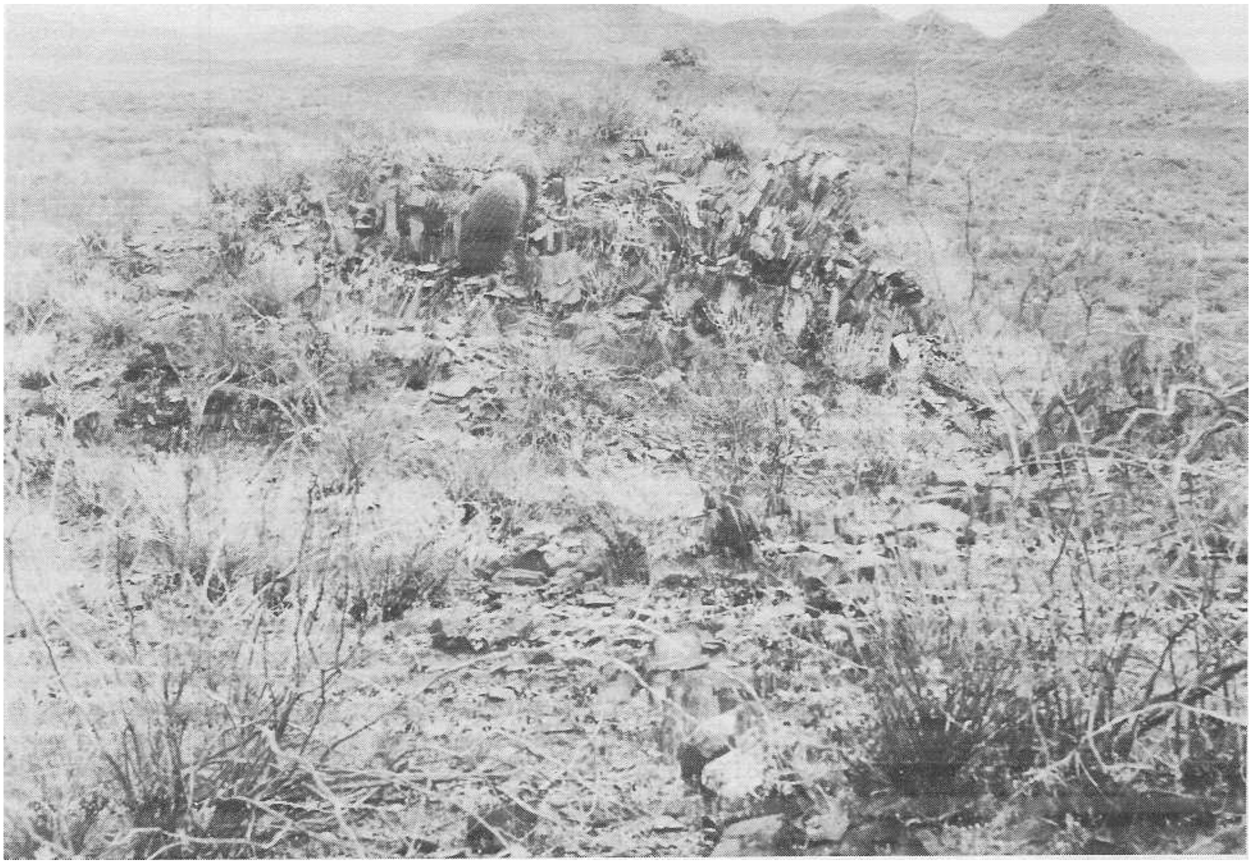

FIGURE 23. - Hogback Structure Assumed by Siliceous Iron Formation Rising Above Leaner and Less Siliceous Schist and Greenstone of the Precambrian Yavapai Series, Pikes Peak Deposit, T 6 N, Rs 1 and 2 W, Maricopa County, Ariz.

Approximate determinations indicate that 1/3 or more of the ore may prove magnetic. Octahedra of martite with centers of magnetite suggest that magnetite was the original source of iron in the deposit.

Reserves (20) in the Hieroglyphic Mountains area inferred to a depth of 400 feet were estimated as 100 million long tons averaging about 31 percent iron, 2.8 percent manganese, 36.4 percent silica, 4.1 percent alumina, 1.1 percent lime, 0.1 percent phosphorus, and 0.05 percent sulfur.

When considering the potential of this occurrence with possible extensions exemplified by the Big Boulder deposit 14 air miles northeast, low-grade iron reserves in the Hieroglyphic Mountains area may greatly exceed the 100 million tons inferred.

Big Horn District (Fred Brown) Magnetitic Alluvium

Approximately 6,000 acres of alluvial plain have been located by Fred R. Brown of Picacho as a large magnetite placer deposit in the Big Horn Mountain: area (49, fig. 1) and mining district. The alluvial area comprises parts of secs 9, 10, 14, 15, 16, 17, 19, 20, 21, 22, 23, 27, 28, 29, 30, and 32, T 4 N, R 9 W, Gila and Salt River meridian and baseline. The magnetite placer area starts about 17 miles south of Aguila, just east of the Aguila-Tonopah road.

Titaniferous magnetite occurs in alluvium and stream gravels reportedly ranging in thickness from a few feet to more than 100 feet. The magnetite with minor amounts of ilmenite makes up 3 to 7 percent of the alluvium; parts of the deposit contain as much as 10 percent magnetite.

Beneficiation tests made by lessees in 1961, including screening and magnetic separation, yielded concentrates containing 65 to 69 percent iron and 0.3 to 0.8 percent titania. The area has been prospected by scattered pits 10 to 15 feet deep.

Bilge Pump, New Year, Toro Hematite, Goethite Turgite

Hematite, goethite, and turgite occur as scattered clusters and color prominent northeast-trending quartzite ledges and crinkle folded jasper about 0.2 mile north of the Bards-Little Grand Canyon Ranch road (51, fig. 1) on the Toro, Bilge Pump, and New Year's limonite groups of claims located in 1956-59 by T. Collins, M. W. Rollins, and others. The deposits are in secs 32 and 33, T 8 N, R 2 E, north of the Big Boulder magnetite taconite deposit. The quartzite-jasper beds are about 50 feet thick and can be traced for almost 2 miles. Dips range from 50° N to vertical.

Gold placer-mining operations in the Wickenburg district indicate the presence of abundant magnetite and some hematite, ilmenite, and zircon in alluvium of the area (17, pp. 1180-1181).

Phoenix Mountains Magnetite

Thin layers of magnetite and some hematite (52, fig. 1) occur parallel to the bedding planes in Precambrian quartzite beds in the Phoenix Mountains, about 11 miles north of Phoenix. The occurrence is not of commercial significance (38, p. 45).

White Tank Mountains (Luck Lode) Titaniferous Magnetite

Titaniferous magnetite·.hematite (53, fig. 1) was reported in Precambrian and pegmatitic quartz mica schist during 1955. The occurrence is in the SW¼ T 3 N, R 3 W, along the west flank of the White Tank Mountains, about 12 miles north of Buckeye. During 1954 Luck Lode Mining Co. of Avondale and Buckeye located 22 claims covering the deposit.

Ilmenite and some sphene occur as intergrowths with magnetite in grains 65-mesh to about ½ inch in size and as segregations several inches in diameter.

Sporadic chalcopyrite was noted also. The occurrence extends northwest more than a mile, dipping from 30° to 50° northeast. Numerous small, narrow bodies of diabase intrusive occur within the schist.

Three widely separated bulk samples taken by the Bureau in 1955 contained 5.6 percent iron and 0.76 to 1.18 percent titania. A sink-float concentrate contained 61.7 percent iron and 8.7 percent titania.

Mohave County

Alamo Crossing Hematite

Specularite (54, fig. 1) was reported by J. M. Breedon and H. L. Richardson in 1943. The deposits are irregular replacements in thin-bedded Paleozoic limestone in T 11 N, R 13 W, about 2½ miles west of Alamo Crossing and are similar in origin to those at Swansea and New Planet in Yuma County. The hematite occurrence is poorly defined and is believed small.

Grand Wash Cliffs Hematite

Hematite, partly cupreous, has been reported (63) as replacements in carboniferous limestone near the summit of Grand Wash Cliffs (55, fig. 1), approximately in the N½ T 26 N, Rs 13 and 14 W, about 6 miles east of the Music Mountain mine and 18 miles north of Hackberry (63, p. 144).

Hualapai and Yucca Magnetitic Alluvium

Magnet Mining Corp., Melvin Jones, president of Congress, Ariz., reported extensive magnetitic alluvial deposits in the Hualapai district near Kingman {56, fig. 1) and the Yucca district (57, fig. 1) near Yucca. Preliminary tests indicated about 7 percent magnetite in their Hualapai holdings and about 4 percent magnetite in their Yucca placer holdings.

Navajo County, Fort Apache Indian Reservation Hematite

Introduction

Hematite crops out abundantly in the rugged mesa-canyon terrain (fig. 24) along the Canyon Creek drainage (58, 59, 60, 61, 62, 63, fig. 1) in the northwest part of the Fort Apache Indian Reservation and the southwest corner of Navajo County, Tps 8, 9, and 10 N, Rs 15½ and 16 E. In 1961 the area was part of a larger tract under lease and being explored by The Colorado Fuel and Iron Corp. The area included the more prominent Apache, Chediski, and Split Rock occurrences and numerous other outcroppings and favorable zones. This area is now accessible from Young by truck and jeep roads and is reached by driving 4.4 miles north from Young post office to the junction of the Payson-Heber roads, east and northeast for 12 miles towards Red Lake and the Reservation boundary fence, then east and south for several miles on both sides of Canyon Creek canyon to the various exploration sites.

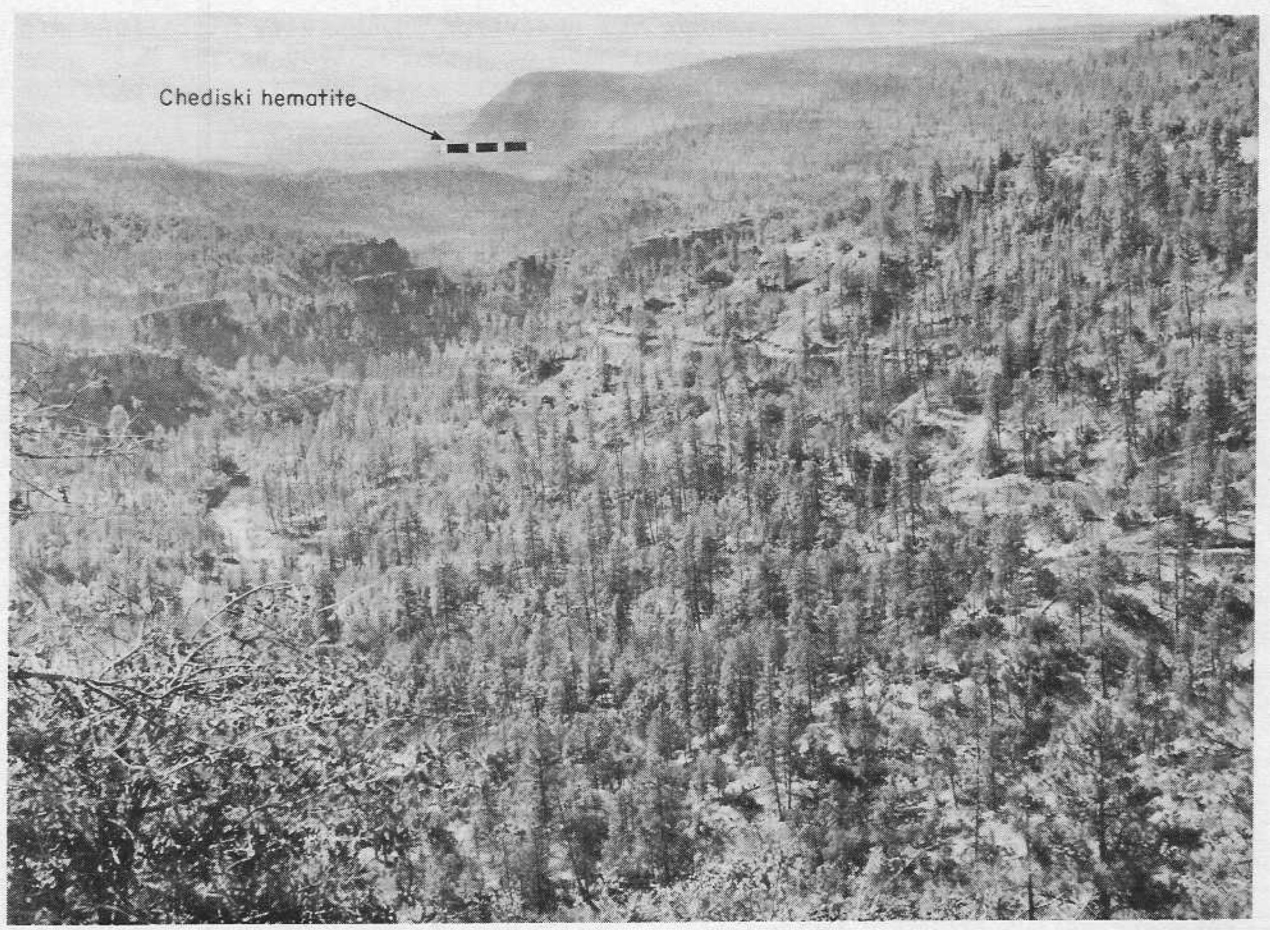

FIGURE 24. - Looking Southeast Down Canyon Creek From Apache Deposits Toward Chedi ski-Hematite Deposits, Tps 8 and 9 N, R 15 1/2 E, Fort Apache Indian Reservation, Navajo County, Ariz. Note rugged terrain and exploration access roads.

Hematite has long been known in this area and adjacent Gila County. The first official notice was discovery of high-grade hematite by H. S. Colcord in the 1890's. Reports on the deposits were made by the U.S. Geological Survey (10) in 1931 and the Federal Bureau of Mines (65) in 1947.

Hematite and magnetite occur commonly in an area roughly 90 miles long, north-northwest from Globe to Young and beyond, and about 36 miles wide as irregular contact metamorphic and pyrometasomatic replacements of Mescal lime-stone, associated with younger Precambrian to Tertiary diabase intrusives. Precambrian sedimentary rocks, including Mescal limestone host rock, have been dilated and shattered into complex fault blocks forming the deeply dissected mesa-canyon terrain (fig. 24).

In addition, concentrations of magnetite were noted in stream beds and valleys below the great areas of magnetite-rich and readily erodible diabase.

Prominent individual occurrences are described separately. Locations are in accordance with Arizona protractions made on June 23, 1960 by the U.S. Bureau of Land Management, using the Gila and Salt River meridian and baseline (10, pp. 51-75; 65, pp. 1-87).

Apache (Alsace Lorraine) Hematite

Two hematite occurrences (58, fig. 1), separated by Canyon Creek, are known as the East Apache (Swamp Creek Mountain) and West Apache (Bear Spring Mountain) deposits, in U.S. Bureau of Land Management protracted secs 25, 26, 35, T 9 N, R 15½ E. The outcrops (fig. 25) were discovered in the 1890`s by H. S. Colcord and were located by R. L. Keith in 1920-22 (mineral survey 3711) as the Alsace Lorraine group of 7 claims. These deposits are reached by driving 16.4 miles north and east from Young post office toward Red Lake and the Reservation boundary gate, then several miles southeast along exploration site roads down Canyon Creek.

The East Apache deposit (fig. 25) crops out in Canyon Creek in sec 25 and can be traced northeast along Swamp Creek Mountain more than 12,000 feet; the West Apache deposit is a continuation of the East Apache and can be traced from the mentioned outcrop in Canyon Creek northwest along Bear Spring Mountain (fig. 25) and west up Bear Spring Creek canyon for about a mile. The iron formation appears cut off at each end by erosion, and there is evidence of faulting and minor displacement. The location and attitudes of the deposits and early Bureau exploration (65) are shown on figure 25.

Hematite occurs widely as more or less bedded, contact-metamorphic and pyrometasomatic replacements of Mescal limestone closely associated with diabase intrusives. Table 18 is a generalized sequence of rocks exposed in the vicinity of the deposits (65).

The Apache hematite zone is conformable with the sedimentary rocks of the section. The attitude of the outcrops suggests an anticlinal structure plunging south and complicated by flexures and faulting. The hematite zone is near the boundary between white Chediski sandstone of the Cambrian Troy formation and the Mescal limestone formation, just below a silicified algal zone. At the Apache deposit the ore ranges from nearly pure red to bluish-black hematite and some specularite to beds interlayered and mixed with chert, jasperoid, sandstone, and shale. Much of the hematite is fine-grained and massive, containing as much as 1-percent apatite and 3- to 5-percent sericite. The hematite ranges in texture from hard and dense to soft and earthy. The lower grade hematite is generally harder and more massive.

Analyses of Bureau composite samples from trenches and drill holes, compiled in table 19, show the quality of the hematite (65). Locations of the trenches and drill holes are shown on figure 25.

The average of all trench sampling and core drilling done was 46.8 per-cent iron. Three carloads of ore mined from the best appearing outcrop area at East Apache (fig. 25) contained 63.96 percent iron, 0.06 percent titania,, 0.038 percent sulfur, 0.186 percent phosphorus, 6.88 percent silica, 0.46 percent lime, 1.15 percent alumina, and 7.36 percent insoluble.

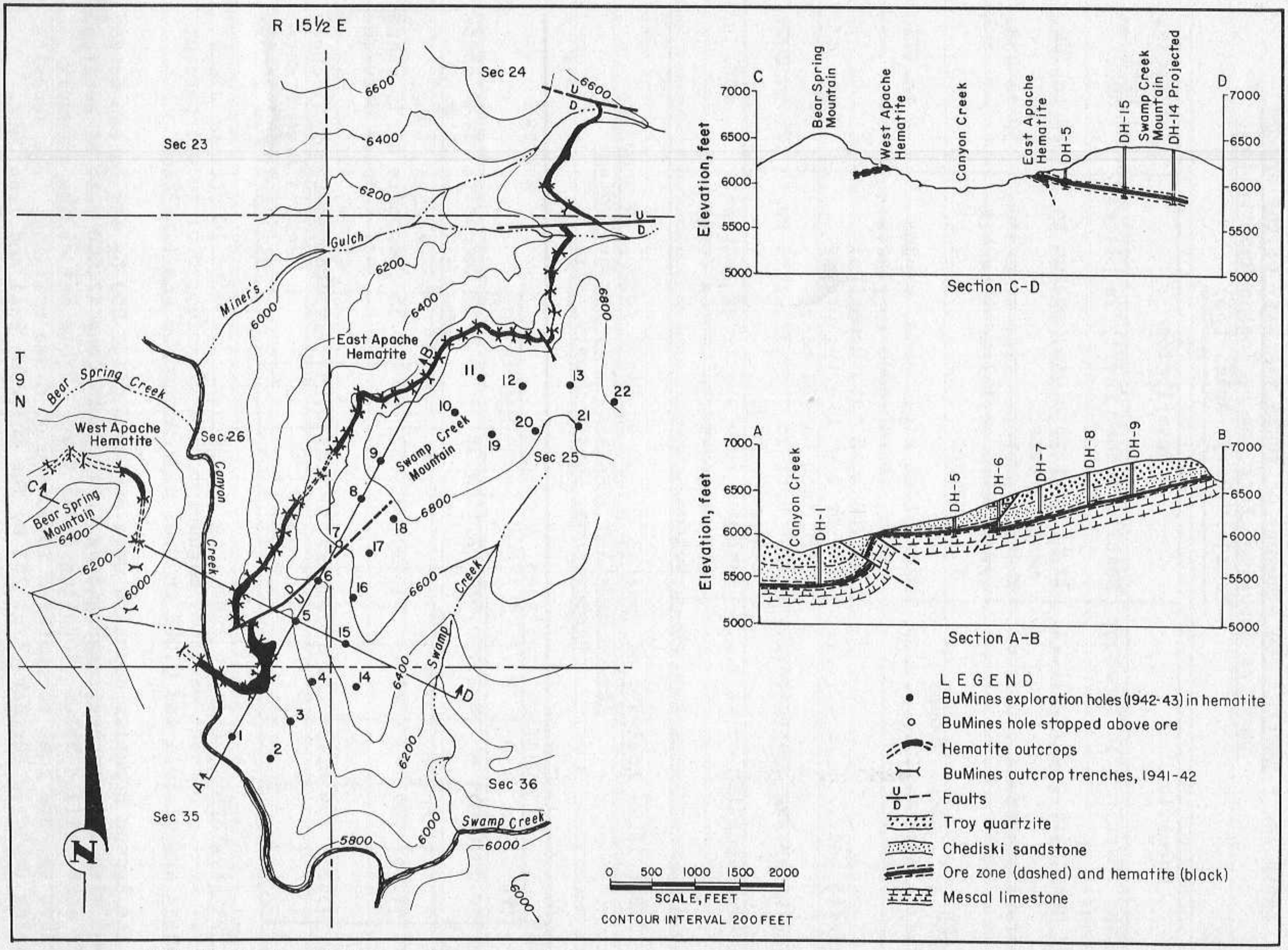

FIGURE 25. - Apache Hematite Deposits and Cross Sections, Fort Apache Indian Reservation, T 9 N, R 15½ E, Navajo County, Ariz. (65).

TABLE 18. - Generalized sequence of rocks vicinity of the Apache hematite deposits, Fort Apache Indian Reservation, Navajo County, Ariz. (65)

Formation	Description	Thickness, feet
Devonian: Martin (?) limestone	Fossiliferous, cherty in places.	400.
Cambrian:		300 to 700.
Troy quartzite	Light gray to brown; medium to massive beds.	50 to 233.
Chediski sandstone	White sandstone, fine to medium grain with sericitic interstitial cement.	
Precambrian, Apache group:		
Mescal limestone	Silicified algal zone, banded chert, ferruginous in places; merges down into hematite.	5 to 125.
Hematite bed	More or less cherty; merges down into banded chert.	3 to 47. 125 to 200.
Dripping Spring quartzite	Light buff to reddish, thin to medium bedded.	
Diabase laccolith or sill	Intruded into overlying quartzite, observed to Canyon Creek bottom.	400.

TABLE 19. - Analyses of Federal Bureau of Mines composite samples, Apache hematite deposits, Fort Apache Indian Reservation, Navajo County, Ariz.

Sample	Chemical analyses, percent									Remarks
	Fe	Mn	TiO_2	P	S	SiO_2	CaO	MgO	Al_2O_3	
1	58.53	0.05	-	0.214	0.020	12.14	0.38	-	2.12	Composite of 41 channel samples from trenches, 1942.
2	42.96	.05	-	.191	.018	30.60	.51	-	2.55	Composite of 15 channel samples between above, 1942.
3	43.35	.04	0.15	.220	.054	27.23	1.28	0.29	2.92	Composite of 41 core samples from 8 core drill holes, 1944-45.

Spectrographic analysis indicates the presence of 1 to 10 percent aluminum; 0.1 to 1.0 percent calcium, magnesium, and titanium; 0.01 to 0.1 percent manganese and nickel; and 0.001 to 0.01 percent copper and vanadium.

The Apache hematite deposits were explored (fig. 25) by the Bureau during 1941-45 with 51 trenches, aggregating 4,111 feet along 12,000 feet of outcrop, and 22 core-drilled holes, totaling 8,985 feet. Table A-1 of the appendix describes the ore zone encountered in Bureau of Mines drilling. The deposits are being explored further (fig. 26) by The Colorado Fuel and Iron Corp.

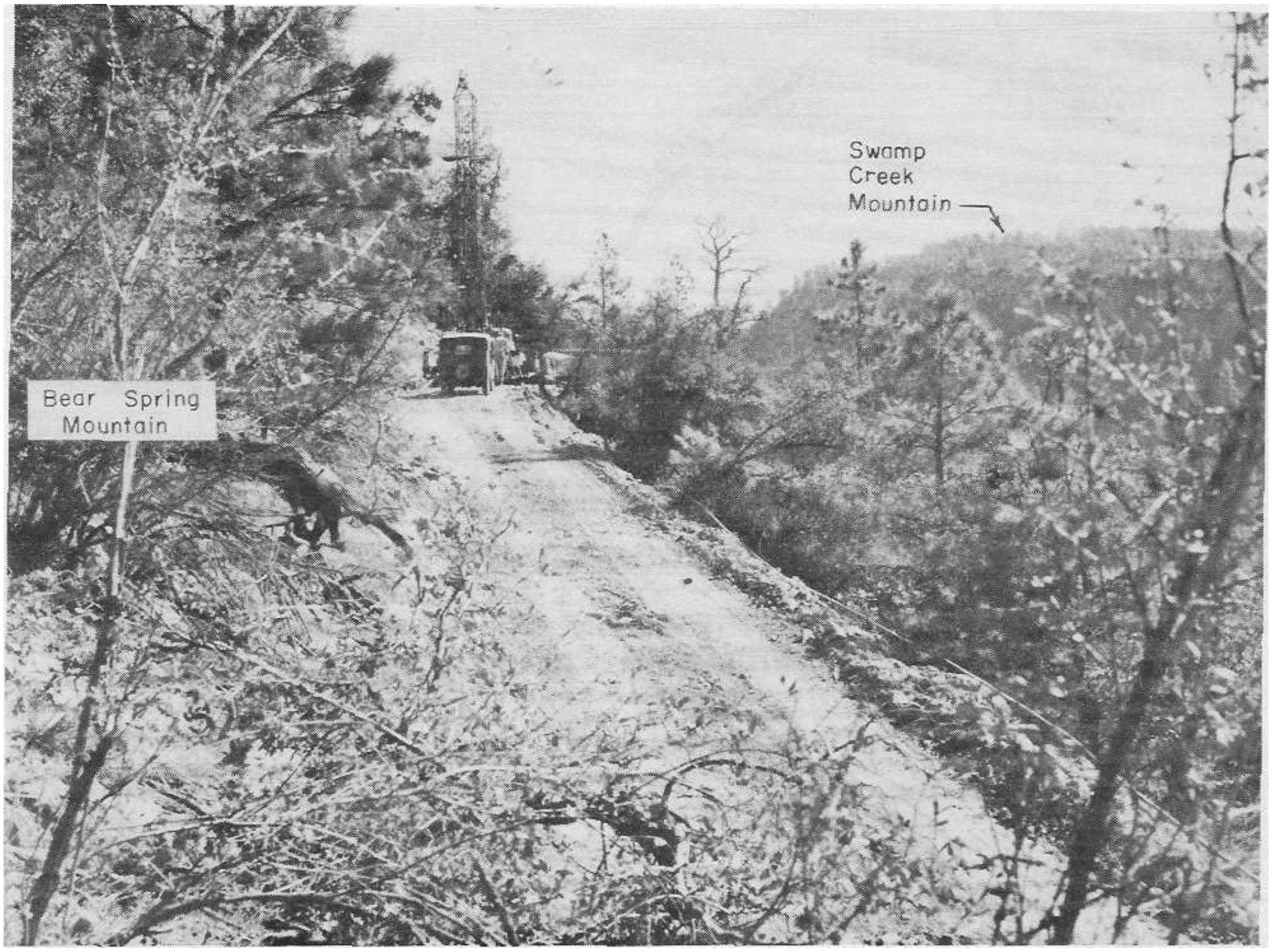

FIGURE 26. - Exploration Drilling, West Apache Hematite Deposit, Bear Spring Mountain, T 9 N, R 15 1/2 E, Fort Apache Indian Reservation, Navajo County, Ariz.

Potential of iron reserves of the Apache deposits and vicinity, evaluating by early multimillion ton estimates of 46 to 67 percent iron based on work of the U.S. Geological Survey and Federal Bureau of Mines (10; 32) and the much larger hematite-rich area in southwestern Navajo and northeastern Gila Counties of which they are a part, appears great. The Apache deposit is considered part of this much larger favorable area of iron mineralization.

Chediski Hematite

The Chediski hematite occurrence (59, fig. 1) is prominent in the canyon walls of Canyon Creek opposite and above its confluence with Willow Creek, (figs. 27, 28) between Lost Tank and Mountain Lion canyons. The area is unsurveyed. The hematite occurrence is downstream about 3 miles south-southeast from the Apache deposits, approximately in the N½ T 8 N, R 15½ E, and is reached from it by exploration access roads (fig. 24). The Chediski, Black Iron, and Iron Mountain groups of lode locations by H. S. Colcord, and others, in 1921-26 were the first in the area.

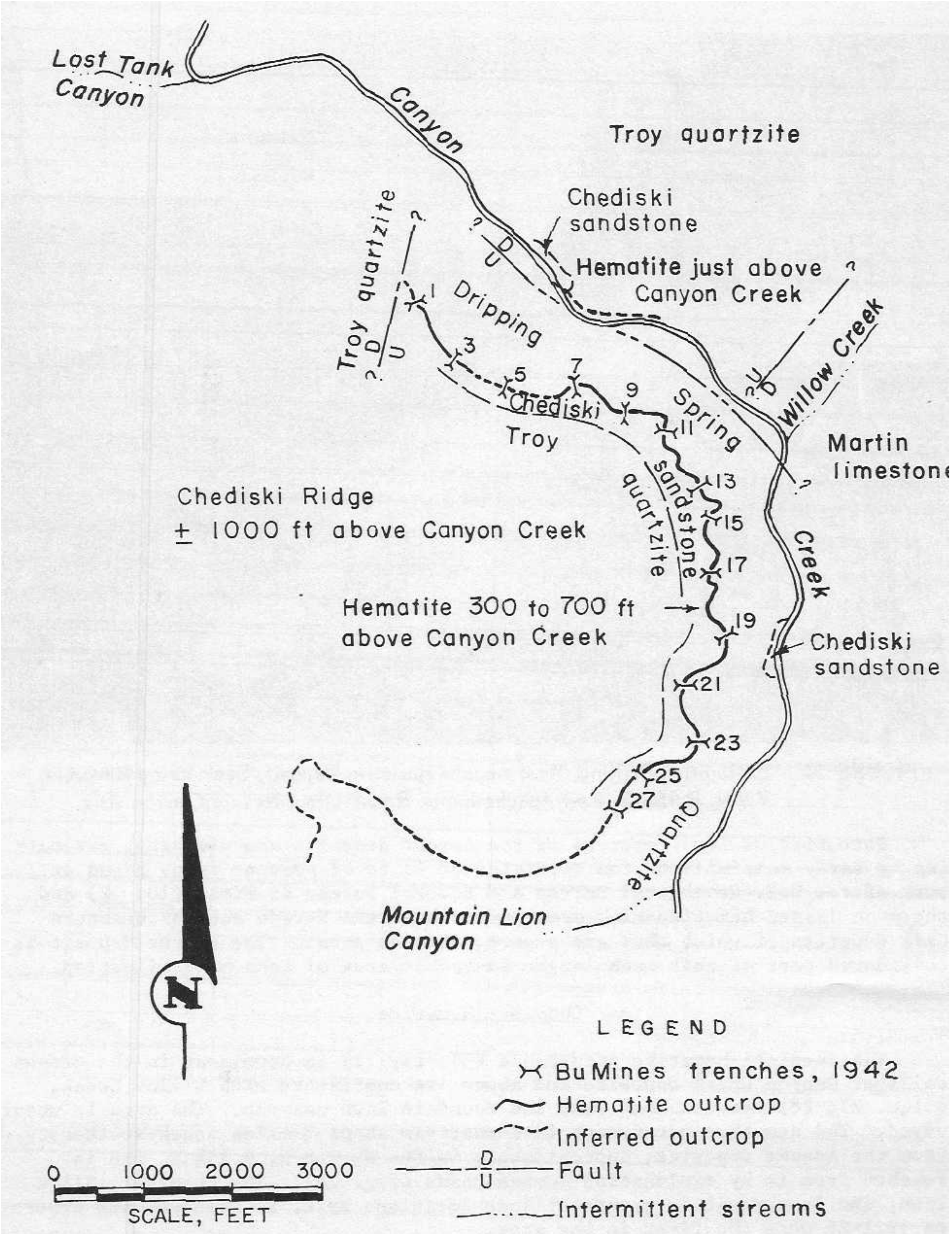

FIGURE 27. - Chediski Hematite Deposit, Fort Apache Indian Reservation, T 8 N, R 15',' E, Navajo County, Ariz. (65).

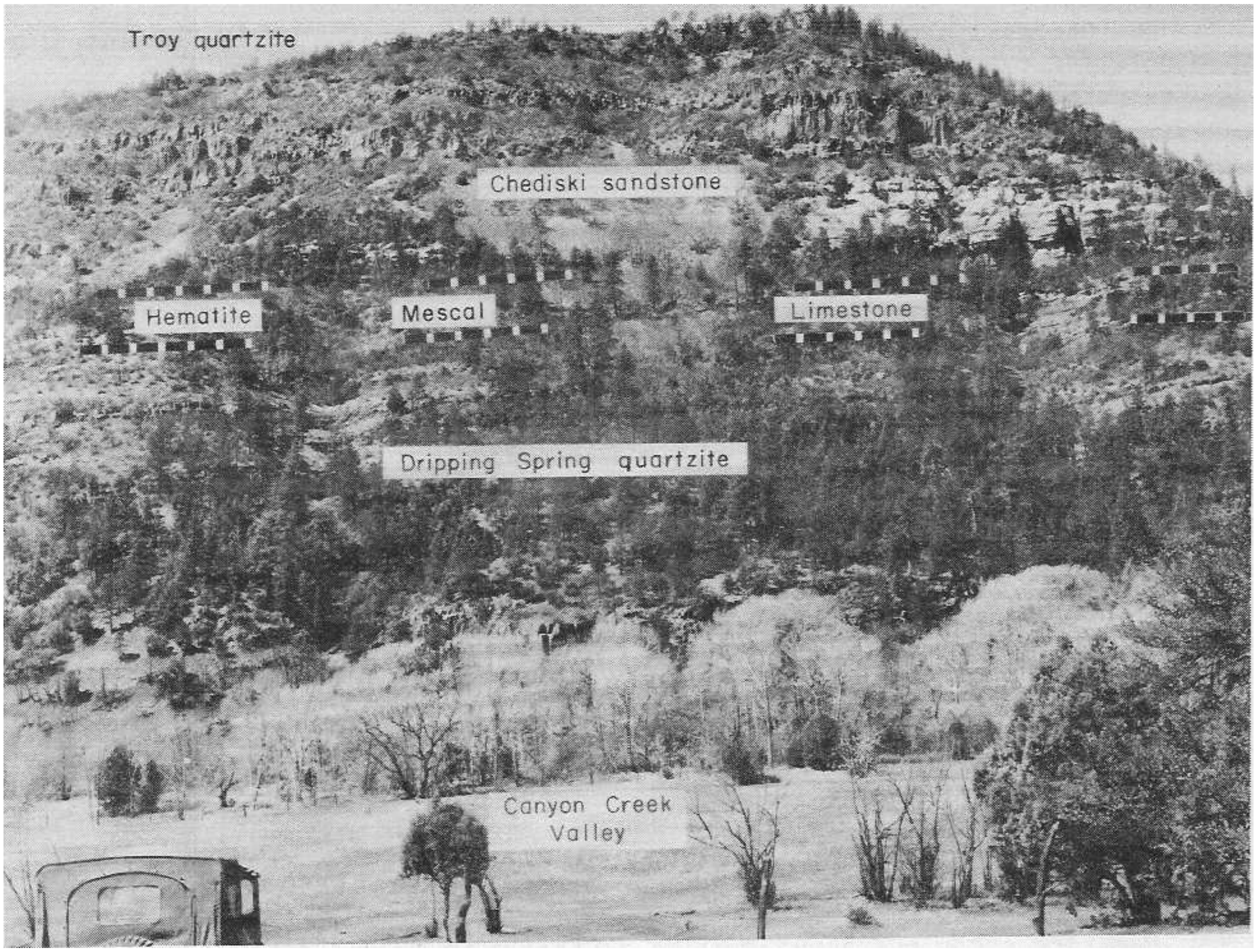

FIGURE 28. - Chediski Hematite Deposit Outcrop, Tps 8 and 9 N, R 15 1/2 E, Fort Apache Indian Reservation, Navajo County, Ariz.

Like the Apache deposits, it is a replacement of Mescal limestone associated with diabase intrusives. Hematite (figs. 27, 28) of varying quality is exposed for about a mile in an arcuate outcrop on the east slope of Chediski Ridge, 300 to 700 feet above Canyon Creek, southwest of its confluence with Willow Creek. A second outcrop is traceable about a mile northwest along the northeast side of Canyon Creek, starting at Canyon Creek level about 0.3 mile above its confluence with Willow Creek. The northwest end of this outcrop is about 30 feet above the creek bed and is covered by talus. Outcrops along the northeast bank of Canyon Creek show 2 to 10 feet of hematite interlayered with siliceous and ferruginous material. The hematite-rich formation on the Chediski Ridge is 2 to 21 feet thick with 23- to 61.5-percent-iron content. A 2,000-foot length near the south end of the Chediski outcrop averaged 18.7 feet in thickness, having a 42.21-percent-iron content. The hematite-rich bed is cut off on the north by a fault. It can be traced south and east interruptedly for several miles farther, but it appears to consist chiefly of low-grade ferruginous to barren material that is interlayered with occasional, discontinuous lenses of high-grade hematite; this is an outcrop impression.

The Chediski hematite deposit (fig. 27) was investigated by the U.S. Geological Survey in 1929 (10) and explored by the Bureau during 1942 (65). Fourteen trenches (fig. 27) were dug across iron outcrops at about 800-foot intervals, exploring about 10,000 feet of the arcuate outcrop. Average composition of the Chediski hematite, exclusive of interbedded low-grade material and barren rock is 48.92 percent iron, 0.10 percent manganese, 23.02 percent silica, 0.285 percent phosphorus, 0.055 percent sulfur, 1.01 percent lime, and 2.26 percent alumina.

The ore is similar to that of the Apache deposits. Maximum-minimum thicknesses and iron content of the Chediski deposit, based on a 35 percent iron cutoff, was 20.7 feet of 51.16 percent iron and 2.4 feet of 53.2 percent iron; the lowest value acceptable was 5.2 feet of 23.15 percent iron. The deposit is an important supplement to the Apache deposit and, like it, is considered part of the much larger hematite-rich area in southwestern Navajo and north-eastern Gila Counties (10, pp. 51-75; 65, pp. 7-8, 15-16, 44-52).

Cow Creek Hematite

Hematite occurring as a replacement of Precambrian Mescal limestone, has been reported (65) between the forks of Cow Creek (60, fig. 1) about 2 miles north of the Apache deposit, approximately in unsurveyed sec 34, T 10 N, R 15½ E, about 1 mile east inside Fort Apache Indian Reservation. This hematite occurrence, like that at the Apache deposits, is considered part of a much greater hematite-rich area in southwestern Navajo and northeastern Gila Counties and adds to its reserves potential (65, p. 23).

Marley-Grasshopper Hematite

Hematite crops out about 2 miles southeast of Marley (61, fig. 1) and southwest of the Marley-Grasshopper road, approximately in sec 12, T 8 N, R 15½ E, unsurveyed. The deposit is reached by exploration access roads from Young to and on the Fort Apache Indian Reservation. The hematite, of varying quality, appears 10 to 12 feet thick and is at the bottom of a canyon in the Oak Creek Watershed.

This hematite occurrence, like those previously mentioned, is considered part of a much larger hematite-rich area in southwestern Navajo and northeast-ern Gila Counties and adds to its reserves potential.

Oak Creek (Grasshopper Ranch) Hematite

A hematite outcrop in Mescal limestone is exposed along the east side of Oak Creek valley (62, fig. 1) a few hundred feet below the rim. The hematite bed, of varying quality, crosses a steep road between Grasshopper ranch and Oak Creek, about 4 miles west-southwest of the ranch, approximately in unsurveyed T 8 N, R 16 E, on the Fort Apache Indian Reservation. The hematite bed strikes N 30° E, and it dips 30° southeast. The outcrop was traced about 1,000 feet and reportedly continues for more than a mile. It continues also south of the road for a considerable length. A character sample taken by the Bureau was cut across an 8-foot-bed thickness, including 1.5 feet of lean chert and 1.0 feet of material considered low grade. The sample contained 36.70 percent iron, 38.60 percent silica, 0.1 percent manganese, 0.212 percent phosphorus, and 0,416 percent sulfur. Some exposures appeared comparable to the hematite of the Apache and Chediski deposits but others were poorer.

This occurrence, like those previously mentioned, is considered part of a much larger hematite-rich area in southwestern Navajo and northeastern Gila Counties and adds to its reserves potential (65, p. 22).

Split Rock (Gentry-Rock Creek) Hematite

Hematite of varying quality crops out in thicknesses of 5 to 30 feet for about 3,000 feet and is intermittently exposed for about a mile (63, fig. 1) along the Canyon Creek watershed between its confluence with Gentry and Rock Creeks, in T 8 N, R 15½ E, unsurveyed. The hematite occurrence is reached by driving 16.4 miles northerly and easterly from Young post office towards Red Lake and the Fort Apache Indian Reservation Boundary gate, then several miles southeasterly along exploration site roads down Canyon Creek and south of the Apache and Chediski deposits.

The hematite (figs. 29, 30) occurs as replacements of silicified Precambrian Mescal limestone similar to that at the Apache and Chediski deposits to the north. Outcrops noted east of Canyon Creek (fig. 30) approximately in sec 27, T 8 N, R 15½ E, were capped by Cambrian Chediski sandstone and exposed about 50 feet of the Precambrian Mescal limestone comprising two 15-foot beds of hematite separated by about 15 feet of ferruginous and algal chert, and shale. West of Canyon Creek (fig. 29) approximately in sec 28, T 8 N, R 15½ E, hematite 2 to 20 feet thick was noted intermittently in the canyon wall.

A character sample taken by the Bureau in 1961 contained 67.9 percent iron, 0.4 percent manganese, 0.2 percent titania, 0.14 percent phosphorus, 0.05 percent sulfur, and 2.4 percent silica.

East of Canyon Creek the hematite is sufficiently shallow for consideration as a limited open-pit area. West of Canyon Creek the hematite (fig. 29) is more deeply buried.

This hematite occurrence, like those previously mentioned, is considered part of a much larger hematite-rich area in southwestern Navajo and northeast-ern Gila Counties and adds to its reserves potential.

Pima County

Ajo Magnetite-Hematite

Magnetite is a common mineral at Ajo (64, fig. 1) in secs 22, 23, 26, 27, T 12 S, R 6 W, Gila and Salt River meridian, and comprises about 1 percent of the extensive Cornelia quartz monzonite (26). It occurs also as veinlets associated with pegmatite in the New Cornelia copper deposit. The brecciated quartz monzonite and the pegmatite veins within the deposit are cut by a complex pattern of magnetite veinlets as much as 4 inches thick and are locally abundant as masses of magnetite-rich copper ore.

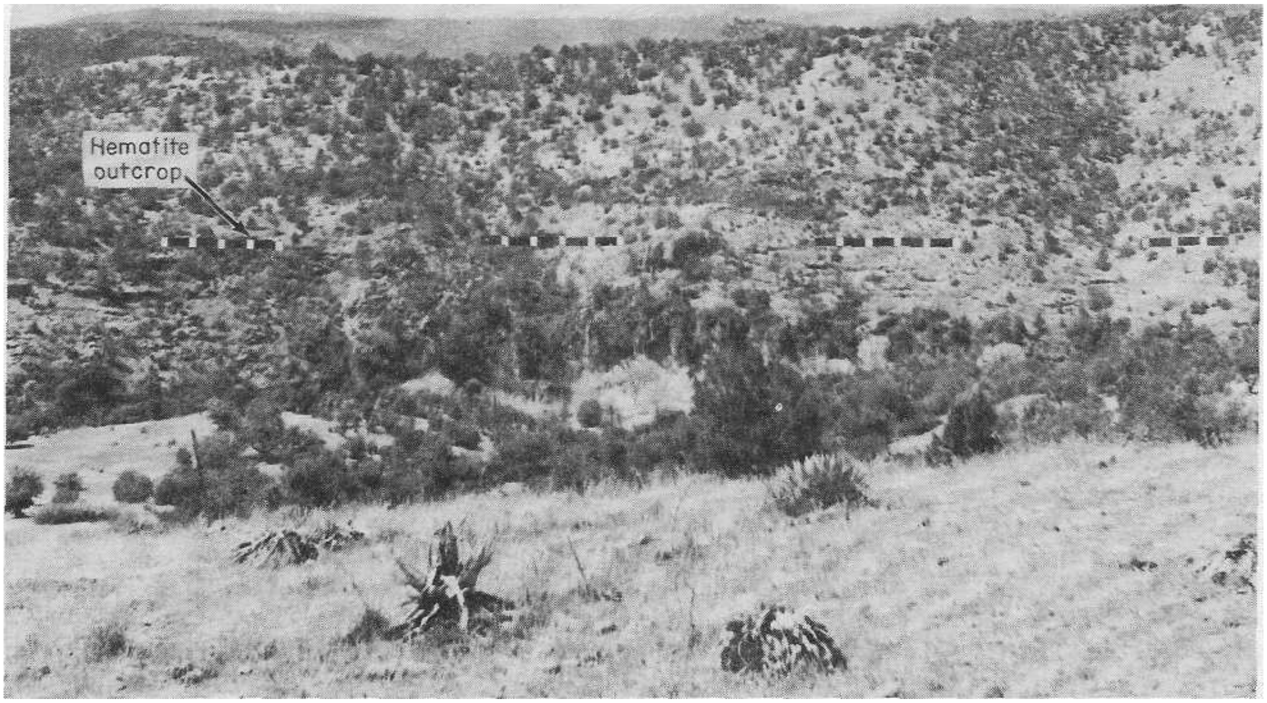

FIGURE 29. - Split Rock Hematite, West Wall of Canyon Creek, T 8 N, R 15Y2 E, Fort Apache Indian Reservation, Navajo County, Ariz.

Large crystals of specularite were noted west of Arkansas Mountain in sec 27 and crystals of specularite are reported abundant in the zone of weathering at New Cornelia. It occurs also as veinlets in the northwest part of the New Cornelia ore body. Hematite is also abundant as the soft, earthy, and disseminated oxidation product of pyrite, copper sulfides, and other ferriferous minerals.

The iron oxides are not considered a source of iron for the iron and steel industry (26, pp. 76, 84, 90, 91).

Quijotoa Mountains Magnetite-Hematite

The Quijotoa magnetite-hematite deposit (65, fig. 1) occupies a ridge along the northeast slope of the Quijotoa Mountains in T 15 S, R 2 E, unsurveyed, on the Papago Indian Reservation and extends northwest into the Sierra Blanca Mountains and southeast as far as Ben Nevis Mountain--about 15 miles.

Horseshoe Basin (Ballam) Magnetite-Hematite

The Horseshoe Basin group of 20 claims belonging to Geo. A. Ballan at the old ghost *town* of Quijotoa are reached by traveling 2.1 miles southeast from

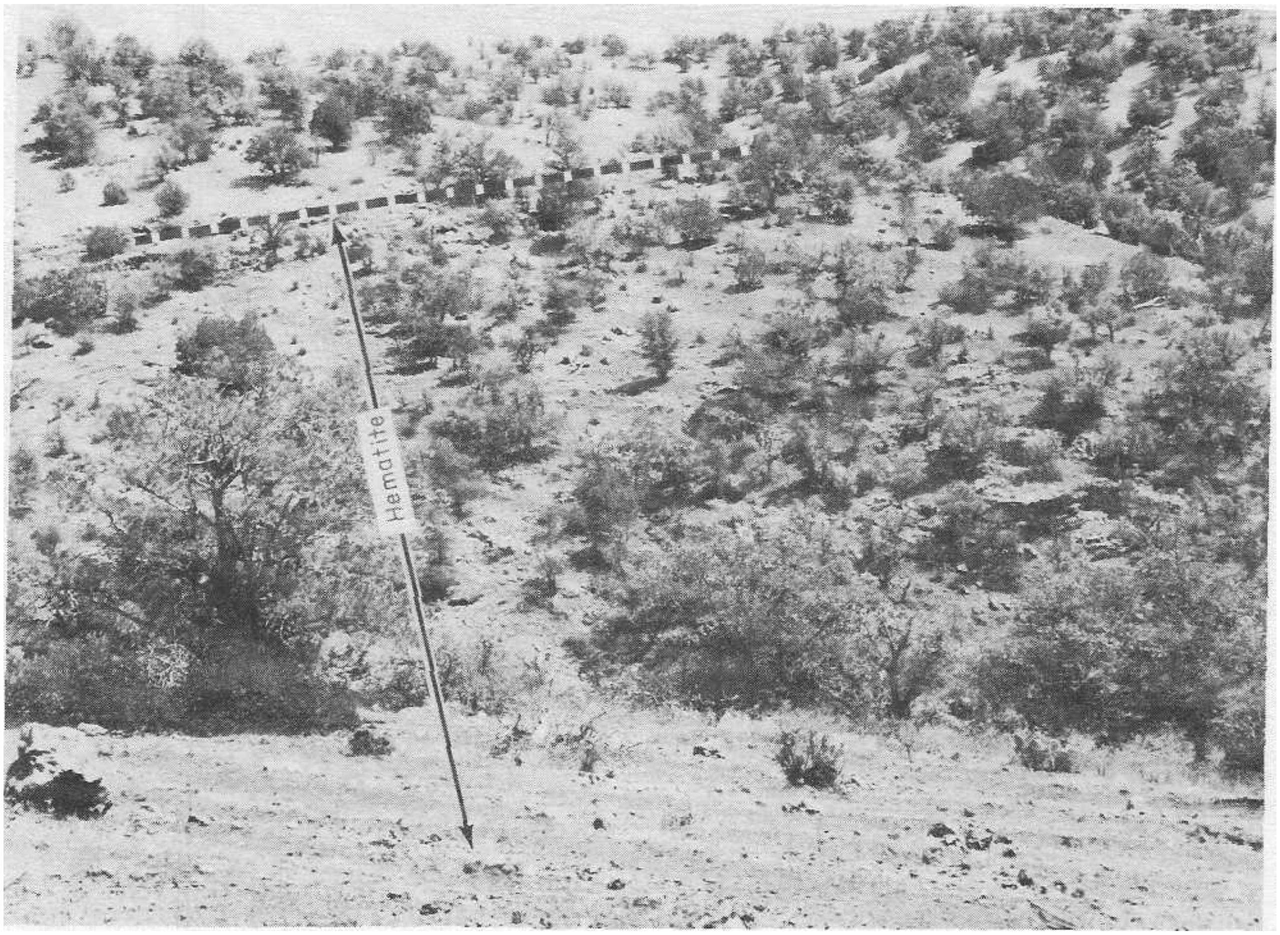

FIGURE 30. - Hematite Outcrop East of Canyon Creek at Split Rock, T 8 N, R 15 1/2 E, Fort Apache Indian Reservation, Navaio County, Ariz.

the junction of Arizona Highway 86 and the County Casa Grande road at (new) Quijotoa or Covered Wells and then 3 miles west across the desert to the Quijotoa Mountains and the Ballam home (fig. 31). Bands of magnetite and, in places, specular hematite with a little ilmenite and malachite were observed in a zone of highly epidotized granite, ranging from 100 feet to 300 feet wide, and were traced intermittently by outcrops about 3 miles. Individual bands of magnetite and hematite appear to be 4 to 30 feet thick. The banded iron formation trends N 30° W and dips 75° NE, to vertical. Depth of more than 500 feet is evidenced by topographic relief. Northwest of the Ballam residence (fig. 31) magnetite occurs in bands about 30 feet wide in an overall width of 120 feet. The calculated mineral content of a sample was 55 percent magnetite, 2.0 percent ilmenite, and 15 percent hematite. In places the iron formation appears to split. To the southeast (fig. 31) specular hematite is prominent at the crest of the hill. The calculated mineral con-tent of a sample indicates 31 percent magnetite, 1 percent ilmenite, and 39 percent hematite. Extensive magnetite-sand placer deposits, containing gold and partly covered by caliche, are present in the desert floor. The results of character sampling by the Bureau are reported as samples 1 to 3 in table 20.

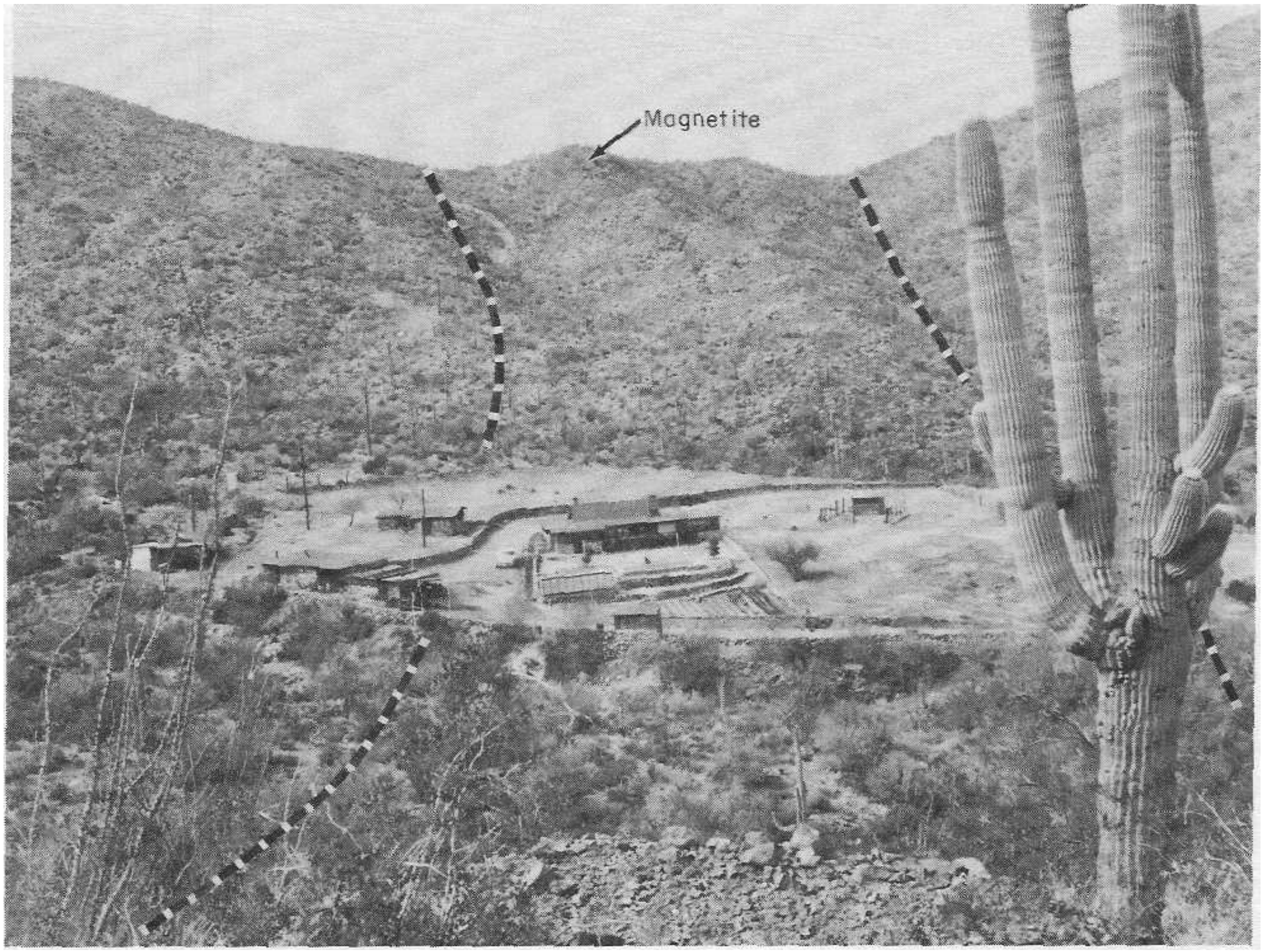

FIGURE 31. - Magnetite-Hematite Outcrop, Ballam-Horseshoe Basin, Quijotoa Mountains, T 15 S, R 2 E, Pima County, Ariz.

Stepp-Laive Magnetite-Hematite

A second group of claims to the northwest, the property of Cline Stepp and Earl Laive of Phoenix, are also in unsurveyed T 15 S, R 2 E, on the Papago Indian Reservation. They are reached by driving 0.25 mile southeast of Quijotoa (Covered Wells) Trading Post to Arizona Highway 86 milepost 91, 3.1 miles past the Indian Mission, and south into the Quijotoa Mountains where the road crosses the outcrop.

Magnetite with some hematite, ilmenite, and malachite, and an abundance of epidote and quartz, in granite, occurs as a series of discontinuous vein-lets as much as 3 feet thick, as ridge-outcrops, and possible splits; this is a surface impression. In part, the iron oxides present a banded appearance alternating with lower-grade siliceous material. The iron-rich formation appears 5 to 40 feet thick and crops out interruptedly along ridges and hills about 1.5 miles. The outcrops trend north-northwest and dip 75° NE to vertical; they are exposed through a topographic relief of 100 feet.

TABLE 20. - Analyses of character samples, Quijotoa Mountains magnetite-hematite, Pima County, Ariz.

Sample	Width, feet	Chemical analyses, percent						Remarks
		Fe	TiO_2	Mn	SiO_2	P	S	
1...	-	50.6	1.0	0.3	19.0	0.21	0.08	Character sample magnetite facies Quijotoa Ballam Horseshoe Basin claims, 1961.
2...	-	49.8	.5	.1	24.4	.02	.08	Character sample specularite hema tite facies; Quijotoa Ballam Horseshoe Basin claims, 1961.
3...	-	50.2	.75	.2	21.7	.12	.08	Metallurgical chip sample compos-ite, 1961.
4...	15	43.7	-	-	21.92	-	-	Channel sample across exposed out crop; Stepp and Laive claims, November 1944.
5...	40	45.75	-	-	17.9	-	-	Channel sample across exposed out crop 75 feet from sample 4, November 1944.
6...	-	55.7	.4	.1	13.2	.69	.11	Character chip sample 1 mile northwest of Ballam Horseshoe Basin claims; December 1959.

The iron formation is exposed in a road cut and an adjacent creekbed, several small assessment cuts and pits along the outcrop, and the outcrops themselves. Results of character sampling are reported under samples 4 to 6 in table 20.

Knight Group Magnetite-Hematite

About 2 miles southwest of the Quijotoa (Horseshoe Basin) road junction with Arizona Highway 86 towards Sells, a desert access road takes off west to the Quijotoa Mountains and a third group of claims known locally as the Knight group. Magnetite with some hematite occurs in epidotized granite in a similar manner to the previously mentioned occurrences and may be its extension.

Results of character sampling by the Bureau reported in table 20, are considered representative for the Knight group also.

Spectrographic analysis of a composite of samples 4 to 5 in table 20 indicates the presence of 0.1 to 1.0 percent vanadium, 0.01 to 0.1 percent nickel, and 0.001 to 0.01 percent copper and zirconium.

Iron Dike, Iron Duke, and Others, Magnetite-Hematite

The Iron Dike, Iron Duke, located by R. S. Byall of Denver, Colo., and many other claims cover the iron outcrop along its extension and present similar characteristics.

Iron Hill-Days Camp Specularite, Morgan Peak
Hematite-Specularite

Hematite (24) crops out northwest along the east slope of *Iron* Hill, through Days Camp and continues to the northeast slope of Morgan Peak, in T 15 S, R 2 E. The hematite occurrence, predominantly specularite, is as much as 50 feet wide with a 75 to 125 foot thick alteration zone on each side, comprising quartz diorite altered to epidote and chlorite. The occurrence is in the vicinity of the old Morgan gold mine, approximately in sec 23, T 15 S, R 2 E, unsurveyed.

The hematite appears low-grade in bulk and more detailed investigation is necessary for evaluation.

Inference on the basis of reconnaissance indicates that low-grade magnetite-hematite in the Quijotoa Mountains might prove valuable in the future as a source of iron. More detailed investigation is necessary however to raise its potential above an inference (16, p. 287; 24, 63 pp.).

Santa Rita and Sierrita Mountains Magnetite

Magnetite reportedly is abundant in the contact metamorphic copper ores at Rosemont Camp in the Santa Rita Mountains and in the Twin Buttes area of the Sierrita Mountains (66, fig. 1). In the Pima district, magnetite is abundant at the Glance (NW corner T 18 S, R 13 E) and in the Senator Morgan mine (NE corner T 18 S, R 12 E). The magnetite is intergrown with chalcopyrite, pyrite, garnet, actinolite, epidote, and chlorite (23, p. 34; 55, pp. 426-427).

The deposits are believed to be only a very small source of magnetite in a complex ore.

Sierrita Mountains Magnetite

Magnetite occurs as irregular contact-metamorphic and pyrometasomatic replacements in segments of gray Paleozoic limestones (67, fig. 1) trending northwest through the E½ Tps 17 and 18 S, R 10 E, Gila and Salt River meridian and baseline, along the west flank of the Sierrita Mountains between Fresnal and Champurrado Washes. The limestones are silicified, folded, and squeezed into assorted lenticular bodies and are associated with granitic intrusives. The limestones range in thickness from a few feet to as much as 100 feet (55, pp. 407-428).

Prominent magnetite outcrops and float in the vicinity of the old Banner silver mine and Aquajita Well are reached by driving 33 miles southwest on Arizona Highways 86 and 286 to the vicinity of the Palo Alto ranch junction, then 9.6 miles east across dry wash terrain to the west slope of the Sierrita Mountains. The magnetite crops out in secs 1, 2, and 12, T 18 S, R 10 E, in the Papago mining district. South of Aquajita Well the deposit is 3 to 5 feet thick and can be traced for several hundred feet by outcrop and float in a thin limestone bed that is poorly defined. The magnetite is associated with some pyrite, chalcopyrite, and oxidized copper minerals. A character sample by the Bureau taken in 1961 contained 53.2 percent iron, 0.3 percent manganese, 0.14 percent copper, 0.2 percent titania, 0.05 percent phosphorus, 0.08 per-cent sulfur, and 5.2 percent silica.

Based on indistinct surface expression and the generally thin favorable limestone host rock, the magnetite deposits are considered small and contaminated with pyrite and copper minerals.

Mineral Hill and Daisy, Cupreous Magnetite

Magnetite is prominent at the Mineral Hill and Daisy mines (68, fig. 1) of Banner Mining Co., approximately in sec 35, T 16 S, R 12 E, and sec 2, T 17 S, R 12 E. The mines are in the Pima mining district east of the Sierrita Mountains and about 21 miles south-southwest of Tucson along the San Xavier road

Cupreous magnetite (43) was noted as sporadic, irregular pyrometasomatic replacements at the Mineral Hill and Daisy mines, near the contact between silicified and brecciated Paleozoic limestone and intrusive rocks. In both mines, an igneous intrusive in the footwall appears to be responsible for the mineralization. The zonal mineral sequence outward from the intrusive mass is magnetite, pyrite, chalcopyrite, bornite, sphalerite, and galena. The magnetite zones have been a useful aid in the discovery of several hidden copper ore bodies by geophysical methods. Development and exploration indicate the presence of magnetite below 900 feet depth. The deposits are considered a small source of iron, complicated by the presence of copper and sulfides (43, p. 190, fig. 41C, pp. 193-194; 55, pp. 407-428).

Miscellaneous

Gold placer mining operations (17) in Greaterville and Santa Rita Mountains districts indicate the presence of abundant magnetite and some hematite and ilmenite in alluvium of the area (17, pp. 1180-1181).

Pinal County

Mammoth-Collins Mine Hematite

Specular hematite, occurring as glistening black masses was abundant in the lower levels of the Collins zinc-lead mine, secs 26 and 27, T 8 S, R 16 E, in the Mammoth mining district (69, fig. 1). The hematite is associated with chlorite and a little fluorite. Amorphous earthy hematite is abundant in all oxidized ore bodies of the Mammoth district. The mine was inaccessible to investigation during 1961 (50, p. 37).

Florence-Oracle Junction-Red Rock Magnetitic Alluvium

Extensive alluvial deposits that are a potentially enormous source of low-grade, more or less titaniferous magnetite occur in a gently sloping desert plain (70, 71, 72; fig. 1) at 2,000 to 3,500 feet altitude, starting about 25 miles northwest of Tucson and extending northwest toward Florence and Casa Grande. The magnetite deposits are in an area comprising about 800 square miles (40 miles northwest by 20 miles northeast) roughly bounded by Oracle, Florence Junction, Casa Grande, Red Rock, and Oracle Junction; they are accessible from U. S. Highway 80-89 and Arizona Highway 789 along the northeast side of the area and Arizona Highway 84-93 along the southwest side. Access roads lead to the various property units.

Deposits are of alluvial origin in which titaniferous magnetite is intermingled and stratified with the tan to buff colored sand, gravel, and silt derived from earlier erosion similar to that shown in a later section on figure 46. The magnetite deposits are part of the desert plain (fig. 32) and deep valley fill; they appear to be residual from the erosion of adjacent mountains.

Magnetite was first noted in the silty sand and gravel along Arizona Highway 789, about 6 miles southeast of Florence Junction T 5 S, R 10 E, and was followed more or less continuously to Oracle Junction. South of Tom Mix Monument, magnetite sand was noted as thin surface streaks in many draws and

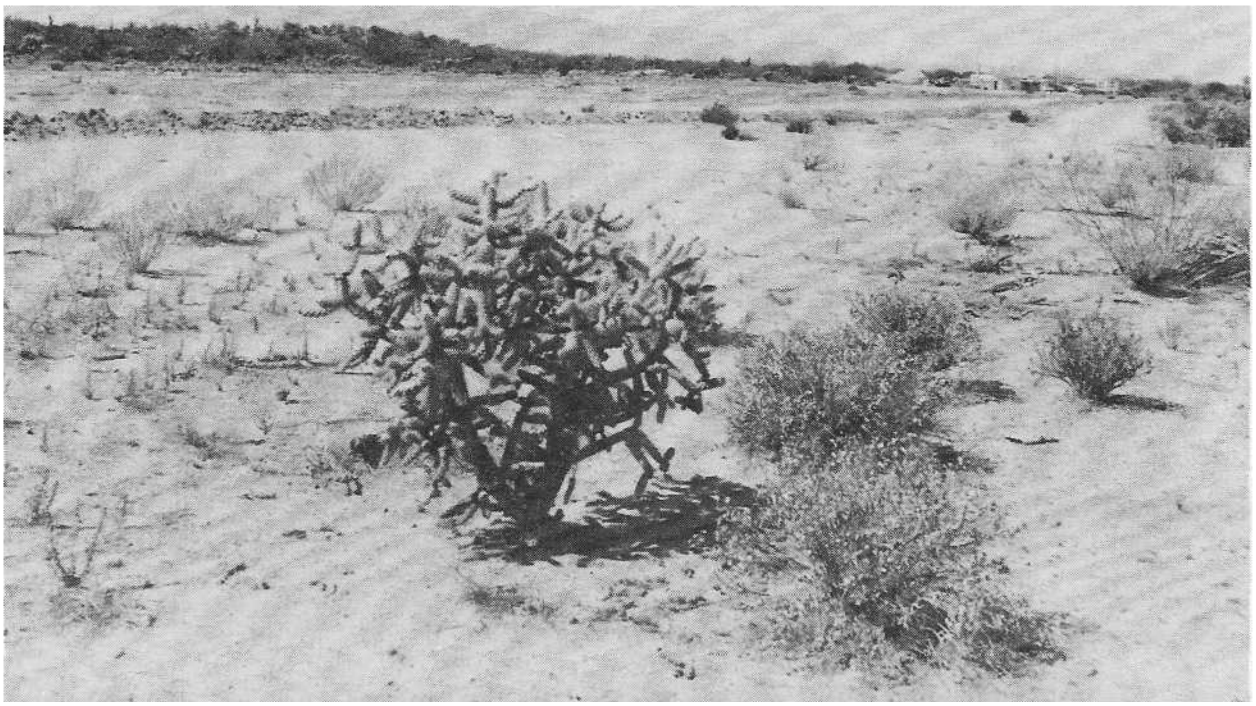

FIGURE 32. - Magnetitic Alluvial Plain North of Oracle Junction, T 8 S, R 12 E, Pinal County, Ariz. Arkota Mining Co. plant in right background.

drywashes comprising the intermittent torrential rain drainage pattern of the area, Magnetite can be seen in Tom Mix, Brady, Bogard, Durham, Forman, and Cadillac Washes. The most prominent locale is in the Omega-Owlhead Butte district (70, fig. 1) in T 8 S, R 12 E, Gila and Salt River meridian and base-line. Many other adjacent localities have been filed on in the Owlhead Butte district.

Magnetite-rich sand was noted also on the Red Rock and S. L. Kelly groups of placer claims (71, fig. 1), approximately in T 7 S, R 11 E, about 21 miles southeast of Florence Junction. Microscopic examination of a character sample considered representative of the whole area showed the presence of magnetite, ilmenite, hematite from magnetite alteration, quartz, slightly altered feldspars, apatite, garnet, epidote, minor specularite, and traces of micas, monazite, and pyroxenes.

Magnetite-rich sand was noted also along the Red Rock to Midway County road (72, fig. 1) on the Cerro, Paramount, Cad, Hard Luck, and S. L. Kelly groups of placer claims (T 9 S, Rs 10, 11, and 12 E). S. L. Kelly of Tucson has located the S½ T 7 S, R 11 E, and the N½ T 9 S, R 11 E, as magnetite placer ground.

Oro Negro Mining Co. of Coolidge controls 1,440 acres of magnetitic alluvium placers east of Florence in secs 3, 4, 9, and 10, T 5 S, R 10 E; 400 acres 7 miles east of Coolidge in T 5 S, R 9 E; and 1,440 acres 7 miles north-west of Casa Grande and 2 miles north of the Southern Pacific Railroad at Bon, in secs 15, 16, 21, and 28, T 5 S, R 5 E. The properties contain 3 to 5½ per-cent magnetite in desert alluvium.

Iron Valley Mining Co. of Tucson controls the Red Rock group of 40 placer claims, comprising 6,400 acres plus a state land prospecting permit for an additional 16,000 acres.

Magnetite-rich sand was also noted about 10 miles southeast of Casa Grande, T 7 S, R 7 E, on the Papago Indian Reservation.

Claims were filed for many square miles of this large low-grade titaniferous magnetite area by Omega Mines, Inc.; Southwestern Iron & Steel Industries, Inc.; Arizona Steel Co.; Standard Magnetite; Arkota Mining Co.; Oro Negro Mining Co.; Iron Valley Mining Co.; S. L. Kelly; and others.

Cursory character sampling of the magnetite deposits indicates a wide range of magnetite content. In the Omega magnetite placer area, property of Southwestern Iron & Steel Industries, Inc., of Tucson, Ariz., T 8 S, Rs 11 and 12 E, approximately 38,000 acres reportedly contain 3 to 15 percent magnetite, possibly averaging as much as 5 percent. Assays of samples indicate from 0.5 to more than 20 percent iron content. A grab sample of the better magnetite-rich sand taken by the Bureau in 1959 contained 20.8 percent iron, 2.1 percent titania, 0.5 percent manganese, 0.26 percent phosphorus, 0.4 percent sulfur and 49.0 percent silica. Besides magnetite, microscopic examination of samples of the sand identified the presence of ilmenite, sphene, apatite, zircon, diopside, quartz, biotite and feldspar. Semiquantitative spectrographic analysis of a character sample taken by the Bureau in 1961 indicated the presence of more than 10 percent iron and silicon; 1 to 10 percent aluminum and titanium; 0.1 to 1.0 percent calcium, magnesium, and manganese; 0.01 to 0.1 percent cobalt, nickel, vanadium, and zirconium; and 0.001 to 0.01 percent copper.

Test pits were still in magnetite-rich sand at depths of 50 feet, as were drill holes to depths of more than 250 feet, T 8 S, R 12 E, (75).

Magnetic concentration tests made by the Arizona Bureau of Mines in 1956 on magnetite-rich sand samples from the Omega area in T 8 S, R 12 E, indicated concentration ratios ranging from 25:1 to more than 100:1. Analyses of magnetic concentrates from the area are shown in table 21.

TABLE 21. - Analyses of magnetic concentrates from magnetite-rich alluvium, Omega-Owlhead Butte area, T 8 S, R 12 E, Pinal County, Ariz.

Concentrate	Chemical analyses, percent								Description
	Fe	TiO_2	Mn	P	S	SiO_2	Al_2O_3	$CaCO_3$	
1	63.2	2.3	0.14	0.19	0.06	4.5	1.15	1.5	Tests by Geo. Roseveare, 1956, Arizona Bureau of Mines; composite of 12 samples tested.
2	62.8	2.8	.30	.39	.36	4.2	-	-	Grab sample by Bureau of Mines, 1959, of Southwestern Iron & Steel Industries, Inc.; concentrate stockpile at property 16 miles north-west of Oracle Junction.

Cleaned concentrates are expected to contain 65 to 67 percent iron. Preliminary trials by Southwestern Iron & Steel Industries, Inc., indicated that about 1 ton of magnetite containing about 55 percent iron could be expected from 15 cubic yards of alluvium.

In 1962 the Omega area was being developed by Arkota Mining Co. The magnetite-rich alluvium was mined by open-pit methods and beneficiated by screening, crushing, and magnetic separation into a high-grade concentrate at the mine. The minus 35-mesh concentrate was trucked about 25 miles northwest to the Arkota Steel Corp. plant near Coolidge, where it was pelletized and smelted into ingot by the Madaras iron ore direct-reduction process (64, pp. 1, 4, 5; 75).

Slate Mountains-Lake Shore Mine Magnetite

Cupreous magnetite is a prominent feature at the Lake Shore mine (73, fig. 1) of Transarizona Resources, Inc., Casa Grande, Ariz. The property is in secs 23, 25, 26, and 36, T 10 S, R 4 E, Gila and Salt River meridian and base-line, in flat terrain along the southwest slope of the Slate Mountains, at about 1,800 feet altitude, on the Papago Indian Reservation. It is reached from Casa Grande by driving 28 miles south-southwest by county road to within 2 miles of Gu Komelik, then about 2 miles east to the property.

Magnetite occurs as contact metamorphic pyrometasomatic replacements in Precambrian schist and limestone and Cambrian quartzite, associated with granite, andesite, and diabase intrusives. Ore mined in 1961 (22) was a reddish magnetite-rich quartzite that had been shattered and recemented with quartz, chrysocolla, hematite, calcite and chlorite. The magnetite occurs as solid masses and as disseminations comprising 10 to 15 percent of the deposit. The cupreous magnetite deposit strikes north and dips about 55° east under shallow cover. Magnetometer surveys indicate anomalies under alluvium for about 3 miles along the strike. More than 1,500 feet along the deposit has been explored by drilling. The ore contains 1.5 to 2.25 percent copper, and 15 percent magnetite (22). A character sample of the better magnetite taken in 1961 from the open-pit area contained 44. 9 percent iron, 1.75 percent cop-per, 0.15 percent titania, 0.02 percent phosphorus, and 19.4 percent silica. Reserves, as copper ore, are inferred by the company to be several million tons.

The property is essentially a copper deposit; however, the recovery of magnetite from flotation tailings, as a concentrate containing 65 to 68 per-cent iron is receiving attention (22, pp. 1152-1155; 60, 24 pp.).

Superior (East Wind-Lime Cap) Magnetite

Magnetite crops out as irregular replacements in Precambrian Mescal lime-stone west-northwest of Superior (74, fig. 1), approximately in sec 21, T 1 S, R 11 E, Gila and Salt River meridian and baseline. Outcrops have been located as the East Wind and Lime Cap groups of claims, 2 miles north from the Wm. Martin ranchhouse, and 1 mile west of Roblas Butte. The property is reached from Superior by driving 4.5 miles west on Arizona Highway 789, then about 8 miles north over rough ranch roads to the East Wind No. 4 outcrop up Hewitt canyon. Magnetite (fig. 33) is exposed in thicknesses ranging from 3 to 5 feet, dipping 20° south in an area about one-half-mile square; other exposures probably exist throughout the Mescal limestone and intrusives contact areas. The outcrops have been explored by several shallow adits, shafts, and pits (fig. 33). A character sample taken by the Bureau in 1961 contained 62.3 per-cent iron, 0.2 percent titania, 0.3 percent manganese, 0.03 percent phosphorus, 0.09 percent sulfur, and 2.8 percent silica. Exposures indicate a widespread irregular replacement of limestone by magnetite, however the aggregate appears to be a small source of iron.

Table Mountain (Swingle) Manganiferous Hematite

Manganiferous iron oxides occur in the Bunker Hill District on the Swingle property (75, fig. 1) at the foot of Table Mountain, about 11 miles northeast of Mammoth, in sec 20, T 7 S, R 18 E. The manganiferous iron is found as small replacements in limestone. A 2-ton sample taken by the Bureau in 1955 contained 35.8 percent iron, 19.9 percent manganese, 2.2 percent silica, 2.9 percent alumina, a trace of barium, 1.1 percent lime, and 2.6

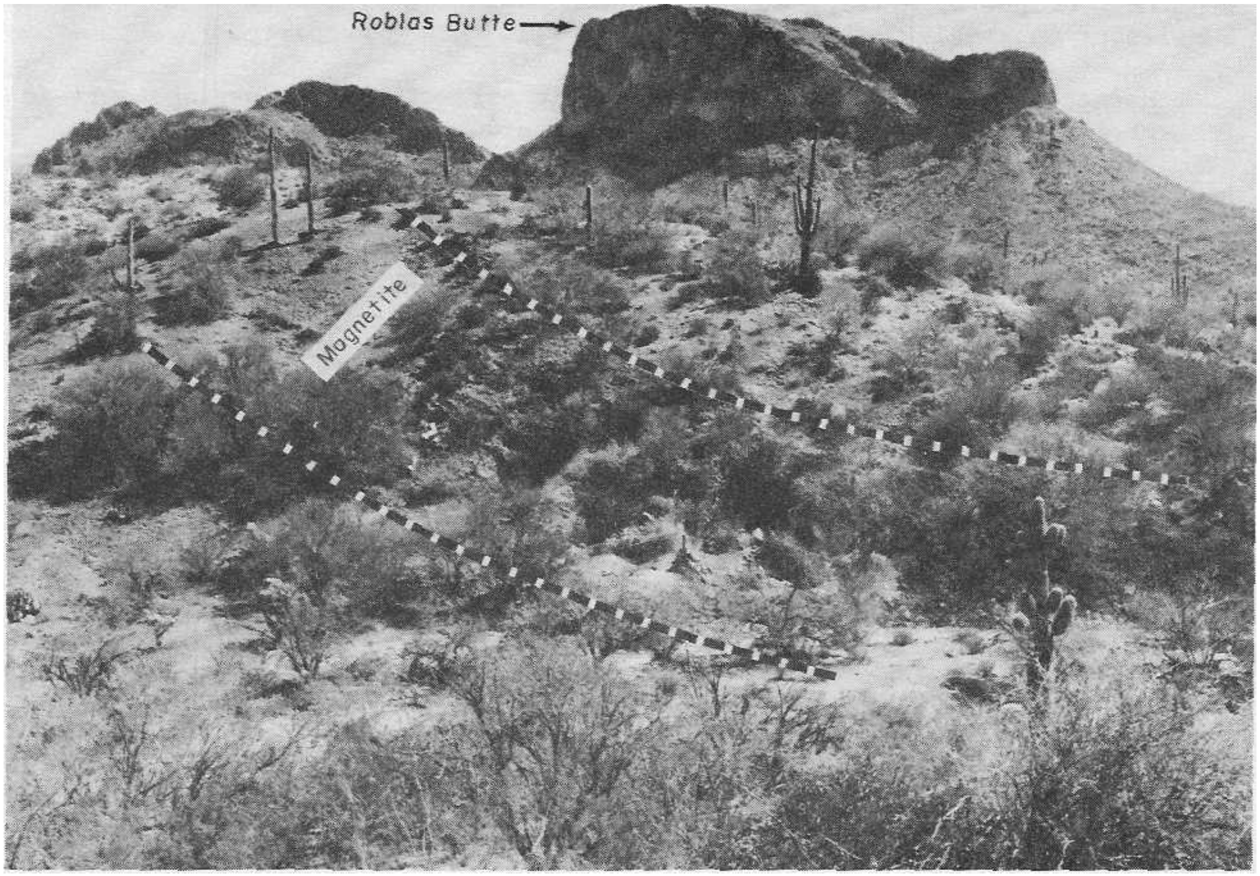

FIGURE 33. - Magnetite Replacement of Precambrian Mescal Limestone, East Wind Claims, T 1 S, R 11 E, Pinal County, Ariz.

percent insoluble. The deposit is developed by shallow shafts and stopes, and appears small.

Troy Magnetite-Hematite

Magnetite with minor amounts of hematite and limonite was noted on the old Troy-Manhattan Copper Co. property in the vicinity of the ghost town of Troy (76, fig. 1). The occurrence is reached from Globe by driving 21.6 miles south on Arizona Highway 77 to the junction of the Dripping Spring and Tatum ranch roads and about 7.5 miles northwest on the Dripping Spring road, then by walking a mile west. The most prominent occurrence is in secs 26, 27, and 28, T 3 S, R 14 E.

Magnetite, some chalcopyrite, pyrite with oxidized copper minerals, and minor amounts of hematite and limonite occur as irregular contact-metamorphic pyrometasomatic replacements in blocks of Mescal limestone associated with diabase intrusives. These fault blocks of Mescal limestone trend northwest in the Dripping Spring Mountains for many miles northwest and southeast of

Troy. At the Rattler or Manhattan mine, magnetite, chalcopyrite, and pyrite as a fine-grained aggregate contained 27 to 30 percent iron, 3 to 3.7 percent copper, 27 to 30 percent silica, 1 percent lime, 20 percent magnesia, and some gold and silver. Character samples of the better magnetite on the Buckeye and Rattler claims contained 37 to 60 percent iron and 0.02 to 1.0 percent titania.

The magnetite deposits were poorly exposed in 1961. They appeared as irregular replacements, more or less paralleling the bedding in small fault blocks of Mescal limestone associated with diabase and granitic intrusives. Individual replacement bodies appeared small; however, the host Mescal lime-stone is exposed as complex and comparatively small fault blocks for many miles in the Dripping Spring Mountains both northwest and southeast of Troy (57, pp. 12, 22).

Miscellaneous

Gold placer mining operations in the Tucson district indicated the pres-ence of abundant magnetite and some hematite and ilmenite in alluvium of the area (17, pp. 1180-1181).

Santa Cruz County

Copper Mountain Hematite-Limonite

Hematite and limonite occur on the Copper Mountain group of claims 3 miles east of Patagonia (77, fig. 1), approximately in sec 9, T 22 S, R 16 E, Gila and Salt River meridian and baseline, on the south side of Red Rock can-yon. The outcrop stands out as a 150 foot high and 70 foot thick ledge of red, ferruginous, leached, and silicified rhyolite, striking N 60° W. The rhyolite is pitted with pyrite casts, and some of it is heavily impregnated with iron oxides. Adjoining gravels are cemented by hematite and limonite. Croppings above and 200 feet southeast are weakly stained with malachite and azurite. A character sample taken by the Bureau in 1961 contained 18.5 per-cent iron, 1.0 percent titania, 0.1 percent manganese, 0.08 percent phosphorus, 0.48 percent sulfur, and 49.2 percent silica. The deposit is too low-grade and small to be considered a source of iron. Other similar and small deposits occur in the area (62, p. 245).

Line Boy Magnetite-Hematite

Hematite was reportedly abundant at the Line Boy mine near Duquesne (78, fig. 1). The mine is at 5,400 feet altitude on the east flank of the Patagonia Mountains, approximately in sec 22, T 24 S, R 16 E, just north of monument 113 on the United States-Mexico border. The property is reached by traveling over 5 miles of access road south of Duquesne.

A 3-foot thick sheet of fine-grained, friable, and nearly pure specularite is exposed in an adit along the hanging wall side of a 10-foot wide, fine-grained granite porphyry dike that trends west-northwest and has a steep north dip.

The property was developed as a copper prospect, the ore containing bornite, chalcopyrite and pyrite. The deposit is considered small (62, pp. 347, 348).

Yavapai County

Introduction, Precambrian Taconite- and Jaspilite-Like Iron Formations in Yavapai and Maricopa Counties

Magnetite and some hematite were noted in low-grade taconite, semitaconite- to jaspilite-like iron formations, observable in an interrupted pattern more than 70 miles through Yavapai and extending south into Maricopa County (fig. 19) as part of the great Yavapai series. Geographically, the iron formation centers around Cleator-Crown King and extends north beyond Lynx Creek into Tps 16 and 17 N, Rs 1 and 2 W, and south into the Hieroglyphic Mountains, T 6 N, Rs 1 and 2 W, in Maricopa County, Gila and Salt River meridian and baseline. The east-west limits extend beyond Mayer and Stanton.

The Yavapai series consists of metamorphosed volcanic and sedimentary rocks, including diorite, rhyolite, greenstone, quartzite, phyllite, argillite, graywacke, mica schist, hornblende schist, and amphibolites.

The iron-rich formations investigated varied from jaspilite-like beds to predominantly taconite-like occurrences. The area, approximately 35 miles wide and 70 miles long (fig. 19) was too great for comprehensive evaluation and would necessitate extensive geologic investigation, correlation, and basic exploration. However, a number of outcrop areas were given a reconnaissance examination to develop information as to their extent and continuity and were character sampled to form some idea as to their mineral potential. The chemical analyses of character samples in this taconite and jaspilite iron formation are summarized as table 16. The areas investigated X-1-X-21, fig. 19) are mostly in Yavapai County. The 100-million-ton (20) Hieroglyphic Mountains occurrence (X-21) and the extensive Big Boulder taconite (X-20) are reported in Maricopa County.

The jaspilite- and taconite-like areas investigated in Yavapai County (X-1-X-19, fig. 19) are discussed as follows:

Black Hills Magnetite-Hematite Jaspilite

General

Magnetite and hematite occur in numerous jaspilite beds about 8 miles northeast of Dewey in the Precambrian Grapevine Gulch formation (figs. 34, 35, and 36) in the Black Hills, Tps 14, 14½, and 15 N, R 2 E. The beds are part of a thick sequence of steeply dipping fine-grained tuffaceous rocks and chert that trend south-southeast through Yaeger Canyon Ranger Station, Kendall Camp, and beyond the old Black Chief (Warrior) mine. The best exposures are in secs 2, 3, 4, 9, 11, 12, 24, T 14 N, R 2 E, and secs 17, 19, T 15 N, R 2 E, and are reached from Dewey and Yaeger Canyon Ranger Station over difficult access roads and trails.

FIGURE 34. - Jaspilite on the Paul Vojnich Claims, Sec 20, T 15 N, R 2 E, Yavapai County, Ariz.

Individual jaspilite magnetite-hematite beds are as much as 30 feet thick, and some persistent beds can be traced well over a mile. In places the beds show evidence of folding and distortion. Magnetite occurs as streaks and bands and disseminations in microcrystalline quartz. Some hematite is present as separate streaks adjacent to the magnetite or as microscopic inter-growths. In places, parts of the beds consist of bands of almost pure magnetite, how-ever, most is low-grade siliceous and jaspilite-like material manganiferous in part. In places the beds contain more jasper than iron and manganese oxides and may grade along the strike into pure jasper. Other magnetite jaspilite beds contain interbeds of fine-grained tuffaceous rock a fraction of an inch thick. The outcrops of the magnetite-hematite jaspilite beds (fig. 34) form ridges that stand above the surrounding rock. Strike of the beds varies widely due to local folding. The beds dip variously between 30° to vertical. The magnetite-hematite beds were examined in 5 places (83, 88, 81, 102, 82, fig. 1) and correspond to locations X-1 through X-5 on figures 19 and 35. Their descriptions follow:

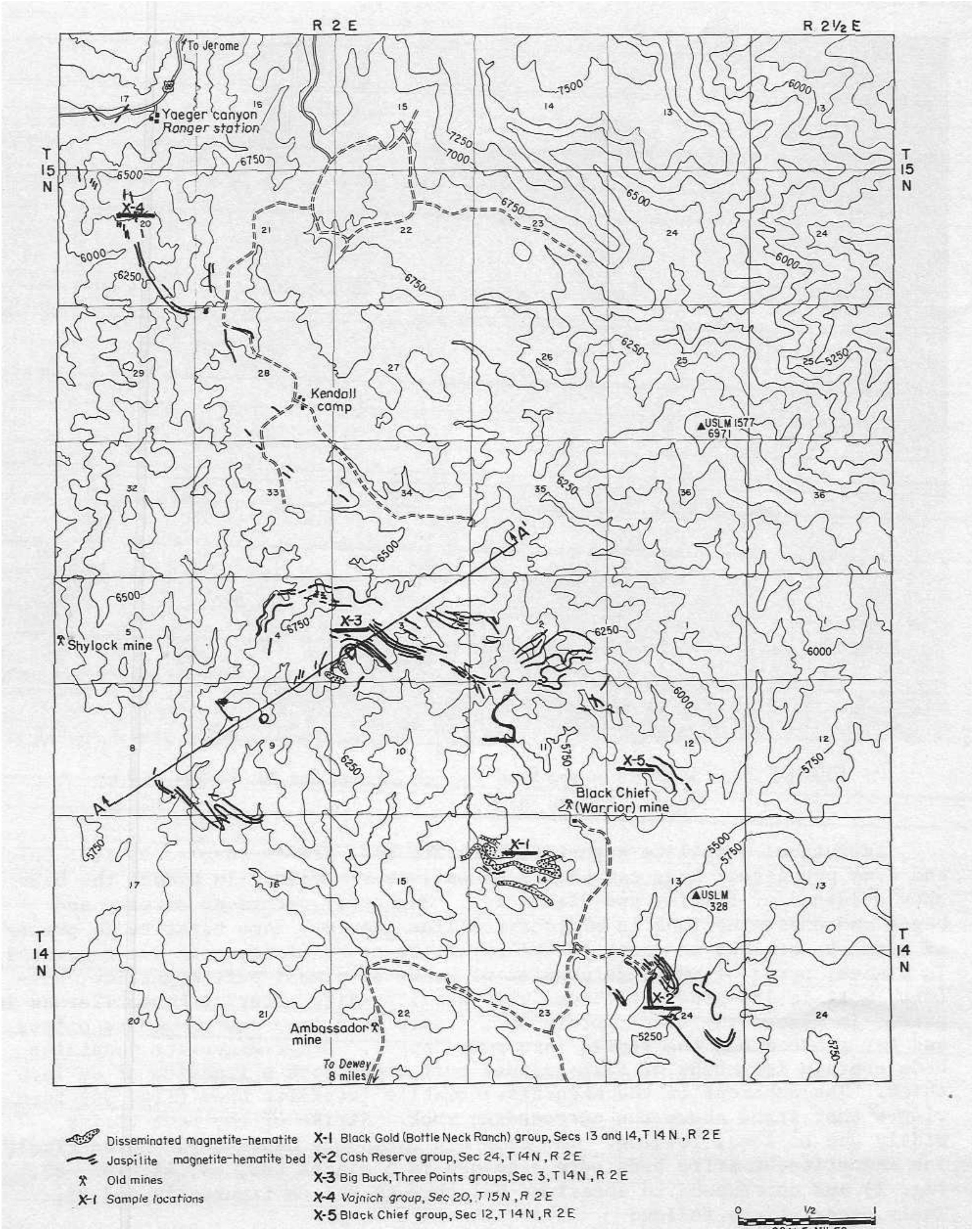

FIGURE 35. - Location of Jaspilite Magnetite-Hematite Beds, Black Hills, Tps 14 and 15 N, R 2 E, Yavapai County, Ariz. (1).

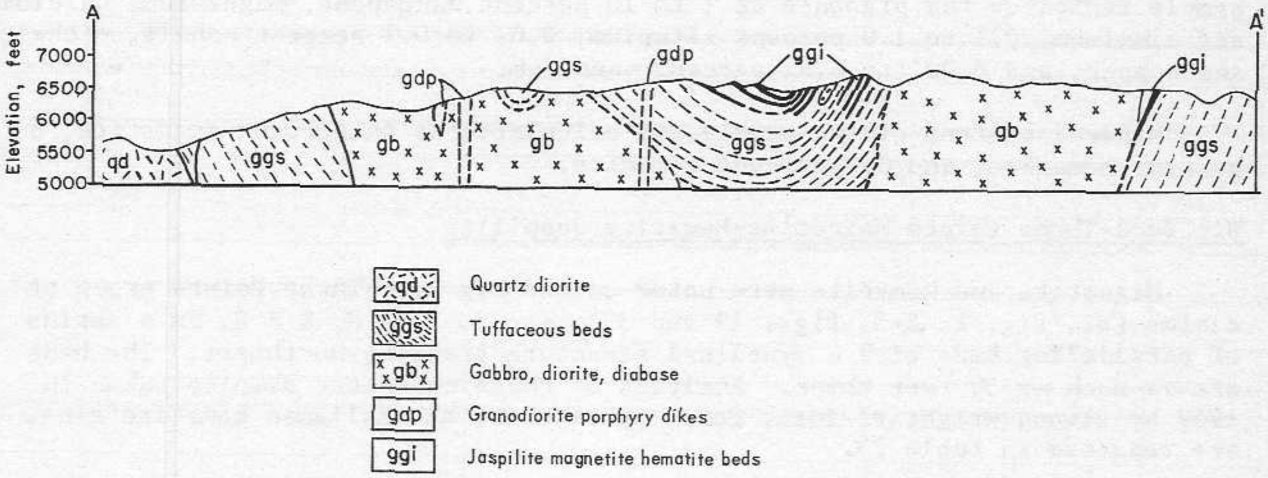

FIGURE 36. - Section Showing Relationship of Jaspilite Magnetite-Hematite Beds, Black Hills, Tps 14 and 15 N, R 2 E, Yavapai County, Ariz. (1).

Black Gold Magnetite-Hematite Jaspilite

At the Black Gold group of claims (83, fig. 1, X-1, figs, 19 and 35), secs 13 and 14, T 14 N, R 2 E, at the head of Ash Creek and 4 mile south-southwest of the Bottleneck ranch, magnetite, hematite, and some manganese oxides occur as a hard, black-to-red, and banded jaspilite iron formation in a dioritic rock. The formation can be traced along its N 65° W strike for more than one-half of a mile in thicknesses from 6 to 25 feet. The formation dips 40° to 80° NE.

Analyses of 2 character samples taken by the Bureau in 1944 appear in table 22.

TABLE 22. - Analyses of character samples, Black Gold group, head of Ash Creek, Yavapai County, Ariz.

Sample	Width, feet	Chemical Fe	analyses,. Mn	percent SiO_2	Remarks
1	8	33.5	4.5	28.5	Discovery cut near Ash Creek.
2	25	33.6	3.4	35.1	Across formation at top of ridge.

Cash Reserve Magnetite Jaspilite

Magnetite occurs on the Cash Reserve group of claims {88, fig. 1,.X-2, figs. 19 and 35) in the NW¼ sec 24, T 14 N, R 2 E. The magnetite occurs in a jaspilite-iron formation that can be traced northwest as several beds for about a mile. Thickness ranges from 6 to 30 feet; much is masked by over-burden. A character sample taken by the Bureau in 1961 contained 36.2 percent iron, 2.9 percent manganese, 0.3 percent titania, 0.21 percent phosphorus, 0.12 percent sulfur, and 37.4 percent silica. Spectrographic analysis of the sample indicates the presence of 1 to 10 percent manganese, magnesium, calcium and aluminum; 0.1 to 1.0 percent titanium; 0.01 to 0.1 percent cobalt, nickel, and copper; and 0.001 to 0.01 percent vanadium.

Mineral content of the sample was calculated as 44 percent magnetite, 6 percent hematite, and 0.5 percent ilmenite.

Big Buck-Three Points Magnetite-Hematite Jaspilite

Magnetite and hematite were noted on the Big Buck-Three Points group of claims (81, fig. 1; .X-3, figs. 19 and 35), sec 3, T 14 N, R 2 E, as a series of paralleling beds with a synclinal structure trending northwest. The beds are as much as 30 feet thick. Analyses of three character samples taken in 1957 by Elwood Wright of Post, Tex., operator of the Seligman hematite mine, are reported in table 23.

The iron in the samples was estimated as 23.2 percent magnetite and 76.8 percent hematite.

TABLE 23. - Analyses of Big Buck-Three Points magnetite-hematite taspilite beds, sec 3, T 14 N_z R 2 E, Black Hills, Yavapai County, Ariz;

Sample	Chemical analyses, percent										
	Fe	Mn	SiO_2	Al_2O_3	CaO	Ti0	Cu	Pb	Zn	P	S
1	37.1	2.9	25.20	3.62	9.1	0.22	Trace	0.2	0.08	0.02	0.05
2	37.4	3.0	25.46	3.81	8.8	.28	do	.3	.10	.02	.07
3	37.3	2.9	25.31	3.86	8.7	.32	do	.3	.07	.02	.04
Average --	37.26	2.93	25.32		8.86	.27	do	.29	.083	.02	.053

'Courtesy Elwood Wright, Post, Tex., operator of the Seligman hematite mine, 1961

Yaeger (Vojnich) Hematite-Magnetite Jaspilite

Hematite and some magnetite were noted in jaspilite beds on the Paul Vojnich group of claims (102, fig. 1; X-4, figs. 19 and 35), sec 20, T 15 N, R 2 E. The jaspilite iron formation (fig. 34) occurs as a series of steeply dipping and northwest trending beds in a gray schist. Where observed, the beds were about 30 feet thick. The magnetite-hematite may not be limited to the jaspilite beds since blebs and streaks of iron oxides were noted in the adjacent schist. The beds were traced more than a mile to where they were masked by overlying formations. The jaspilite beds are fissile and break readily into plates from 1/8 inch to 4 inches thick. Portions are black from manganese staining. Two character samples taken by the Bureau in 1961 are shown in table 24.

Mineral content of sample 1 was calculated as 32 percent magnetite and 1.0 percent ilmenite.

Spectrographic analysis indicates the presence of 1 to 10 percent manganese and aluminum; 0.1 to 1.0 percent calcium and titanium; 0.01 to 0.1 percent cobalt, copper and nickel; and 0.001 to 0.01 percent vanadium.

TABLE 24. - Analyses of Yaeger (Vojnich) hematite-magnetite jaspilite, Yavapai County, Ariz.

Sample	Chemical analyses, percent					
	Fe	Mn	TiO_2	P	S	SiO_2
1	26.9	1.1	0.4	0.15	0.11	53.0
2	34.6	.9	-	.30	-	36.6

Black Chief (Warrior) Magnetite Jaspilite

Magnetite, noted northeast of the old Black Chief (Warrior) mine (82, fig. 1; X-5, figs. 19 and 35), in two parallel jaspilite beds, was traceable more than half a mile northwest in sec 12, T 14 N, R 2 E. A character sample taken by the Bureau in 1961 contained 37.2 percent iron, 4.1 percent manganese, 0.3 percent titania, 0.42 percent phosphorus, 0.09 percent sulfur, and 32.6 percent silica. Spectrographic analysis of the sample indicates the presence of 1 to 10 percent manganese, magnesium, calcium, and aluminum; 0.1 to 1.0 percent titanium; 0.01 to 0.1 percent cobalt, nickel, and copper; and 0.001 to 0.01 percent vanadium.

The mineral content of the sample was calculated as 48 percent magnetite, 4 percent hematite, and 0.5 percent ilmenite.

Potential

Iron and manganese oxides prominent in jaspilite beds of the Yavapai-series can be traced more than 9 miles northwest in the Black Hills area of Yavapai County. Considerable local interest is shown by the numerous mining claim locations in the area. While consideration as individual and isolated beds of low-grade, iron-manganese formation would be relatively unimportant, several observations on admittedly cursory evidence should be included in an evaluation of the potential of the area as a large low-grade source of iron-manganese. These are as follows:

1. Extent for more than 9 miles.

2. Occurrence of the beds as several paralleling structures.

3. Accompanying trace elements.

4. Observations of blebs and streaks of iron oxides outside the jaspilite beds.

5. Resemblance of this iron formation to other midwestern taconite and jaspilite iron formations (1, pp. 9, 17, 19, 92, pl. 1).

Lynx Creek Magnetite Taconite

A band of magnetite taconite (95, fig. 1; X-6, fig. 19) parallels the Walker road in T 13 N, R 1 W. The low-grade iron occurrence is reached from Prescott by driving about 4 miles east on Arizona Highway 69 to its junction with the Walker road, then about 1 mile south-southeast along the Walker road, at which location the iron formation crosses the road. The iron formation (fig. 37) can be traced more than 4 miles south-southeast between and paralleling the Walker road and Lynx Creek, in secs 5, 8, 16, 17, 21, 28, and probably farther.

The iron formation (X-6, fig. 19) on the composite taconite map, has a N 10° W strike and 50° W to vertical dip. Where accessible the formation appears about 300 feet thick. A character sample taken by the Bureau in 1961 contained 36.2 percent iron, 1.9 percent manganese, 0.3 percent titania, 0.10 percent phosphorus, 0.08 percent sulfur, and 52.0 percent silica. A spectrographic analysis of the above mentioned sample indicates the presence of 0.001 to 0.01 percent copper, vanadium and zirconium; 0.01 to 0.1 percent cobalt, nickel and titanium; 0.1 to 1.0 percent calcium and magnesium; and 1 to 10 percent manganese and aluminum.

This taconite-like iron occurrence is one of several outcroppings within a 35 mile wide by 70 mile long area (fig. 19) that could be a future low-grade source of iron. At this stage further engineering, geological, and metallurgical investigations would be necessary to raise its potential above conjecture.

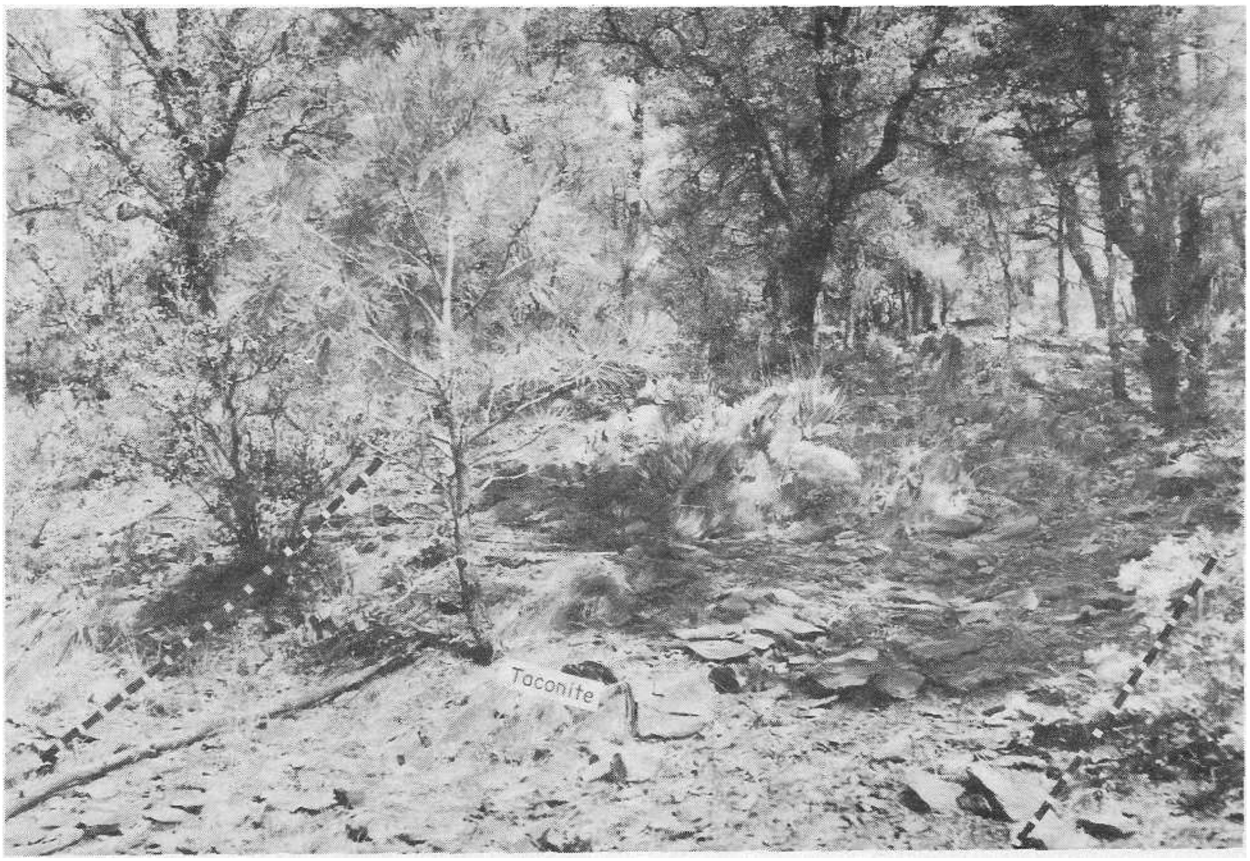

FIGURE 37. - Magnetite Taconite Outcrop Vicinity Lynx Creek, Approximate Sec 17, T 13 N, R 1 W, Yavapai County, Ariz.

Mayer-Stoddard Magnetite Taconite

A band of magnetite-hematite taconite (96, fig. 1; X-7, fig. 19) crosses the Stoddard mine road about 2 miles northeast from Mayer along a ridge occupying the center of sec 24, T 12 N, R 1 E. The taconite (X-7, fig. 19) is about 2 miles north of the Blue Bell-siding taconite (X-9, fig. 19) and is probably an extension of it. The hard, siliceous taconite iron formation (fig. 38) crosses the Stoddard mine road with a N 20° E strike and 70° W dip; its width of approximately 300 feet was traced about a mile.

A character sample taken by the Bureau in 1961 contained 27.2 percent iron, 1.4 percent manganese, 0.20 percent titania, 0.02 percent copper, 0.10 percent phosphorus, 0.09 percent sulfur, and 51.0 percent silica.

This taconite-like iron occurrence is one of several outcroppings in Yavapai schist within a 35 mile wide by 70 mile long area (fig. 19) that could be a future low-grade source of iron. At this stage further engineering, geological, and metallurgical investigations would be necessary to raise its potential above conjecture.

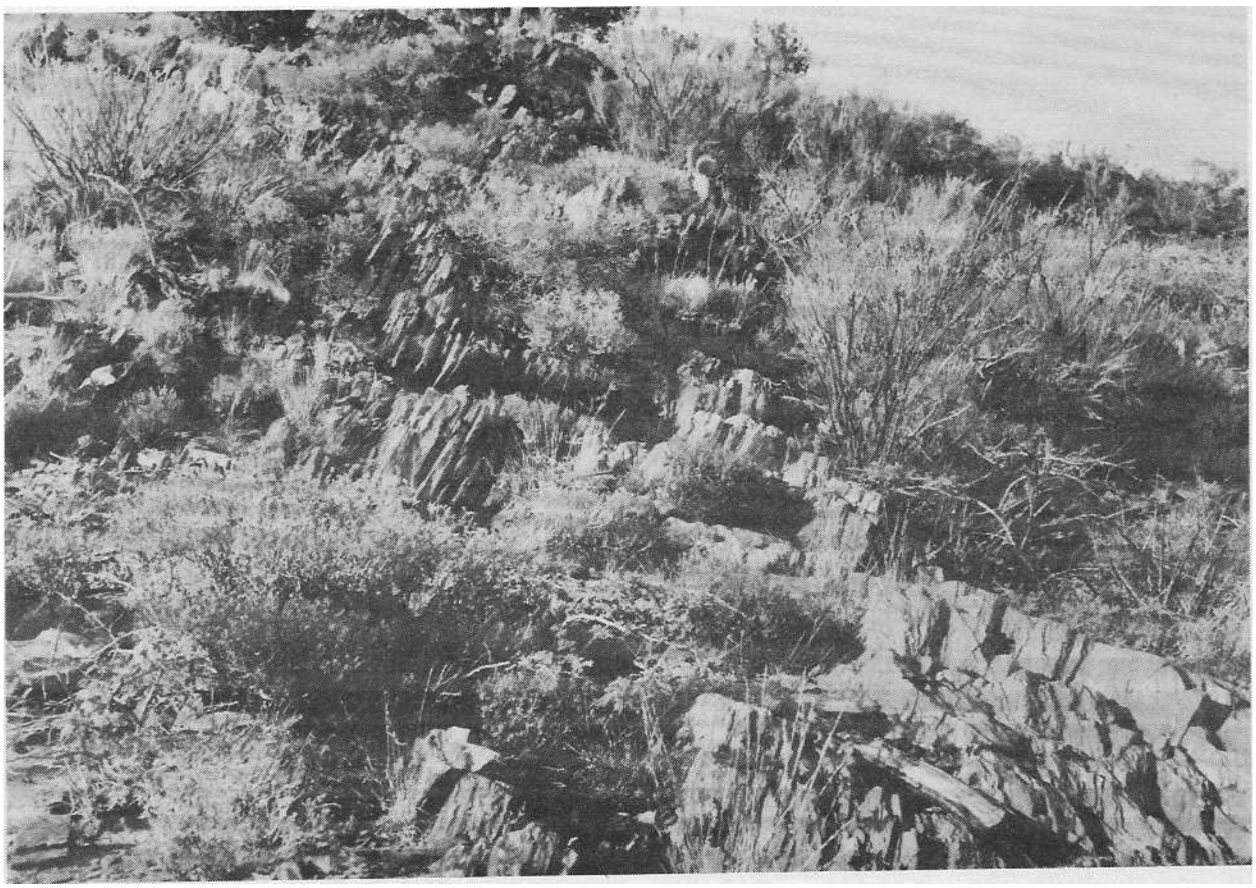

FIGURE 38. - Stoddard Magnetite-Hematite Taconite, Sec 24, T 12 N, R 1 E, Yavapai County, Ariz.

Copper Mountain Taconite-Jaspilite

Laminated magnetite-hematite iron formation (89, fig. 1) occurs within the Precambrian Yavapai (schist) series at many places in the vicinity of Copper Mountain in T 12 N, R 2 E, about 3 miles east-northeast of Mayer.

Large pieces of magnetite occur near the Stoddard mine on Copper Mountain, (X-8, fig. 19) about 4.5 miles east-northeast of Mayer by road.

A detailed examination of the area was not advisable at this stage, how-ever, the occurrences appear similar to the Mayer-Stoddard taconite occurrence and, like it, are considered part of the potentially large taconite-like iron formation delineated in part by the outcrop areas X-1 through X-21 on figure 19 (29, 11 pp. ; 41, pp. 26, 35-36, 156).

Blue Bell Siding Magnetite-Hematite Taconite

A taconite-like iron formation (86, fig. 1; X-9, fig. 19) was noted just east of the old Blue Bell railroad siding (fig. 39) and was traced more than a

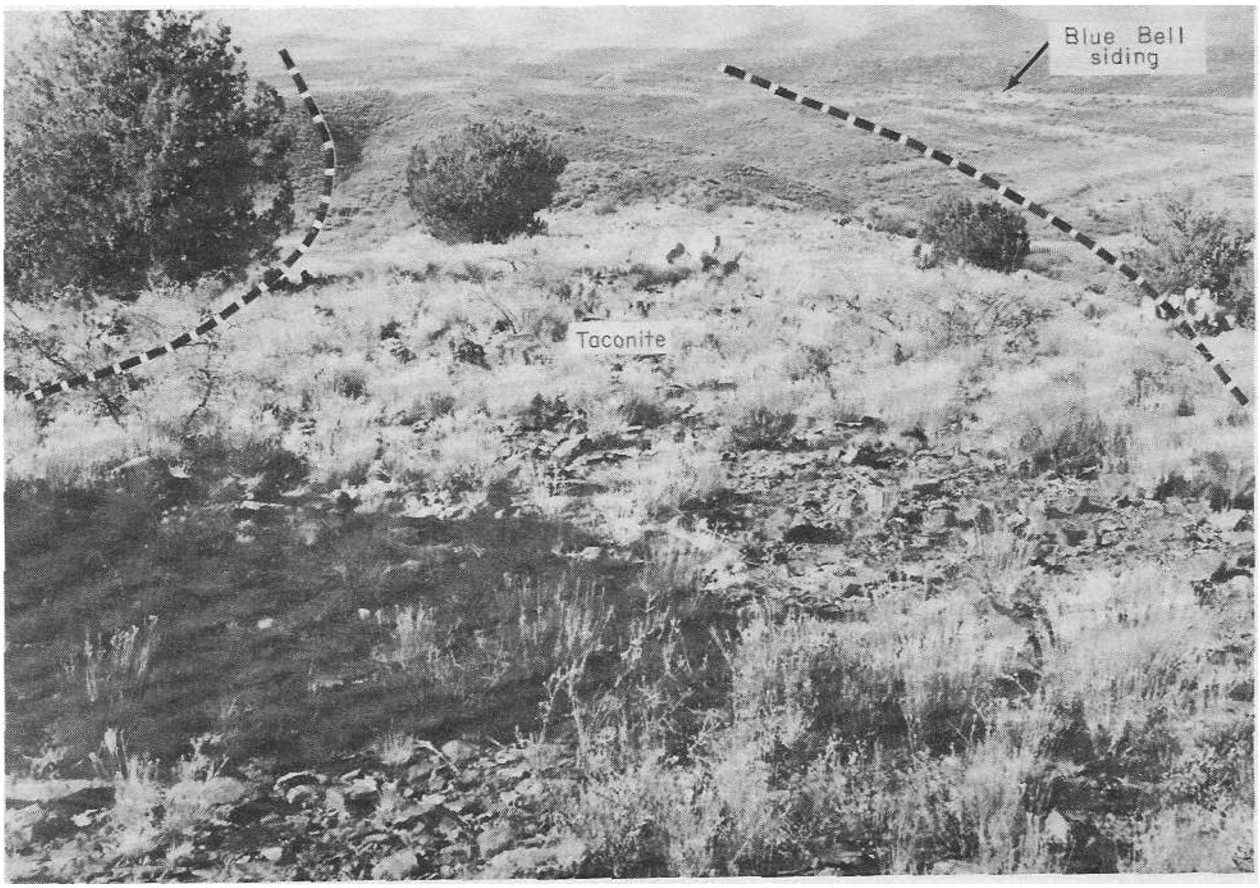

FIGURE 39. - South Along Blue Bell Siding Magnetite-Hematite Taconite, T 12 N, R 1 E, Yavapai County, Ariz.

mile through the W½ secs 25 and 36, T 12 N, R 1 E. The iron formation follows a ridge that is crossed by Arizona Highway 69 and is also dissected by Big Bug Creek, in sec 36. It extends from a point east of the old Mayer smelter stack, south beyond Blue Bell siding, and across the Mayer-Cordes-Crown King road, about 1.1 miles south of the junction with Arizona Highway 69.

Hard, siliceous magnetite and some hematite are prominent as bands from 1/8 inch to as much as 6 inches thick comprising a slaty to schistose and taconite-like iron formation in the Yavapai series. The magnetite-rich formation is about 300 feet thick and was traced more than 1.5 miles. The formation strikes N 10° E and dips 75° W. In places the formation appears either as a schist, banded and slaty, or as a jaspilite. Where dissected by Big Bug Creek it is hard and more or less banded and contains streaks and blebs of white quartz.

Two character samples taken about a mile apart by the Bureau in 1961 contained 27.3 and 35.6 percent iron; 0.2 and 0.3 percent titania; 1.9 and 1.8 percent manganese; 0.17 percent phosphorus; 0.10 percent sulfur; and 39.0 percent silica respectively. Spectrographic analysis of a character sample indicated the presence of 1 to 10 percent aluminum and manganese; 0.1 to 1.0 per-cent calcium and magnesium; 0.01 to 0.1 percent cobalt, copper, nickel and titanium; and 0.001 to 0.01 percent vanadium and zirconium. The mineral content was calculated as 29 percent magnetite, 9 percent hematite, and 0.5 percent ilmenite.

This taconite-like iron formation (X-9, fig. 19) is one of many outcrop-pings in Yavapai schist within a 35 mile wide by 70 mile long area that could be a future low-grade source of iron. At this stage, further investigations would be necessary to raise its potential above conjecture.

Blue Bell Mine Magnetite-Hematite Taconite

Taconite-like iron formation (85, fig. 1; X-10, fig. 19) was noted as part of the Yavapai series between the Blue Bell and Jubilee mines, approximately in secs 15, and 22, T 11 N, R 1 E, about halfway between Mayer and Cleator. The area is reached by driving about 6 miles south-southwest from Blue Bell siding.

At the Jubilee mine, sec 22, T 11 N, R 1 E, a steep west-dipping iron formation occurs in amphibolitic tuff, agglomerates, quartzites, graywacke, and argillite and can be traced in an interrupted pattern more than a mile (30, p. 109).

The iron formation strikes N 20° E and dips 75° NW. The hard, siliceous, banded formation (fig. 40), containing magnetite and some hematite, was traced an estimated 2 miles between the Blue Bell and Jubilee mines. It is about 300 feet wide. A character sample taken by the Bureau in 1961 contained 29.0 per-cent iron, 0.9 percent manganese, 0.6 percent titania, 0.10 percent phosphorus, 0.11 percent sulfur, and 52.4 percent silica. Spectrographic analysis indicated the presence of 1 to 10 percent aluminum and manganese; 0.1 to 1.0 per-cent calcium and magnesium; 0.01 to 0.1 percent cobalt, copper, nickel and titanium; and 0.001 to 0.01 percent vanadium and zirconium.

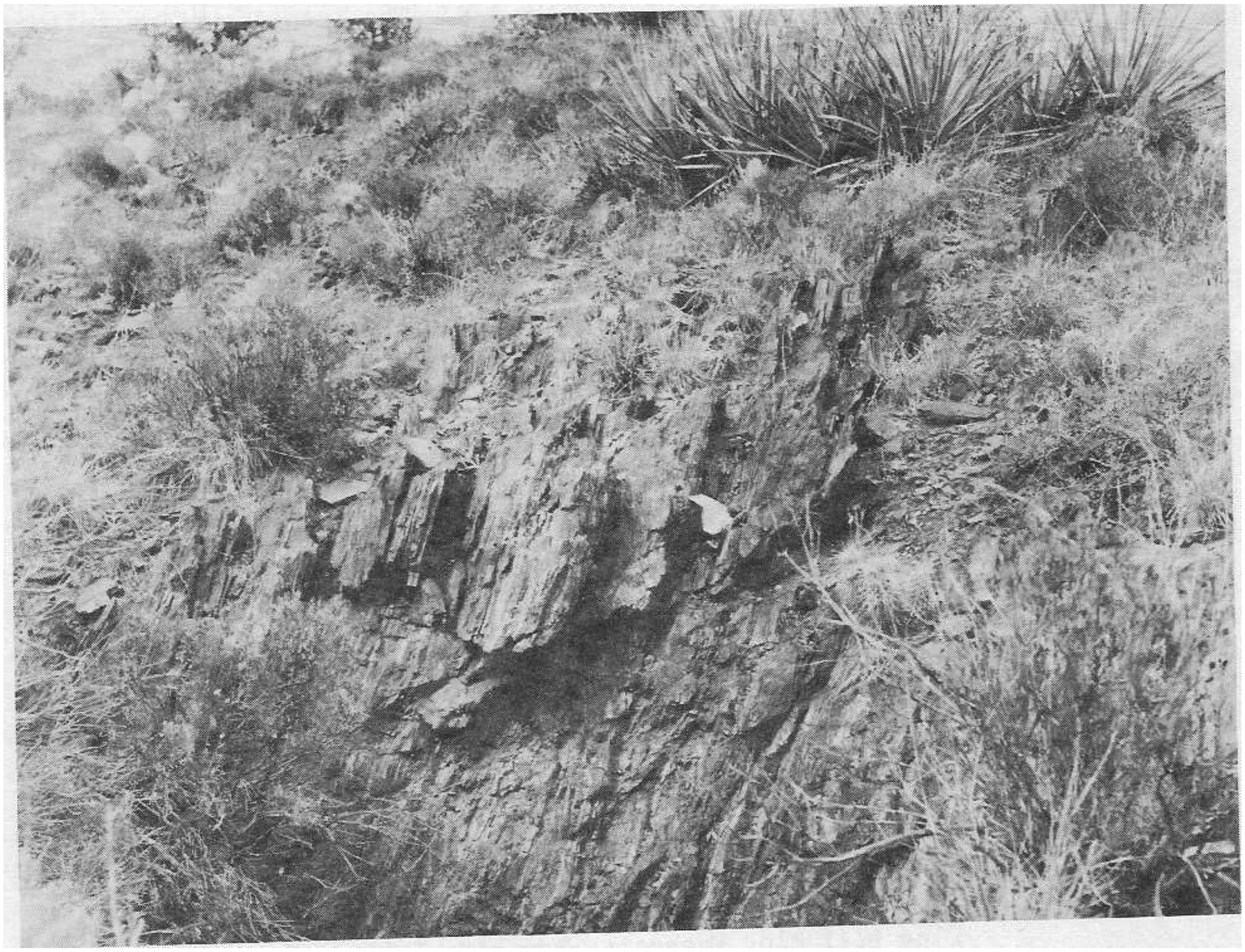

FIGURE 40. - Blue Bell Mine Taconite, T 11 N, R 1 E, Yavapai County, Ariz.

This taconite-like iron formation (X-10, fig. 19) is one of many outcroppings within a 35 mile wide by 70 mile long area that could be a future low-grade source of iron. Further geologic and metallurgical investigations would be necessary to raise the potential above conjecture.

De Soto Mine Magnetite Taconite

Magnetite was noted (90, fig. 1; X-11, fig. 19) as a low-grade taconite-like iron formation at the De Soto Copper Co. property near the summit of the high ridge dividing Peck canyon from Crazy Basin. Cursory investigation cated a formation width of about 100 feet. The iron formation strikes N 23° E and dips 70° NW. A character sample taken by the Bureau across the formation in 1961 contained 28.3 percent iron, 0.9 percent manganese, and 0.2 percent titania. The mineral composition was calculated as 25 percent magnetite, 15 percent hematite, and 0.5 percent ilmenite.

The property is approximately in secs 31 and 32, T 11 N, R 1 E, about 3 miles west of Cleator. This taconite-like iron outcropping (X-11, fig. 19) is one of many within a 35 mile wide by 70 mile long area that could be a future low-grade source of iron. At this stage, further geologic, engineering, and metallurgical investigations would be necessary to raise the potential above conjecture.

Los Felice (Townsend Butte) Manganiferous Magnetite-Hematite

Magnetite, hematite, and manganese oxides are prominent (94, fig. 1; X-12, fig. 19) in a 200 to 300 foot wide taconite-like zone within the Yavapai series on the Los Felice-St. John Gold & Copper Co. property in sec 1, T 11 N, R 1 E, about 1 mile east of Cleator (formerly Turkey Creek Station), at Townsend Butte on the Crown King Highway. The property comprises 12 lode claims owned by Mrs. John Slak, Mayer, Ariz.

The siliceous iron-manganese formation (fig. 41), estimated as 300 feet wide, can be traced north along its strike more than 7,000 feet, and is exposed vertically through a relief of more than 300 feet. The formation dips 80° W to vertical. The property was explored for gold and copper by an inclined shaft and short adits.

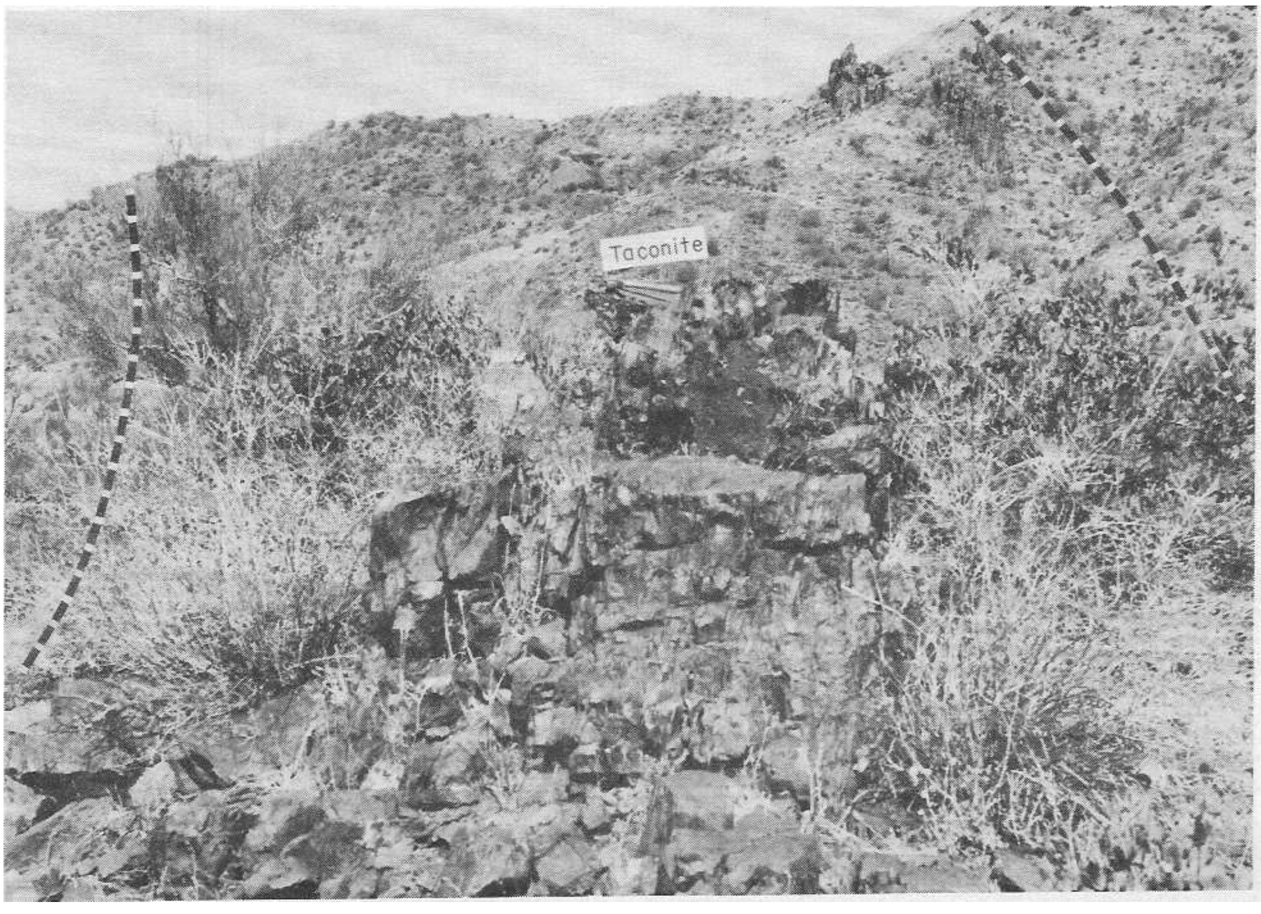

FIGURE 41. - Manganiferous Magnetite-Hematite Taconite, Townsend Butte, 1 Mile East of Cleator, T 11 N, R 1 E, Yavapai County, Ariz.

Results of sampling by John Slak and the Bureau compiled in table 25 indicate the quality of the deposit.

TABLE 25. - Results of sampling iron-manganese formation at the Townsend Butte-Los Felice-St. John Gold and Copper Co. property, Cleator, Ariz.

Sample	Width, feet	Chemical analyses, percent						Remarks
		Fe	Mn	Insol	TiO_2	P	S	
1....	10	32.75	5.8	36.0	-	-	-	In 100-foot adit; in schist about 150 feet east of shaft and 50 feet below its collar; Bureau of Mines, July 1943.
2....	10	38.32	1.9	35.2	-	-	-	100 feet down inclined shaft; Bureau of Mines, July 1943.
3....	20	32.78	4.3	39.6	-	-	-	In canyon, 300 feet south of inclined shaft and 125 feet below its collar; Bureau of Mines, July 1943.
4....	-	38.88	10.91	-	-	-	-	South of road, in canyon, John Slak, owner-operator, Cleator, Ariz., July 3, 1945.
5....	-	24.60	9.72	-	-	-	-	Along road and north of it; John Slak, Cleator, Ariz., July 3, 1945.
6....	-	26.92	9.78	-	-	-	-	North of road; John Slak, Cleator, Ariz., July 3, 1945.
7....	-	27.20	6.65	-	-	-	-	South of road; John Slak, Cleator, Ariz., July 3, 1945.
8....	-	32.75 38.32	1.9 5.8	-	-	-	-	Large composite samples, John Slak, Cleator, Ariz., July 3, 1945.
9....	-	35.4	3.9	35.0	0.2	0.3	0.13	Character sample, Bureau of Mines, 1959.
10....	-	29.4	1.3	51.2	.2	.22	.09	Character sample, Bureau of Mines, 1961.
11....	-	25.1	3.6	49.0	.3	.26	.25	Do.

Sample 10, the hanging-wall segment of the formation, consisted of 36 percent magnetite, 0.5 percent ilmenite, and 5 percent hematite. Sample 11 in the footwall segment of the formation contained 21 percent magnetite, 0.5 per-cent ilmenite, and 14 percent hematite.

Spectrographic analysis indicated the presence of 1 to 10 percent aluminum and manganese; 0.1 to 1.0 percent calcium, magnesium, and titanium; 0.01 to 0.1 percent cobalt, nickel and copper; and 0.001 to 0.01 percent vanadium.

This taconite-like iron outcropping (X-12, fig. 19) is one of many within a 35 mile wide by 70 mile long area that could be a future low-grade source of iron. At this stage, further geologic, engineering, and metallurgical investigations would be necessary to raise the potential above conjecture (42, p. 36, 156).

Banded magnetite taconite was also noted along the road 1 mile southeast of Cleator, approximately in secs 6 and 11, T 10 N, R 1 E (42, p. 36).

Black Canyon Magnetite-Hematite Taconite

Magnetite is prominent (92, fig. 1; X-13, fig. 19) 1 mile south of the old Howard Copper Mine, approximately in sec 31, T 10 N, R 1 W, and it is reached with difficulty about 4 miles west from Bumble Bee.

The magnetite occurs as a laminated, crinkled, and folded structure with much red jasper. The formation can be traced for about a mile north along its strike; it is about 200 feet thick. The iron formation is part of the Yavapai series, extending for many miles in the area.

This outcropping of iron formation (X-13) like the many others shown on fig. 19, is part of an extensive area that may be a large low-grade source of iron for the future. Like the others, more detailed investigations are necessary to raise the potential above conjecture (29, 11 pp.; 42, p. 156).

Precambrian Yavapai schist is prominent in a north-northwest trending band dipping 80° W to vertical. It is about 2 miles wide and can be traced more than 20 miles between Rock Springs and Cleator-Townsend Butte in the Black Canyon area of Yavapai County. The Yavapai sequence includes mica, hornblende, and siliceous schists; quartzite, slate, sandstone, phyllite, argillite, banded ferruginous and specularitic quartzite, and graywacke, hornfels, tuffs, and agglomerates interbedded with magnetite-hematite-rich iron formations. Where metamorphosed, the rocks are amphibolitic and contain hornblende, garnet, tourmaline, epidote and mica.

Two bands of magnetite-hematite iron formation were identified and mapped by Jerome (30) in the Black Canyon area west of Black Canyon Creek. Jerome's main band of iron formation (Yif, fig. 19) starts north of Soap Creek, about 4 miles northwest of Rock Springs, and extends north-northwest for approximately 14 miles through secs 20, 17, 8, 7, and 6, T 9 N, R 2 E, secs 31, 30, and 19, T 92 N, R 1 E, and secs 36, 25, 24, 13, 12, and 1, T 10 N, R 2 E. A second band of iron formation (Yq-if, fig. 19) parallels the first about 14 miles west and can be traced for about 6 miles north-northwest between Soap and Castle Creeks, approximately in secs 19, 18, and 7, T 9 N, R 2 E, and secs 36, 25, and 24, T 9½ N, R 1 E.

The main iron formation (Yif, fig. 19) dips 80° W to vertical, is about 1,000 feet wide, and consists of light gray, banded, ferruginous and specularitic quartzite, amphibolitic tuff, and argillite that is interbedded with magnetite-hematite-rich members as much as 200 feet thick that appear discontinuously along the strike of the formation. North of the Thunderbolt mine, in sec 24, T 10 N, R 1 E, occurs a single band of iron-rich beds. South of the Thunderbolt mine, several iron-rich zones appear in parts of the main iron formation. In some localities this increase in magnetite-hematite-rich members may be the result of duplication by folding and faulting. The iron-rich members are banded, comprising thin bands made up of 75- to 90-percent magnetite-hematite with 25- to 10-percent quartz, alternating with bands made up of

75- to 90-percent quartz and 25- to 10-percent magnetite-hematite. Late limonite and calcite are common, and the iron-rich members are stained and coated with manganese oxides at many locations. The banded, iron-rich units occur as magnetite- and garnet-rich rock, ferruginous chert, jasper, jasperoid, and jaspilite and a mixture of granular quartz, limonite, and manganese oxides.

Similar iron-rich units are found both east and west of the main iron formation. East of the main band of iron formation (Yif, fig. 19) thin-bedded, iron-rich units occur interbedded in a sequence of tuffs, agglomerates, quartzites, graywacke, and andesite and dacite. West of the main band of iron formation, thin-bedded iron-rich beds occur in a 1,000-foot wide zone of inter-bedded tuff, agglomerate, ferruginous quartzite, and graywacke.

The second band of iron formation (Yq-if, fig. 19) about 1¼ miles west of the main formation (Yif, fig. 19) comprises about 800 feet of quartzite and graywacke interbedded with bands and lenses of siliceous, amphibolitic, and magnetite-hematite-rich rock,

Magnetite in all the iron-rich units occurs generally as masses and coarse-to-fine octahedral crystals with some hematite, comprising about 25 percent of the rock. Locally, thin beds contain as much as 90 percent magnetite.

At the Thunderbolt mine, sec 24, T 10 N, R l E, several zones of magnetite-hematite iron formation were noted across a 2,000-foot sequence of argillites, tuffs, agglomerates, quartzites, and graywacke. The bands of iron formation, as much as 200 feet thick, dipping steeply westward, appear discontinuously along their north-northwest strike.

Drag-folded bands of magnetite-hematite iron formation were noted in the argillite in the Columbia mine area.

Magnetite-hematite iron formation was noted in argillite 0.5 mile northwest of Bland Hill approximately in secs 18, 19, 20, and 29, T 10 N, R 2 E.

Magnetite-hematite-rich beds were noted as crinkly drag-folded iron formation in argillite about mile northwest of Arrastre Creek and in the vicinity of the Valencienne mine, approximately in sec 9, T 9 N, R 2 E.

Deposits of magnetitic sand and alluvium were noted along creeks comprising the Black Canyon drainage area (29, 30, 42).

Goodwin Magnetite Taconite

Magnetite crops out (91, fig. 1, X-14, fig. 19) as a low-grade, taconite-like iron formation in the Yavapai series (fig. 42) just west of the old ghost town of Goodwin, 12.2 miles west of Mayer, approximately in sec 28, T 12 N, R 1W.

The magnetite taconite crops out (fig. 42) as a hard, siliceous, and laminated iron formation with a slaty cleavage. The formation strikes N 30° E

FIGURE 42. - Magnetite Taconite, T 12 N, R 1 W, Vicinity of Goodwin, Yavapai

and dips 70° NW. A grab sample taken by the Bureau across a 50-foot exposure contained 20.8 percent iron, 0.7 percent manganese, 0.6 percent titania, 0.12 percent phosphorus, 0.17 percent sulfur, and 50.6 percent silica. The mineral content of the sample comprised 24 percent magnetite, 4 percent hematite, and 1 percent ilmenite.

To the south the iron content of the formation increases. This outcrop-ping (X-14) like the many others shown on figure 19 is part of a much larger taconite area that may be a large low-grade source of iron for the future. Like the others, it requires more detailed geologic and metallurgical investigations.

Blind Indian Arrastra Creek-Longfellow Ridge Magnetite Taconite

Taconite-like magnetite was traced interruptedly more than 15 miles south from the outcrop west of Goodwin. The outcrops are in difficult terrain with heavy forest and underbrush.

The Blind Indian-Arrastra Creek outcropping of the iron formation (84, fig. 1; X-15, fig. 19) is prominent along the ridge at the head of Blind Indian and Arrastra Creeks at about 5,500 feet altitude, approximately in sec 8, T 11 N, R 1 W. It is reached by driving 4 miles south of Goodwin and walking westward over a mile up the steep slopes towards Longfellow Ridge and Spring.

Magnetite with some hornblende, epidote, tourmaline, and garnet occur as a laminated, banded, siliceous, and taconite-like iron formation (fig. 43) in a hornblendic facies of the Precambrian Yavapai series. Reconnaissance for a mile north and south indicates that the formation is probably as much as 500 feet wide and is continuous along its N 10° E strike and 70°-80° W dip. In places the formation is highly contorted. A character sample taken by the Bureau in 1961 contained 34.0 percent iron, 0.1 percent manganese, 0.3 percent titania, 0.1 percent phosphorus, 0.1 percent sulfur, and 39 percent silica.

This outcropping (X-15) like the many others shown on figure 19 is part of a much larger taconite area that may be a large low-grade source of iron

FIGURE 43. - Magnetite Taconite Outcrop, Longfellow Ridge at Head of Blind Indian Creek, T 11 N, R 1 W, Yavapai County, Ariz.

for the future. Like the others, more detailed engineering, geologic, and metallurgical investigations are necessary to raise its potential above conjecture (29, p. 11).

Pine Creek Magnetite Taconite

Taconite-like, siliceous and banded magnetite iron formation (fig. 44) was traced interruptedly through heavy forest and underbrush about 3 miles (97, fig. 1; X-16, fig. 19) west of Pine Creek, from Walnut Spring south to the junction of the Pine Creek road with the Senator Highway, through secs 29, 32, T 11 N, R 1 W, and sec 5, T 10 N, R 1 W.

The magnetite iron formation is part of the Yavapai series and is similar to the Blind Indian-Arrastra Creek-Longfellow Ridge outcropping 2 miles to the north. The Pine Creek occurrence is probably its extension. The iron formation has a north strike with evidences of folding. Dips range from 80° W to vertical. The iron formation was estimated as 300 to 500 feet wide and a character sample, takin in 1961 by the Bureau, in sec 29, contained 33.8 percent iron, 0.1 percent manganese, 0.3 percent titania, 0.11 percent phosphorus,

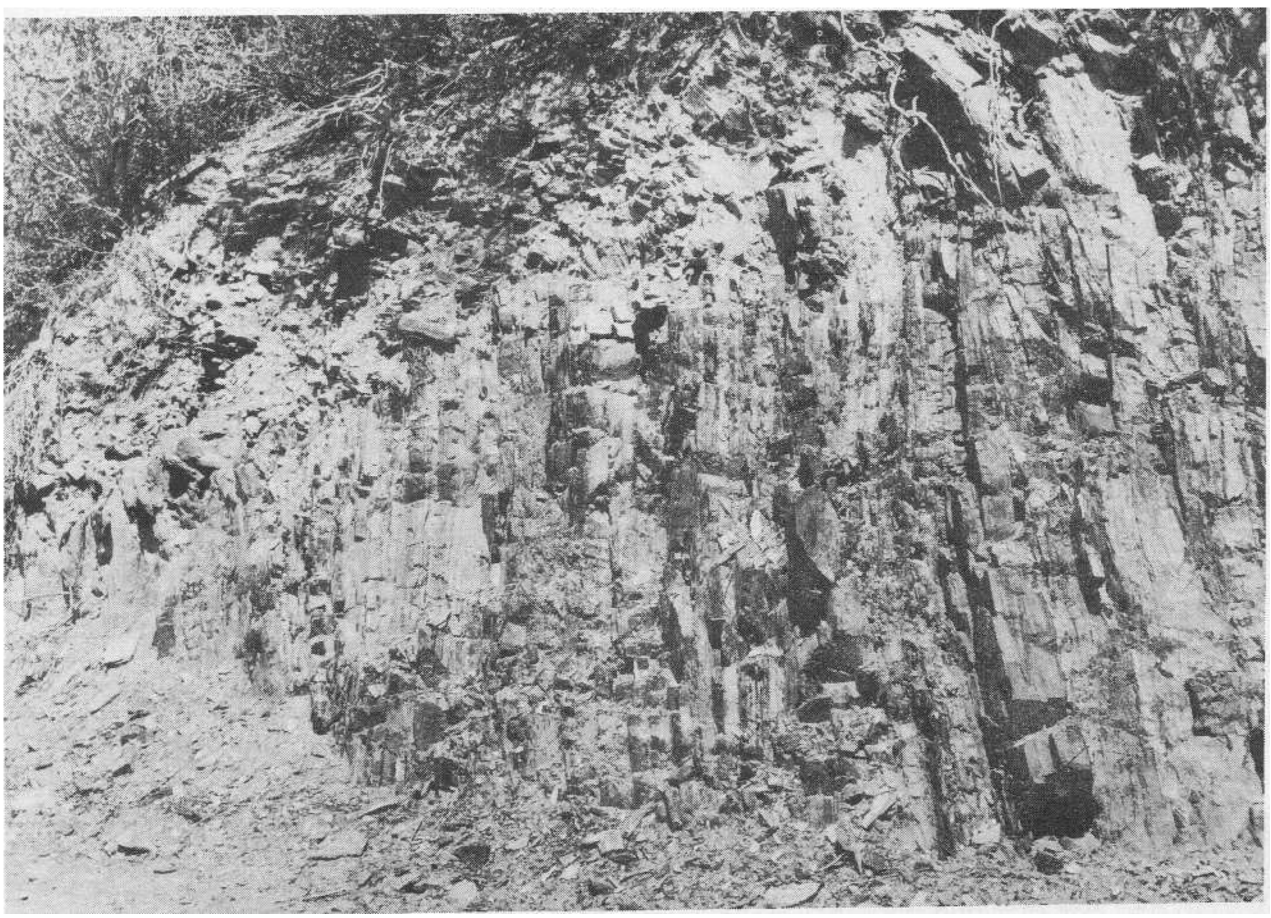

FIGURE 44. - Magnetite-Hematite Taconite, Pine Creek Drainage, Tps 10 and 11 N, R 1 W, Yavapai County, Ariz.

0.08 percent sulfur, and 38.2 percent silica. Spectrographic analysis indicated the presence of 1 to 10 percent aluminum, calcium, and magnesium; 0.1 to 1.0 percent manganese and titanium; 0.01 to 0.1 percent cobalt, copper, and nickel; and 0.001 to 0.01 percent vanadium and zirconium.

This outcropping (X-16) like many others shown on figure 19 is part of a much larger taconite area that may be a large low-grade source of iron for the future. Like the others, more detailed investigations are necessary to raise the potential value above conjecture.

Ash Creek Magnetite Taconite

Taconite-like, siliceous and banded magnetite iron formation (79, fig. 1; X-17, fig. 19) was traced west of Ash Creek and the Minnehaha Flat road about 4 miles through secs 18, 19, 30, 31, T 10 N, R 1 W. The iron formation is probably a continuation of other occurrences traced south from Goodwin.

The magnetite iron formation is part of the Yavapai series and is similar in character and mineral content to the Pine Creek and Blind Indian-Arrastra Creeks-Longfellow Ridge outcropping occurrences 2 and 6 miles north, respectively.

This outcropping (X-17, fig. 19) is part of a much larger taconite-like iron formation area that may be a large low-grade source of iron for the future, however, more detailed investigations are necessary to raise the potential value above conjecture.

Stanton Magnetite Taconite

Magnetite is prominent in the Yavapai series in the vicinity of Stanton and north along the Stanton-Yarnell road, in secs 24, 25, 35, 36, T 10 N, R 5 W (100, fig. 1; X-19, fig. 19). The magnetite (fig. 45) occurs in a laminated, siliceous, taconite-like iron formation that can be traced north for 3 or more miles as a taconite, schist, quartzite, and greenstone sequence in the Yavapai series. Dips range from 50° W to vertical. The Precambrian formation appears about a mile wide, west of Rich Hill; the better magnetite (fig. 45) is exposed in a 200-foot width along the steep slope west of the road. The magnetite iron-formation (X-19, fig. 19) is similar to the outcroppings (X-6-X18, fig. 19). Character samples of the Stanton taconite taken by the Bureau in 1961 contained 20.6 and 30.6 percent iron, 0.2 and 0.4 percent titania, 1.8 and 2.9 percent manganese, 0.11 and 0.27 percent phosphorus, 0.10 and 0.08 percent sulfur, and 59.2 and 43.8 percent silica respectively. Semiquantitative spectrographic analysis indicates the presence of 1 to 10 percent manganese and aluminum; 0.1 to 1.0 percent calcium, magnesium, and titanium; 0.01 to 0.1 percent cobalt, copper, and nickel; and 0.001 to 0.01 percent vanadium. The mineral content of the sample was calculated as 16 percent magnetite, 13 percent hematite, and 0.5 percent ilmenite.

The deposit appears low-grade and large, however, its full potential can be established only by more detailed exploration and sampling.

FIGURE 45. - Taconite-Like Outcrop, Sec 25, T 10 N, R 5 W, North of Stanton and West of Stanton-Yarnell Road, Yavapai County, Ariz.

Wasson Peak-Oro Belle Taconite

A siliceous magnetite taconite-like iron formation (101, fig. 1; X18, fig. 19) was noted along the road south of Wasson Peak and 0.8 mile west of the Oro Belle mine, approximately in sec 34, T 10 N, R 1 W. The formation has a due north strike and a vertical dip. The iron formation (X-18, fig. 19) appears similar to those in the area that have been previously discussed; it is one more indication of continuity.

Big Iron Hematite

Hematite was noted on the Big Iron group of claims (80, fig. 1), in the SE; sec 16, T 22 N, R 8 W, near Markhams Well. The property is reached from Seligman by driving 17 miles southwest along the old Kingman road, The claims were located by Clive W. Stephens in 1959.

Hematite, red jasper, and white quartz replace Paleozoic limestone in a zone about 100 feet wide that can be traced north more than 1,000 feet. The hematite occurs irregularly and ranges from a red coloration to almost pure clusters of hematite. A character sample of hematite matrix with quartz and gray limestone contained 36.5 percent iron, 22.2 percent silica, and 41.3 percent lime.

The Big Iron property is in the prospect stage and is developed by small, shallow assessment pits. Hematite replaces the limestone host rock erratic-ally in the surface exposures, and the deposit appears to be a small source of iron that would require sorting.

Boulder Creek-Milholland Creek Titaniferous Magnetite-Hematite

Titaniferous magnetite and hematite crop out as discontinuous lenticular bodies (87, fig. 1) in a gabbro mass about 2½ miles northwest of Bagdad, in the SW¼, T 15 N, R 9 W. The deposits occur centrally along a northeast trending band of gabbro as much as 4,000 feet wide and more than 4 miles long. The gabbro is intrusive into schists and is cut by granite and aplite dikes.

Northeast of Centipede Mesa, on the south side of Boulder Creek just below its confluence with Copper Creek, a coarse-grained magnetite-hematite-ilmenite-rich facies of the gabbro is exposed. The lenticular bodies of titaniferous magnetite are about 20 feet thick and several hundred feet long. The magnetite contains some specularite and hematite as an intergrowth. The magnetite is associated with ilmenite, hematite, pyrite, and apatite; all of these minerals plus hornblende, epidote, chlorite, zoisite, leucoxene, and uralite are accessory minerals in the gabbro (3). Two samples of the best titaniferous magnetite contained 60.09 and 62. 02 percent iron with 9.80 and 8.20 percent titania, respectively, and a trace of manganese.

A second outcrop of massive titaniferous magnetite, including dark red bands of secondary hematite occurs southwest of Centipede Mesa on Milholland Creek and is about 1¼ miles southwest of the first mentioned exposure. The gabbro at this exposure is gneissic and the magnetite occurs as discontinuous, parallel, and steeply-dipping lenticular bodies 3 to 8 feet thick. The magnetite occurs with ilmenite, hematite, pyrite, and some enstatite. A sample of the best titaniferous magnetite contained 60.35 percent iron, 8.40 percent titania, and a trace of manganese.

Similar bodies of titaniferous magnetite and hematite occur in other areas within the gabbro. They are parallel to the banding in the enclosing gabbro and grade into it. A trenching program (2) during 1952 indicated that the deposits investigated were larger and that the titania content was higher below the outcrops.

Further exploration, sampling, and metallurgical investigation are necessary to determine the full potential of these occurrences. At present the deposits, in aggregate, appear to be a substantial source of low-grade iron, high in titania.

Jerome and Bradshaw Area Iron Oxides

Jarosite and limonite are common in the gossan over many sulfide deposits in the Jerome and Bradshaw area (93, fig. 1).

Specular hematite is present in late veins at the United Verde mine and is common as veinlets in all the Precambrian rocks south of Jerome.

Magnetite is an accessory mineral in altered facies of the Spud mountain rhyolite 2.5 miles east of the Iron King mine where it is present as crystals and irregular masses (1, p. 92).

Santa Margarita District Alluvial Magnetite

Magnetite-rich alluvium is prominent in the sand and gravel of the piedmont area in the Weaver and Date Creek Mountains (98, fig. 1). Magnet Mining Corp., Melvin H. Jones, President, of Congress, Ariz., has located 55 sections as placers in the drywash drainage area of Martinez, Antelope, and Stanton Creeks, in Tps 8, 9, and 10 N, Rs 5 and 6 W, in the Santa Margarita district northwest of Wickenburg. The magnetite-rich area is crossed by U.S. Highway 89 and the Atchison, Topeka & Santa Fe Railroad.

Magnetite occurs concentrated in thin layers in sand-gravel alluvium and also disseminated in lesser amount through the tan- to buff-colored sand and gravel. The layered sequence and stratification of concentrated magnetite (dark) and lighter colored and lower-grade magnetite in sand and gravel is shown in the 6-foot deep back-hoe pit (fig. 46).

Channel samples from 19 locations scattered throughout sec 6, T 8 N, R 5 W, to depths as much as 25 feet, indicate that the deposit contains 1.7 to 10.9 percent magnetite by weight, averaging 5.5 percent magnetite by weight. Data on several wells in the area indicates alluvium as much as 3,000 feet thick in places.

A composite of samples taken in creek bottoms averaged 1.75 percent magnetite. A more general composite of samples averaged 1.55 percent magnetite. A spectrographic analysis made by the Bureau in 1961 indicated the presence of more than 10 percent iron and silicon, 1 to 10 percent aluminum and titanium, 0.1 to 1.0 percent calcium, magnesium, and manganese, 0.01 to 0.1 per-cent cobalt, nickel, vanadium, and zirconium, and 0.001 to 0.01 percent copper.

Microscopic examination of the sample indicated the presence of magnetite, ilmenite, hematite from magnetite alteration, quartz, feldspar, micas, minor clay, and garnet, and traces of specularite, epidote, and zircon.

Pioneer magnetic separation tests on the samples yielded concentrates containing 60.48 and 60.70 percent iron, 0,05 percent titania, 0.50 percent manganese, 0.24 percent phosphorus, and 11.20 percent silica.

Part of the area, 5 miles north of Wickenburg, in a gulch joining with Martinez Creek, in secs 14, 23, 25, 36, T 9 N, R 6 W, and secs 6, 8, 17, T 8 N,

FIGURE 46. - Magnetite Stratification, Magnet Mining Co. Property, Tps 8, 9, and 10 N, Rs 5 and 6 W, Santa Margarita District, Yavapai County, Ariz.

R 5 W, was located in 1943 as the Magnetite Iron-Desert Iron group of 12 placer claims by C. C. Findly. This alluvial deposit averages 50 feet in width more than 6 miles. A composite sample from various test pits averaged 28.1 percent iron.

Alluvium in the area is a potentially large source of magnetite sand, which could be mined cheaply and beneficiated by screening and magnetic separation into a high-grade iron product. Agglomeration or pelletizing may be necessary to make the iron acceptable as a furnace feed.

Seligman (Juniper Mountains, Cowden) Hematite

Hematite occurs (99, fig. 1) prominently in the Juniper Mountains, 18.6 road miles south of Seligman on the Walnut Creek road, at about 5,600 feet altitude. Seligman is the nearest shipping point, on the Atchison, Topeka & Santa Fe Railroad. The occurrence has been known also as the Cowden and Iron Chancellor deposit. The deposit is covered by 13 patented claims (Mineral

Survey 2282) and 16 located claims in secs 15, 21, 22, 23, 26, and 27, T 20 N, R 6 W, in the Chino mining district. The patented group includes the Iron Chancellor, Iron Horse, Camp Bird, Fairview, Federal 1 and 2, Ben Franklin 1-2, Hematite, Lone Jack 1 and 2, Machias, and Monitor; the unpatented lode locations comprise the Ben Franklin 3-11, Hematite 2-3, and Iron Horse 2-6. The deposit is the property of Cowden Livestock Company (E. Roy Cowden) of Phoenix and was leased in 1961 to E. P. Campbell Drilling Co., Lubbock, Tex.

High-grade red to bluish black hematite, 2 to 40 feet thick in drill holes and pits, occurs as lenticular contact-metamorphic pyrometasomatic replacements, as much as 1,000 feet long, in gently eastward dipping Paleozoic Redwall limestone along its contact with irregular, sill-like intrusive masses of andesite. Andesite and alluvium cover part of the claims. The hematite bodies are prominently exposed (fig. 47) along the Walnut Creek road more than half a mile in secs 22 and 27, T 20 N, R 6 W. Ore bodies are indicated by outcrops, float, and hematite-rich, red soil. Favorable areas for exploration are the vicinity of limestone-intrusives contacts. Hematite deposits in the area have been explored by numerous test pits, adits, a limited amount of rotary- and wagon-drilling, and 7 diamond-drill holes. Ore bodies on the Iron Chancellor, Iron Horse, and Lone Jack claims (figs. 47 and 48) have been mined

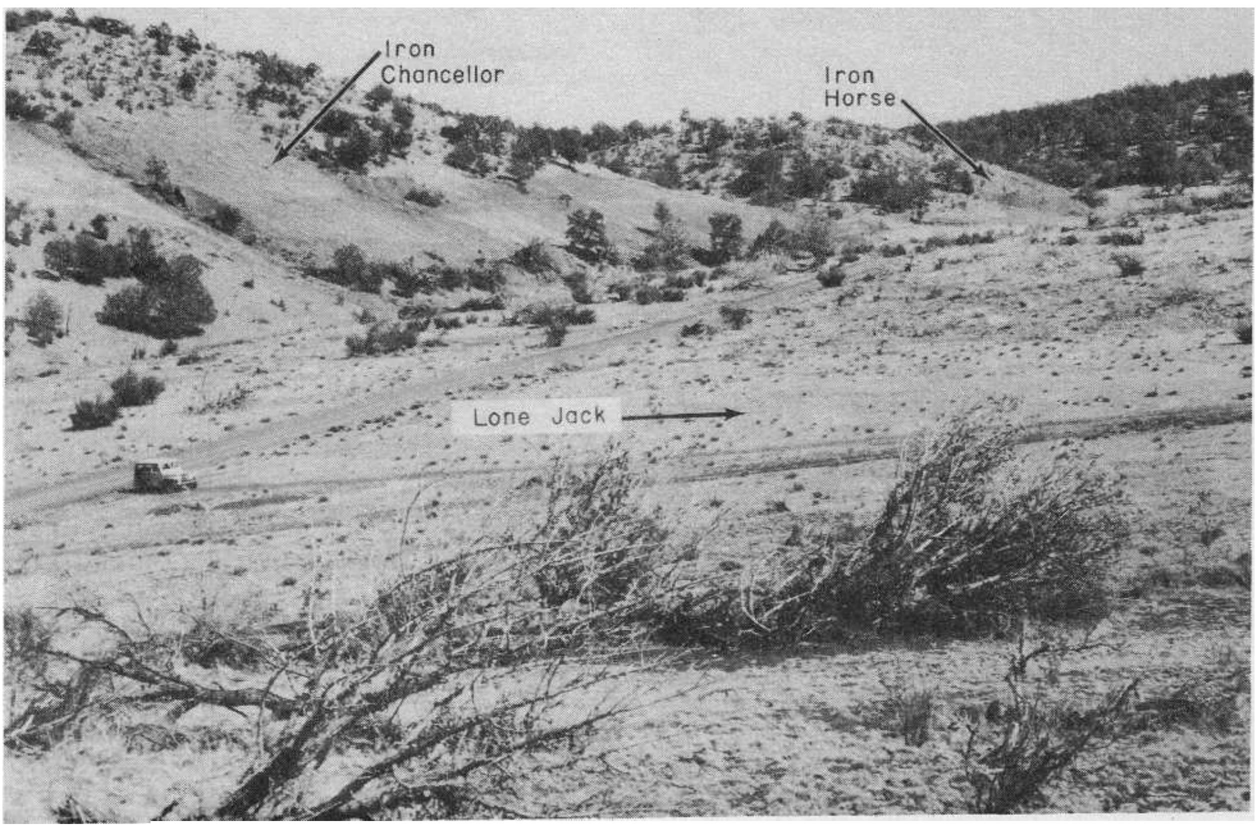

FIGURE 47. - Outcrop and Mining Area, Iron Chancellor Claim, Seligman (Cowden) Hematite Deposit, T 20 N, R 6 W, Yavapai County, Ariz.

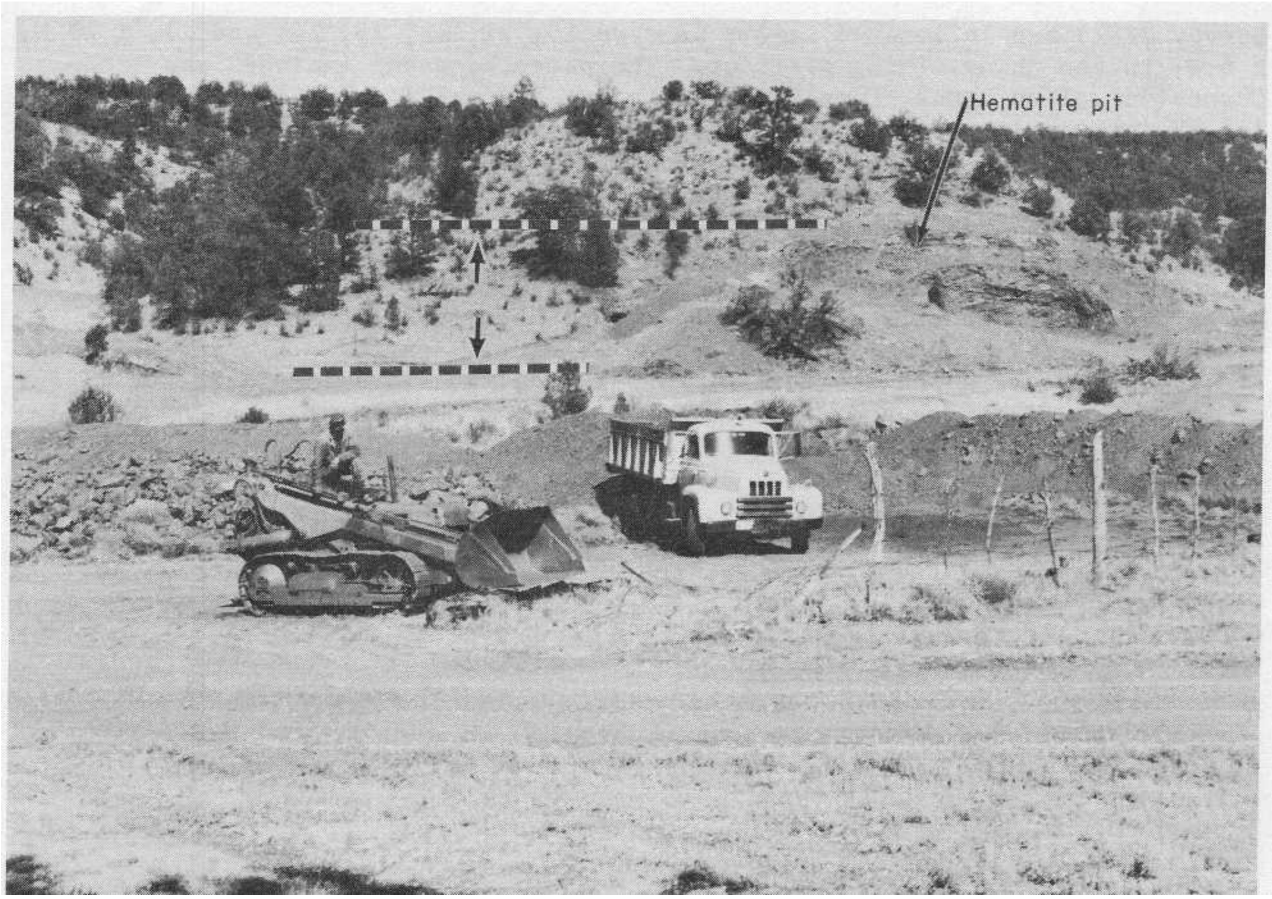

FIGURE 48. - Mining Area and Equipment, Seligman-Cowden Hematite Deposit, T 20 N, R 6 W, Yavapai County, Ariz.

chiefly in open cuts and were the source of production in 1961. A very high-grade hematite has been produced. This product is used principally as mineral pigment although other markets are being developed. The quality of the ore is shown by analyses in table 26.

In addition, qualitative spectrographic analyses by various laboratories indicated the presence of as much as 0.01 percent lead, 0.03 percent zinc, 0.16 percent copper, 0.05 percent arsenic, 0.10 percent titanium, 0.01 percent molybdenum, 0.005 percent chromium, and 0.005 percent vanadium. The 1960 iron content and specific gravity of the hematite iron ore in different sizes is compared in table 27.

The Seligman (Cowden) occurrence comprises a number of small to intermediate sized replacement bodies of very high-quality, massive to powdery hematite that in the aggregate are a source of abundant iron for special uses and a statewide iron ore market.

Deposits in the Juniper Mountains area, including low-grade hematite, may have a potential of second category magnitude.

TABLE 26. - Analyses of Seligman (Cowden) hematite, Yavapai County, Ariz.

Sample	Chemical analyses, percent							Remarks
	Fe	Mn	P	S	SiO_2	CaO	Al_2O_3	
1....	62.0	-	0.01	Trace	8.7	0.6	-	Bureau of Mines character sample 1943; sample more than 15 feet in thickness.
2....	63.1	-	.01	-	1.8	4.6	-	Bureau of Mines character sample 1943; sample more than 20 feet in thickness.
3....	55.52	0.1	.005	0.02	5.35	3.64	1.95	Bureau of Mines, 1943; composite of 11 samples.
4....	59.20	-	-	-	-	-	-	Bureau of Mines, 1948; Iron Chancellor adit J; sample more than 5 feet in thickness.
5....	60.92	-	-	-	-	-	-	Bureau of Mines 1948; Iron Chancellor north side adit Q; sample more than 4.8 feet in thickness.
6....	61.0	-	-	-	2.0	4.5	-	Bureau of Mines character sample 1948; McBride group of claims.
7....	58.3	.06	-	.04	5.08	4.23	3.19	Composite sample, 1956; Western Drilling Co.; courtesy Elwood Wright, mine operator, Post, Tex,.
8....	64.3	.03	.03	.03	2.9	.07	.5	The Colorado Fuel and Iron Corp. 1904; courtesy Elwood Wright, Post, Tex.
9....	63.8	.04	.026	.01	3.1	1.5	.9	Do.
10....	68.4	.07	.02	.1	1.5	.3	.1	Lone Jack claim character sample courtesy Elwood Wright, Post, Tex.
11....	60.6	.14	.032	.1	2.20	-	1.93	Columbia-Geneva Division, U.S. Steel Corp.; courtesy Elwood Wright, Post, Tex.

TABLE 27. - Seligman (Cowden) hematite iron ore characteristics'

Size	Fe, percent	Specific gravity
Plus 1-inch...........	63.2 to 66.4	4.21 to 4.79
Plus 4-inch...........	64.4 to 66.9	4.21 to 4.23
Minus 4-inch...........	63.1 to 64.7	4.59 to 4.70

'Courtesy Elwood Wright, mine operator, Post, Tex.

Miscellaneous

Gold placer operations in the Arizona City, Columbia, Black Canyon Creek, Skull Valley, Walker, Bridle Creek, Musquette Gulch and Prescott districts indicate the presence of abundant magnetite and some hematite and ilmenite in the alluvium of the areas (17, pp. 1180-1181).

Yuma County

Plomosa Mountains Hematite-Limonite

General

Hematite and some limonite were noted in an interrupted pattern more than 20 miles along the east flank of the Plomosa Mountains (103, 107, 110, 116, 117, 121; fig. 1), about 3 to 5 miles west of Bouse and the old Bouse-Quartzsite road. The deposits are part of a north trending chain of low, iron-manganese stained foothills and ridges (fig. 49) paralleling the main Plomosa Range. This foothills area extends through Tps 3, 4, 5, 6, and 7 N, Rs 16, 17, and 18 W, Gila and Salt River meridian and baseline, and includes many hematite and manganese lode claims. The occurrences have been known more than 70 years and have been prospected for gold, silver, manganese, and iron. The deposits have been located many times through years, when interest was renewed. The deposits are at about 1,500 feet altitude in desert terrain and are reached by numerous access roads west of the old Bouse-Quartzsite road,

Black and red to yellow outcrops--which in places include bodies of manganiferous hematite-limonite, ferruginous manganese, and high-grade manganese--

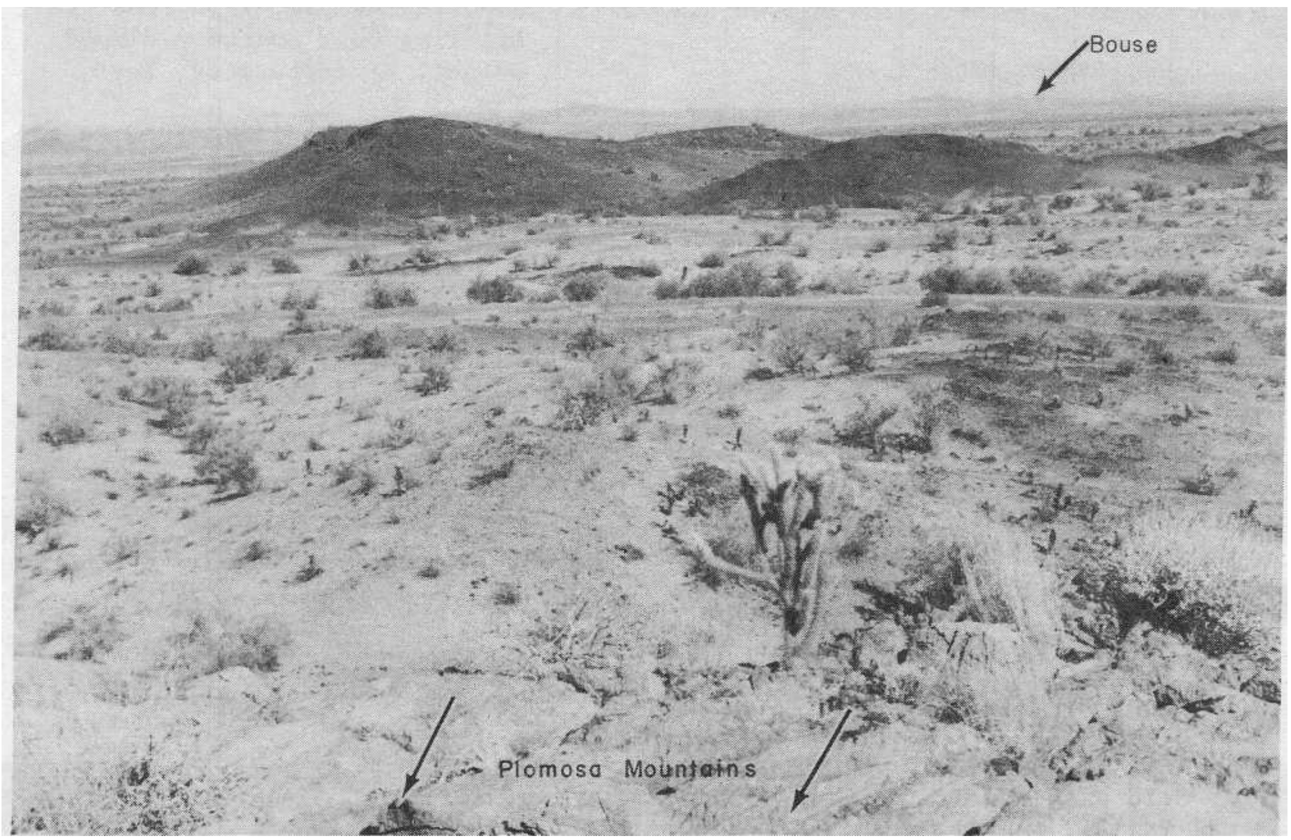

FIGURE 49. - Iron-Manganese-Rich Foothills Along East Flank of Plomosa Mountains, Tps 6 and 7 N, R 17 W, Yuma County, Ariz. Bouse is in far right background.

are prominent 3 to 5 miles west of Bouse in north-central Yuma County. Hematite appears as contact metamorphic replacements in Paleozoic limestone associated with local intrusives. Several deposits, cropping out in an interrupted pattern for more than 20 miles along the Plomosa Mountains, are described as follows:

Black Chief Group Manganiferous Hematite-Limonite

Manganiferous hematite with some limonite was noted on the Black Chief 1-6 group of lode claims (103, fig. 1), 5 miles west of Bouse, approximately in unsurveyed sec 24, T 7 N, R 18 W, Gila and Salt River meridian and baseline. The claims have been located several times by various people since World War II.

The deposit occurs as a partial replacement along a steeply dipping and northeast trending breccia zone in Paleozoic limestone. Productive parts of the replacement are 2 to 6 feet wide and crop out along the crest of a hill about 300 feet. The manganiferous hematite-limonite occurs in lenticular masses and strands within the breccia zone.

The deposit was developed for its manganese content in 1953 and about 2,000 tons were mined and beneficiated at the Manganese Corp. of Arizona heavy-media plant near Bouse. The bulk of the manganese concentrates contained too much iron to be acceptable. Underground, adit workings were inaccessible in 1961. The deposit appears small (21, p. 74)

Black Jack (Bird) Hematite

Manganiferous hematite was noted on the Black Jack group of lode claims (105, fig. 1), approximately in unsurveyed secs 18 and 19, T 7 N, R 17 W, 3.5 road miles west of Bouse, in a low iron-manganese stained and north trending range of foothills (fig. 49) paralleling the Plomosa Mountains. The claims are the property of Century Mining Co. of Bouse.

The claims appear to be part of the old Bird group of 18 claims located by C. L. Terry in 1942.

Century Mining Company was engaged (1961) in constructing a ferrosilicon heavy media beneficiation plant near Bouse to treat ores from the claims in the area.

To the east, nearby manganese deposits are irregular masses of manganese oxides along breccia zones in volcanic rocks.

A manganiferous hematite deposit is prominent on the Black Jack No. 1 claim as a black to reddish, clinker-like outcrop of an irregular, contact-metamorphic replacement of gray, Paleozoic limestone associated with Precambrian granitic intrusives. Limestone in the area has a north-northeast strike with variations and a 10° to 30° west dip. The deposit comprises massive hematite, specularite, limonite, and manganese oxides and varies in texture from pulverulent to hard and siliceous. One drill hole by Century Mining Co.

penetrated 70 feet of hematite. The red, yellow to bluish-black hematite-limonite-manganese replacement body is traceable by outcrop and float in an area about 3,000 feet long north and as much as 1,000 feet wide east.

Two character samples taken by the Bureau in 1961 contained 25.8 and 29.7 percent iron, 4.7 and 12.7 percent manganese, 0.6 percent titania, 0.06 per-cent phosphorus, 0.71 percent sulfur, and 37.4 percent silica. A large grab sample taken by the Bureau in 1955 contained 39.8 percent iron and 6.9 percent manganese. Selective mining by Century Mining Co. is expected to result in an ore containing 35 percent iron and 30 percent manganese that will be amenable to sink-float beneficiation (21, p. 76).

Black Mesa Hematite

Hematite reportedly occurs in the old Plomosa district along the west slope of the Plomosa Mountains at Black Mesa (106, fig. 1) in T 3 N, R 17 W, about 18 miles southwest of Vicksburg. The Black Mesa hematite deposits occur about halfway up the west slope along a horizon between broken limestone forming the base of the mountains and a thick overlying sheet of volcanic rock that caps the upper half of the range. The deposits, mainly hematite and specularite, were reported as much as 30 feet thick in places. The presence of these deposits was not verified (33, pp. 383-384).

Black Mule Hematite

Manganiferous hematite was noted along the old Bouse-Quartzsite road on the Black Mule group of lode claims (107, fig. 1), 8.5 road miles south-south-west of Bouse, approximately in sec 30 and 31, T 6 N, R 17 W. The claims are the property of Century Mining Co. of Bouse.

Structure is poorly exposed in flat terrain in shallow pits along the rusty-red to black outcrop. Like many others along the west flank of the Plomosa Mountains, manganiferous hematite-limonite replaces Paleozoic lime-stone along its NW strike and its 45° SW dip. The deposit is insufficiently exposed to estimate its size. A character sample taken by the Bureau from shallow pits on the West Black Mule No. 7 claim in 1961 contained 21.4 percent iron, 1.3 percent manganese, 0.8 percent titania, 0.12 percent phosphorus, 0.22 percent sulfur, and 43.6 percent silica.

Black Stud Group Hematite

Manganiferous hematite was noted on the Black Stud group of claims (108, fig. 1), approximately in unsurveyed sec 31, T 7 N, R 17 W. The claims are the property of J. F. Hicks and the Century Mining Co. of Bouse. They are reached from Bouse by driving 2.7 miles southwest along the old Bouse-Quartzsite road and then 2.8 miles west towards the east flank of the Plomosa Mountains.

Manganiferous hematite is exposed on the Black Stud group of claims in shallow pits along outcrops ranging from rust red to black. Like many deposits in the foothills of the Plomosa Mountains, manganiferous hematite occurs as replacements of Paleozoic limestone associated with local intrusives along its NE strike and 35° SE dip. The deposit is insufficiently exposed to delineate. A character sample of the better ore taken by the Bureau in 1961 contained 41.8 percent iron, 0.4 percent manganese, 0.2 percent titania, 0.02 percent phosphorus, 1.24 percent sulfur, and 14.4 percent silica.

Bouse Gold and Copper Co. Hematite

Hematite was noted (109, fig. 1) on the old Paradise Extension, Dollie W., and Llano group of 7 patented claims of the company formerly known in 1946 as Bouse Gold and Copper Co., T 7 N, R 18 W, about 5 miles west of Bouse in the Plomosa Mountains. Reddish-brown hematite crops out about 300 feet along the north strike in 30 to 40 feet thicknesses. The deposit appears to be a hydro-thermal replacement in Paleozoic limestone, similar to New Planet and Swansea. A character sample taken by the Bureau in 1946 contained 39.5 percent iron. The deposit has been developed by a 45° incline north driven down dip more than 100 feet, in a search for copper and gold. The shaft was inaccessible in 1961.

Good Bet and Smokey Hematite

Hematite was noted (112, fig. 1) as partial replacements of Paleozoic limestone on the former Good Bet 1-28 and Smokey claims in T 7 N, R 16 W, about 4 miles southeast of Bouse. Samples from the Good Bet claim in 1942 contained 15.5 to 36 percent iron. Five samples from the Smokey claim contained 18.23 to 35.82 percent iron. The hematite appears only a partial replacement and is diluted by much calcareous and siliceous material. The hematite occurrences appear small, irregular, and low grade.

Iron Mine Hematite

The old Iron Mine (4), variously known as the Terry, Brewer, and Anderson mine, is reached by driving 4.8 miles south of Bouse on the old Bouse-Quartzsite road and 3.5 miles west towards the foothills of the northern Plomosa Mountains (117, fig. 1). It is approximately in sec 18, T 6 N, R 17 W. The property was formerly located by C. L. Terry, Bird L. Terry, H. R. Brewer, Paul Simpson, D. F. Mendenhall, Anderson Mining Co., San Antonio Mining Co., and others.

Red to black hematite, with varying amounts of limonite and siderite, partly replaces Paleozoic limestone as irregular contact metamorphic deposits at or near intrusive contacts. The hematite appears impure and contains much calcareous material, chert, and jasper. The hematitic bed retains it original limestone characteristics. A character sample taken by the Bureau in 1961 contained 47.0 percent iron, 0.3 percent manganese, 0.3 percent titania, 0.11 percent phosphorus, 0.36 percent sulfur, and 19.4 percent silica. Where observed, the ferruginous limestone exposures rest on Precambrian biotite granite with widely divergent dips. The iron-enriched portion of the lime-stone appears as much as 10 feet thick and may prove extensive but low-grade.

The property has been known for over 60 years and has been explored by shallow adits, shafts reportedly as much as 50 feet deep, surface trenches, and pits almost all of which were inaccessible in 1961. There has been no production from the property (4, p. 92).

Little Butte Hematite

Hematite was noted at the Little Butte Copper mine (119, fig. 1), at the north end of the Plomosa Mountains, 4 miles northwest of Bouse and 1 mile southwest of the Atchison Topeka & Santa Fe Railroad, in the NW¼ sec 8, T 7 N, R 17 W, near Little Butte. In the vicinity of the Little Butte incline, Paleozoic limestone has been partly to completely replaced by specular hematite associated with malachite, azurite, and chrysocolla. Small fissures and joints also have been filled by hematite. Underground workings from the old incline, reportedly 385 feet deep in 1910, were inaccessible in 1961. From the little information available the deposit appears small (4, pp. 93-95).

Phoenix and Yuma Groups Hematite

Hematite was noted on the old Phoenix and Yuma group of 33 claims unpatented as of 1922 in the Plomosa Mountains (123, fig. 1), approximately in sec 6, T 5 N, R 17 W, about 8 miles south-southwest of Bouse. The claims were the property of Smith and Ellis of Los Angeles, Calif., during 1942. The area is spotted with stringers and massive bodies of hematite partly covered by debris. The only good exposure was on the Yuma claim. The hematite deposits are in a Precambrian-Paleozoic complex of granite-gneiss-schist, limestone, and sedimentary schist and appear as replacements of metamorphosed Paleozoic limestone. A sample of the best ore, taken by the Bureau in 1942 and more than 20 feet in thickness contained 61.38 percent iron, 0.094 percent sulfur, 0,016 percent phosphorus, and 8.26 percent silica.

During 1917 a total of 19 cars of ore was shipped from the Yuma claim to Columbia Steel Co., at Pittsburgh, Calif.

Black Diamond Magnetite

Magnetite was noted (104, fig. 1) on the Black Diamond group of claims located by W. F. Mitchell in 1957, approximately in sec 18, T 3 N, R 17 W. The deposit is reached by driving 10.4 miles east of Quartzsite on U.S. High-way 60-70 and then south over poor access roads for 7.5 miles towards Black Mesa.

The magnetite occurs as irregular, contact metamorphic replacements in Paleozoic limestone associated with intrusive granite. Magnetite outcrops 5 to 10 feet thick can be traced 300 feet north along a steep hillside high on the west side of Black Mesa wash. The enclosing limestone dips 40° to 60° E.

A character sample of the better magnetite taken by the Bureau in 1961 contained 49.7 percent iron, 0.3 percent manganese, 0.2 percent titania, 0.04 percent phosphorus, 0.13 percent sulfur, and 9.6 percent silica.

There has been no production from this prospect. The magnetite deposit appears small but is an indication of other occurrences.

Buckskin (Williams) Mountains Hematite

General

The Buckskin (Williams) Mountains extend more than 30 miles east along the northern border of Yuma County, paralleling the Bill Williams River. Buckskin Mountains are largely Precambrian gneiss and schist with masses of Paleozoic limestone and marble (4, 16). The western part of the mountains are covered by a thick sheet of basaltic volcanics as much as 1,000 feet thick (figs. 50 and 51). In the vicinity of the New Planet mine, Precambrian granite gneiss is overlain by about 900 feet of intercalated and metamorphosed Paleozoic limestones and amphibolites. At the gneiss-limestone contact is a 20-foot-thick conglomerate of limestone, quartz, and gneiss. Above the lower limestone series is a more massive limestone, as much as 100 feet thick. At Mineral Hill, 3 miles west of the New Planet mine, a basal series of argillites are overlain unconformably by quartz-chlorite-mica schists and limestone

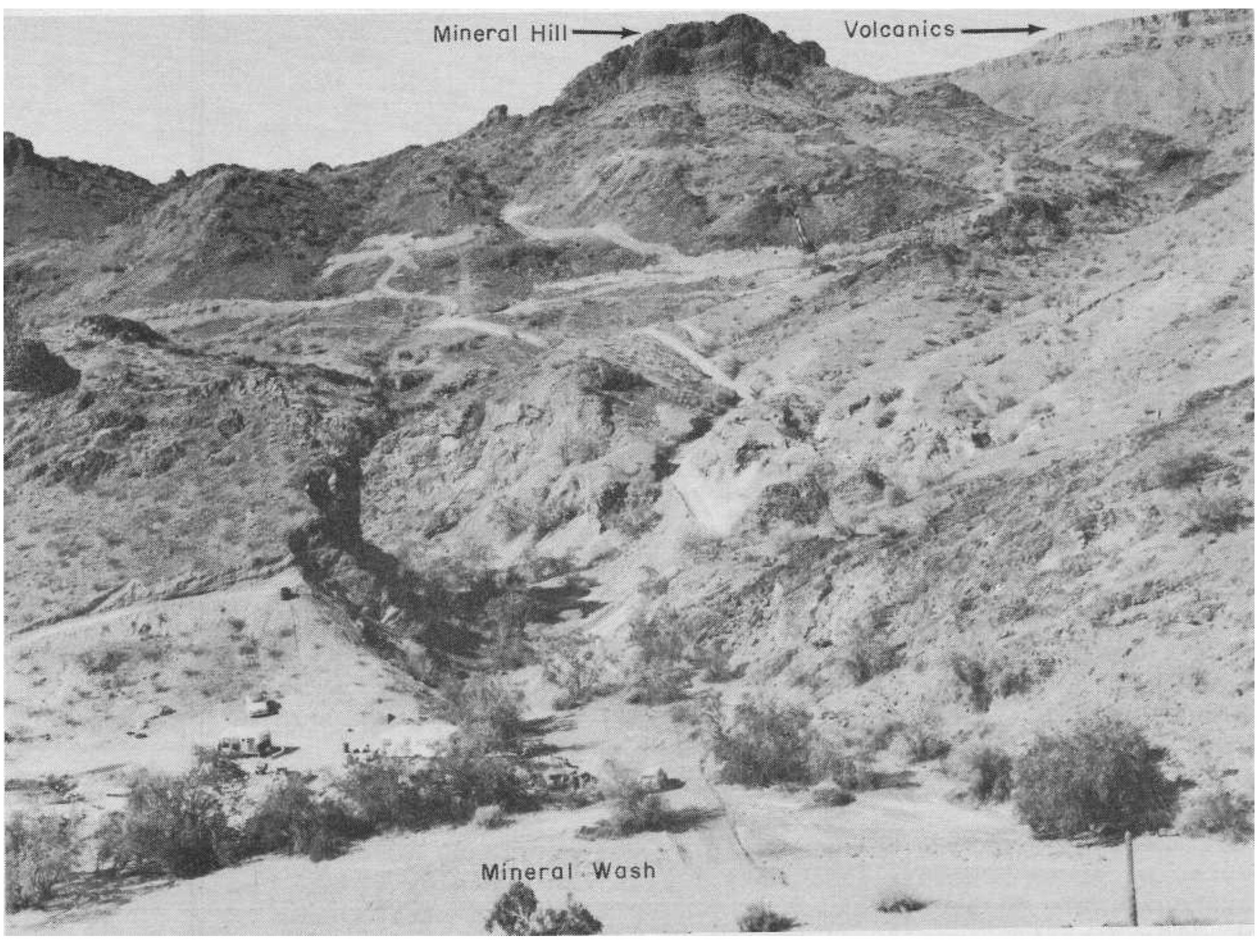

FIGURE 50. - Mineral Hill Cupreous Hematite Deposit, T 10 N, R 17 W, Yuma County, Ariz.

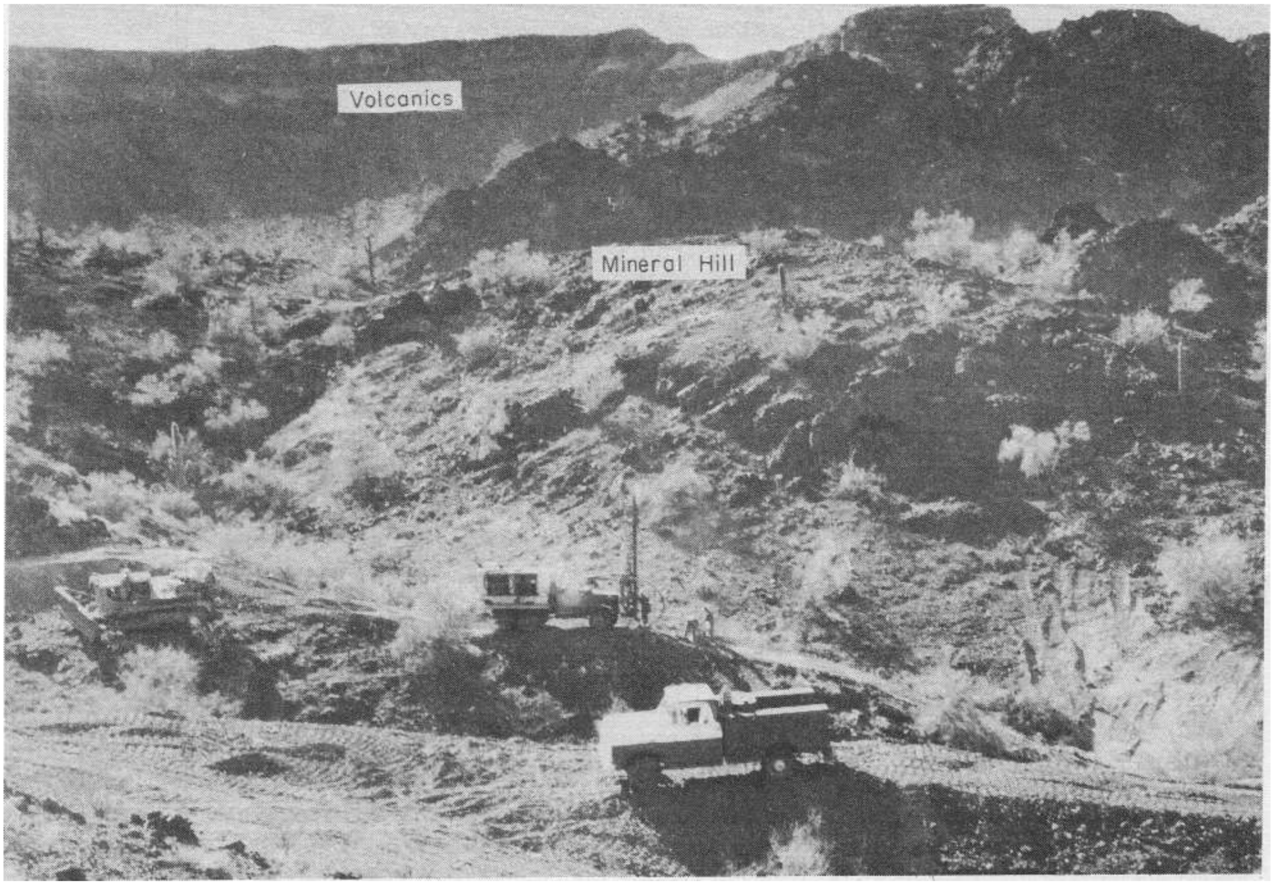

FIGURE 51. - Exploration Drilling, Marvel Mining Co., at Mineral Hill, T 10 N, R 17 W, Yuma County, Ariz.

cut by an intrusive rock metamorphosed to schist. About 9 miles east-southeast of the New Planet mine in the vicinity of Swansea the country rock is granitic gneiss overlain unconformably by dark brown massive limestone, as much as 100 feet thick, with layers of amphibolite. The limestone is cut by diabase dikes. At Brown Mountain, about 8 miles west-southwest of the New Planet mine, a large area and many smaller areas of dark brown, massive lime-stone occur above gneiss.

Numerous concentrations of cupreous hematite have long been known within the Buckskin Mountains at Brown Mountain, Highline, Mauuuoth, Mineral Hill, New Planet, Ruthie-Linda, and Swansea. Their descriptions follow:

Brown Mountain Cupreous Hematite

Massive hematite and specularite are prominent across approximately 2,000 acres on Brown Mountain (110, fig. 1) in the vicinity of the Copper Pride mine, approximately in secs 3 and 4, T 9 N, R 17 W, and secs 33 and 34, T 10 N, R 17 W. The deposits are 14 miles east of Parker and 7 miles southwest of Planet. During 1913 the area was located as a northeast trending block of claims

(3,600 by 7,500 feet) including the Copper Pride, Gold Cliff, Elizabeth, Elizabeth's Pride, Grande, Marshall, Clime, Circle, Hole, Admiral, General, Keepsake, Moonbeam, Copper Ridge, Mound, Axe, Square, Triangle, Home, Drum, Bell, Black Copper, Baby's Dream, Nugget Nos. 1 and 2, Chunck Nos. 1 and 2, Ocean, Bay, Bond, and Copper Gap group of claims (7).

Hematite associated with malachite and chrysocolla and some gold occurs largely as partial and irregular replacements of Paleozoic dolomitic lime-stones in contact with Precambrian gneiss. Accessory minerals include chlorite, epidote, sericite, biotite, muscovite, hornblende, and calcite. The deposits are similar to those at Planet, Mineral Hill, and Swansea to the north. Where observed, the deposits crop out in thicknesses of 2 to 15 feet and range from 18° to 80° in dip.

The size and quality of the hematite deposits could not be ascertained, and the area remains a prospect (4, p. 123; 7, pp. 42-57).

Highline Hematite

Hematite was noted in 1957 on the Highline No. 1 claim (115, fig. 1), west of Planet Peak and about 16 miles east of Parker, in T 10 N, R 17 W. The hematite occurs as irregular contact metamorphic replacement bodies in altered Paleozoic limestone beds. The claims were located by B. M. Reynolds and Henrietta Miller.

The hematite occurrence is insufficiently disclosed to determine the size of the deposit.

Knight Group Hematite

Hematite is (118, fig. 1) abundant on the Knight group of claims, about 5 miles south to southwest of Swansea. The occurrence is a replacement of metamorphosed Paleozoic sediments similar to many others in the Buckskin (Williams) Mountains area. A sample of the hematite-rich outcrop contained 49.4 percent iron, 0.1 percent manganese, 0.2 percent titania, 0.09 percent phosphorus, 0.10 percent sulfur, and 23.0 percent silica.

Mammoth (Corona Copper) Hematite

Hematite and some chrysocolla, quartz, barite, and fluorite occur in a silt-like formation a few feet thick along the contact between a gneiss schist complex and overlying granite breccia at the Mammoth prospect on the old Corona Copper Co. property in the Buckskin (Bill Williams) Mountain area, in the northwest corner of T 8 N, R 14 W, (120, fig. 1). The deposit is small (4, P. 122).

Mineral Hill Cupreous Hematite

Specular hematite crops out prominently at Mineral Hill (fig. 50) in the Buckskin Mountains area (121, fig. 1) in secs 2, 3, 10, and 11, T 10 N, R 17 W, in the northwest corner of Yuma County, just west of Mineral Wash and about a mile south of its confluence with the Bill Williams River. It is 3 miles west of the New Planet hematite deposit. The hematite occurrence is best reached by driving 24.7 miles northeast from Parker through Osborne and Mineral Washes. It can be reached also by driving north across desert terrain from Bouse about the same distance over poorer roads.

The hematite-rich area comprises 15 patented mining claims, 14 lode locations, and 2 placer claims, listed in appendix table A-2. The terrain is rugged between Mineral Wash, about 500 feet altitude, and the crest of Mineral Hill, about 1,200 feet altitude. Topography is characterized by shallow-walled canyons and isolated hills. Farther west, about 1,500 feet altitude, a basalt-covered plateau (figs. 50, 51) extends toward the Colorado River.

Specular hematite occurs as irregular hydrothermal replacements of metamorphosed Paleozoic sediments similar to those at New Planet and Swansea and the rocks forming Mineral Hill appear to be continuous with those overlying the Precambrian gneiss in the vicinity of the New Planet mine, Both areas were probably lifted, folded, and faulted at the same time. Dips range widely from horizontal to 50° SW due to folding and faulting. Specularite occurs with the oxidized copper minerals malachite, azurite, and chrysocolla of later origin, since they are commonly found in fractures in the hematite.

Massive hematite occupies several horizons. Outcrops more than 25 feet thick were noted. In addition, the host rock is heavily impregnated and stained with hematite. Veinlets, disseminations, and coatings of specularite occur between the beds of massive hematite. Specularite was observed also as films and layers from 1/64 inch to as much as 4 inches thick along jointing and fractures in the brown-stained country rock. As shown on the map (fig. 52) two replacement beds of cupreous hematite crop out and can be traced east-northeast towards Specularite Point and southeast paralleling the Norma Fault more than 2,200 feet. The beds appear to merge to a composite thickness of more than 40 feet around Specularite Point. The average thickness between the top of the "Upper Iron Bed" and the bottom of the Basal Iron Bed is about 75 feet.

Mineral Hill has been sporadically explored (fig. 52) by shallow pits and cuts along the outcrop, shallow adits, and shafts in search of gold and copper. The workings did not expose the hematite to advantage. From January to May 1961 the property was explored further by Marvel Mining Co. of Salt Lake City, Utah, for copper and hematite. Exploration drilling (figs. 51, 52) was accomplished by a truck-mounted wagon drill (fig. 51). In the softer formations a rotary head was substituted for the percussion drill. Cuttings, about 25 pounds per 3 feet of hole, were blown out of the hole and collected in plastic containers and then split for storage and analysis. Drill roads required blasting and grading with a bulldozer.

A character grab sample taken by the Bureau in 1961 of the outcrop material at Mineral Hill contained 38.1 percent iron, 0.1 percent manganese, 0.1 percent titania, 5.55 percent copper, 0.07 percent phosphorus, 0.36 percent sulfur, and 27.6 percent silica; spectrographic analysis indicated the presence of 1 to 10 percent aluminum, calcium, and copper; 0.1 to 1.0 percent

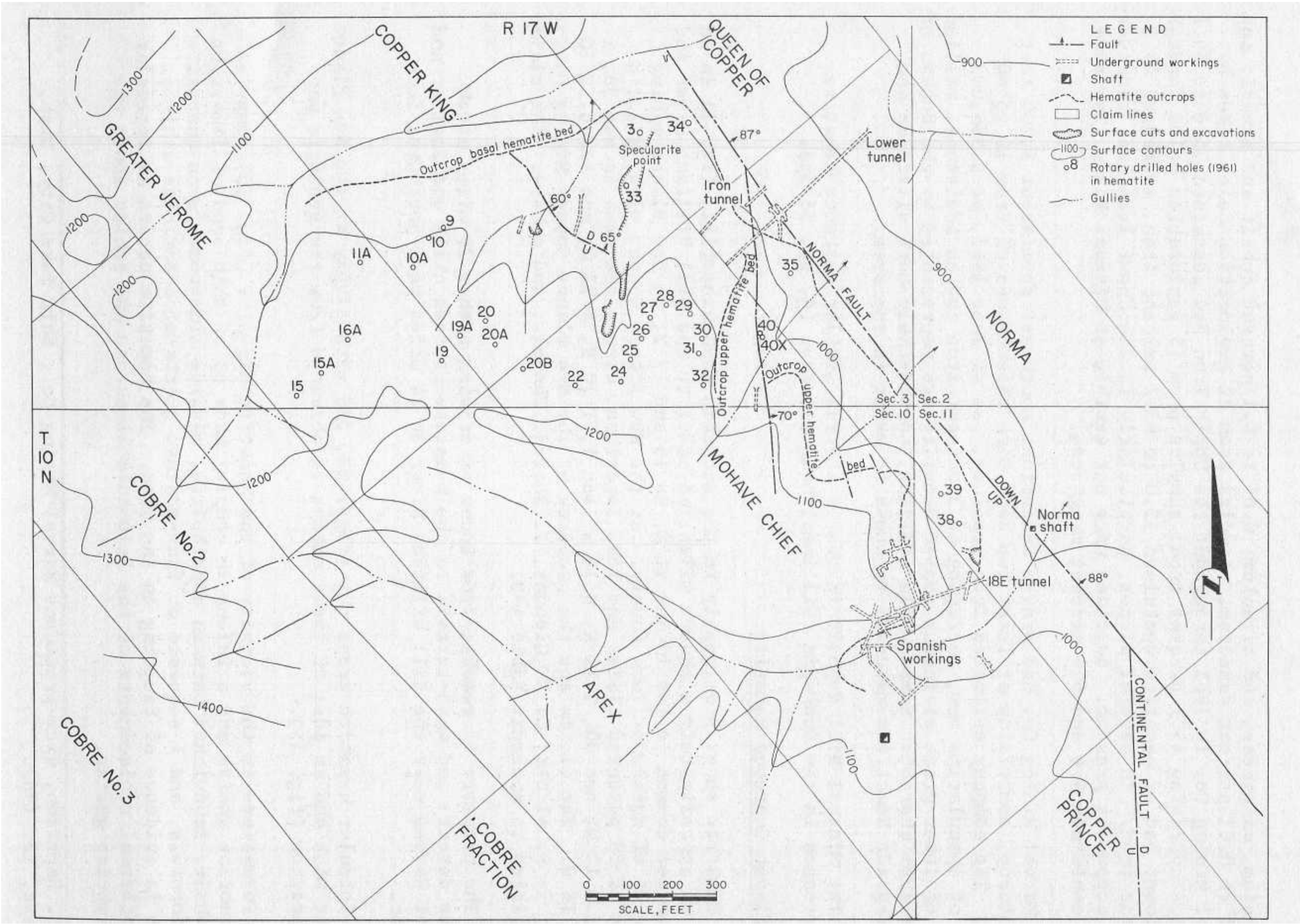

FIGURE 52. - Exploration Map, Cupreous Hematite Area, Mineral Hill, Yuma County, Ariz. (Adapted from surface map of Marvel Mining Co., Salt Lake City, Utah.)

magnesium, manganese, and titanium; 0.01 to 0.1 percent cobalt and nickel; and 0.001 to 0.01 percent vanadium. Samples from 22 exploration holes taken by Marvel Mining Co. in 1961 throughout the Upper Iron Bed contained 35.8 to 55.7 percent averaging 45.1 percent iron; samples from 15 exploration holes through the lower bed of hematite contained 33.0 to 63.2 percent iron, averaging 49.3 percent iron. In several places, particularly in the Upper Iron Bed, consider able copper is present. Sulfides were not visible at Mineral Hill. Two samples contained 4.6 and 6.4 percent manganese.

Marvel Mining Co. has proven extensions southwest from about 2,200 feet of outcrop, comprising at least two beds with thicknesses of from 10 to 40 feet. The company estimated iron reserves,[7] as of June 1961, at 3,356,000 tons of specularite ore, averaging 48.3 percent iron and, an additional million tons of lower grade siliceous copper-hematite ore represented by the Bureau of Mines 1961 character sample. In addition, considerably more siliceous and lower-grade hematitic material is known to exist in the area.

The Mineral Hill deposit is one of several similar cupreous hematite occurrences in the Buckskin (Williams) Mountain area (4, pp. 55-59).

New Planet Cupreous Hematite

Hematite shows prominently in the Buckskin Mountains (122, fig. 1) in an area of approximately 4 square miles, adjacent to the Bill Williams River and the corner common to Tps 10 and 11 N, Rs 16 and 17 W, in the Planet mining district of northwest Yuma County. At the New Planet Copper mine, a solid block of 89 patented claims and lode locations, covers the area in sec 36, T 11 N, R 17 W; sec 30, T 11 N, R 16 W; sec 1, T 10 N, R 17 W; and sec 6, T 10 N, R 16 W. The claims are the property of the New Planet Copper Mining Co., N.Y.; E. R. Alcott, G. L. Gibbons, J. Buzard, Phoenix; and others. The claims are listed in appendix table A-3.

The property is reached from Bouse by driving either 29 miles north across desert- and wash-terrain to the hematite-stained hills and Smelter and Planet Washes near the Bill Williams River or 24 miles west-northwest from Parker.

Specular hematite crops out (figs. 53, 54) extensively at the New Planet copper mine and an idea of their extent is obtained from the geologic map and section (fig. 55).

Formations in the vicinity of the hematite deposits (fig. 55) comprise Precambrian gneiss and a Paleozoic complex made up of thin beds of limestone and shale, sandwiched between amphibolite, massive limestone, some quartzite and hornfels, and a sequence of fine-grained quartz-mica-sericite schists. There is evidence of faulting in the area. The hematite occurs as irregular hydrothermal replacements of the Paleozoic limestone and schist above the Precambrian gneiss.

[7]D. E. Harrison, vice-president Marvel Mining Co., Salt Lake City, Utah, Sept. 12, 1962.

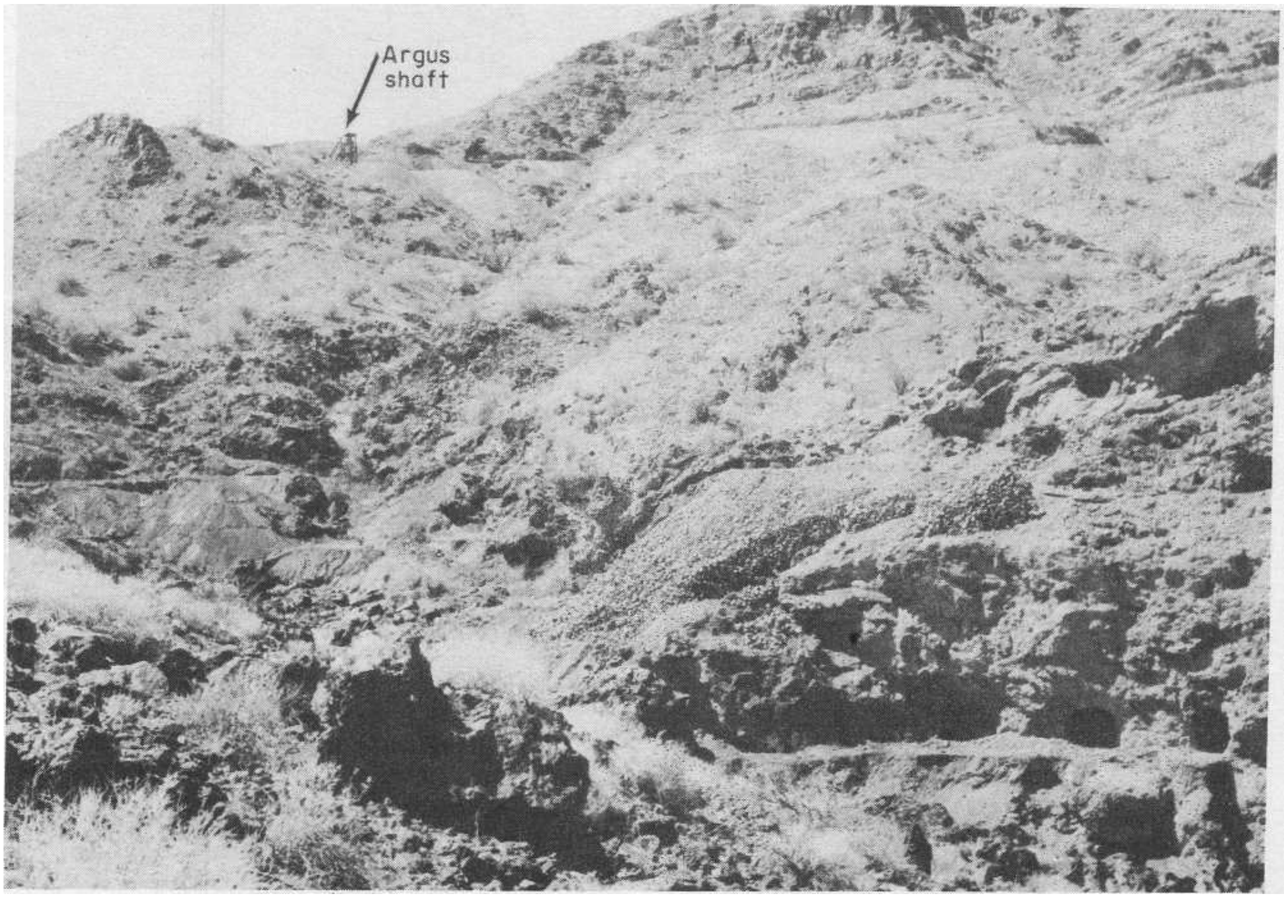

FIGURE 53. - Looking Southwest at Hematite Outcrops, Old Copper Workings and Argus Head-frame, New Planet, Tps 10 and 11 N, Rs 16 and 17 W, Yuma County, Ariz.

Individual bodies of hematite are as much as 700 feet long, 250 feet wide, and 50 feet thick--consisting mainly of specularite and massive hematite with some limonite, malachite, azurite, chrysocolla, and a little pyrite, chalcopyrite, bornite, gold, and silver. Gangue minerals include quartz, calcite, and limestone. Mineralogic investigation disclosed a fine inter-growth of tabular crystals of specularite with sporadic grains of quartz, orthoclase, pyrite, bornite, and chalcopyrite. Interstices and fracture planes were filled with malachite. Hematite to a depth of about 10 feet is hard; below this depth it appears increasingly pulverulent.

The iron content of the hematite deposits varies widely, depending on completeness of replacement of limestone and schist. For comparison, hematitic schist samples contained as low as 6 percent iron, while a 5-foot Bureau core-drill sample (DDH-3, fig. 55) of the best hematite contained 67.82 per-cent iron, 0.013 percent copper, 0.030 percent sulfur, and 1.16 percent silica. A character sample of the more cupreous hematite taken in 1961 contained 57.9 percent iron, 7. 90 percent copper, 0.05 percent lead, 0.09 percent sulfur, 0.1 percent lime, 1.65 percent alumina, 1.6 percent silica, and 2.4 percent insoluble. Spectrographic analysis indicated the presence of copper and small

FIGURE 54. - Looking Northeast at Argus Shaft, Hematite Outcrops (X), and Distant Bill Williams River, New Planet, Yuma County, Ariz.

amounts of manganese, titanium, nickel, vanadium, chromium, cobalt, zinc, lead, silver, gallium, zirconium, and strontium.

The cupreous hematite deposits were discovered in 1863 and were developed as the New Planet copper mine. By 1906, about 50,000 tons of 10 percent cop-per ore was produced. The property has been idle since. During 1943-44 the New Planet mine area (fig. 55) was partly explored by the Bureau (15), and during 1945, hematite reserves were estimated (32) at 1.25 million long-tons, averaging 60 percent iron. As of 1961 there had been no production of iron from the property; however, there has been a renewed interest in this area.

With a lower grade cutoff, beneficiation, and advances in technology, very much larger reserves of hematite might be developed in this area (4, pp. 41-44, 46-55; 6, p. 388; 15, 37 pp.; 32, pp. 7, 10; 44, pp. 26, 27; 70, pp. 521, 523).

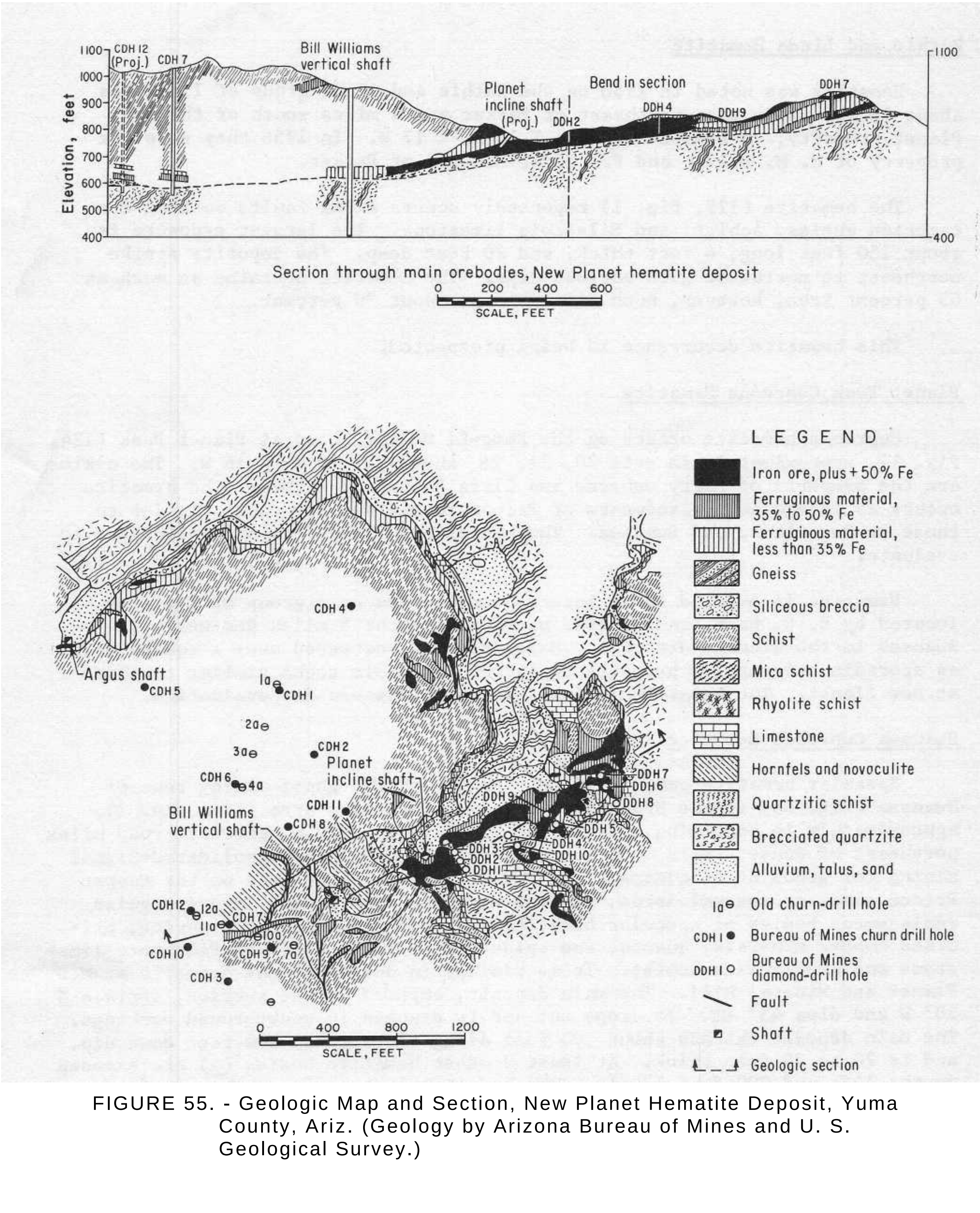

FIGURE 55. - Geologic Map and Section, New Planet Hematite Deposit, Yuma County, Ariz. (Geology by Arizona Bureau of Mines and U. S. Geological Survey.)

Ruthie and Linda Hematite

Hematite was noted in 1958 on the Ruthie and Linda group of 11 claims about 18 air miles east-northeast of Parker and 4 miles south of the New Planet property, in secs 24 and 25, T 10 N, R 17 W. In 1958 they were the property of R. M. Driver and F. and A. McHenry of Parker.

The hematite (125, fig. 1) reportedly occurs along faults cutting Pre-cambrian gneiss, schist, and Paleozoic limestone. The largest exposure is about 150 feet long, 4 feet thick, and 20 feet deep. The deposits strike northeast to northwest with various dips. The hematite contains as much as 65 percent iron, however, much will average about 30 percent.

This hematite occurrence is being prospected.

Planet Peak Cupreous Hematite

Cupreous hematite occurs on the Dome-El Molino group at Planet Peak (124, fig. 1), approximately in secs 20, 21, 28, and 29, T 10 N, R 16 W. The claims are the property of Harry Osborne and Clara Botzum of Parker. The hematite occurs as irregular replacements of Paleozoic sedimentary rocks similar to those at New Planet and Swansea. The hematite is insufficiently disclosed to evaluate.

Hematite is exposed in an interrupted pattern on a group of 9 claims, located by H. C. Horn, and others, of Parker, about 5 miles due west of Swansea in the Cienega district. Exposures are scattered over a square mile as sporadic outcrops of hematite replacing Paleozoic rocks similar to those at New Planet. The hematite is insufficiently exposed for evaluation.

Swansea Cupreous Hematite

Specular hematite occurs in the vicinity of the ghost-mining town of Swansea (fig. 56) in the Buckskin (Williams) Mountains area (126, fig. 1), approximately in adjoining secs 29 and 32, T 10 N, R 15 W, about 23 road miles northeast of Bouse. This occurrence is on the old Clara Consolidated-Signal Mining Co. group of 61 claims. The best exposures noted were on the Copper Prince claim as several large, steeply dipping, overlapping, and irregular replacement bodies of specular hematite with some chalcopyrite, pyrite, oxidized copper minerals, quartz, and epidote in a fault block of Paleozoic lime-stone and amphibolite schist. It is similar in origin to the deposits at New Planet and Mineral Hill. The main deposit, exposed on the surface, strikes N 20° W and dips 45° NE. It crops out and is exposed in underground workings. The main deposit extends about 100 feet along the strike, 200 feet down dip, and is 20 to 30 feet thick. At least 2 other hematite bodies (4) are exposed on the 145- and 200-foot levels. The hematite contains as much as 2.5 percent copper and dump rock indicates manganese oxides also. Samples of the specularite contained 40 to 60 percent iron. A character sample of dump rock taken by the Bureau in 1961 contained 20.4 percent iron, 0.54 percent copper, 0.15 per-cent titania, 0.63 percent sulfur, 0.01 percent phosphorus, 0.08 percent manganese, and 55.8 percent silica.

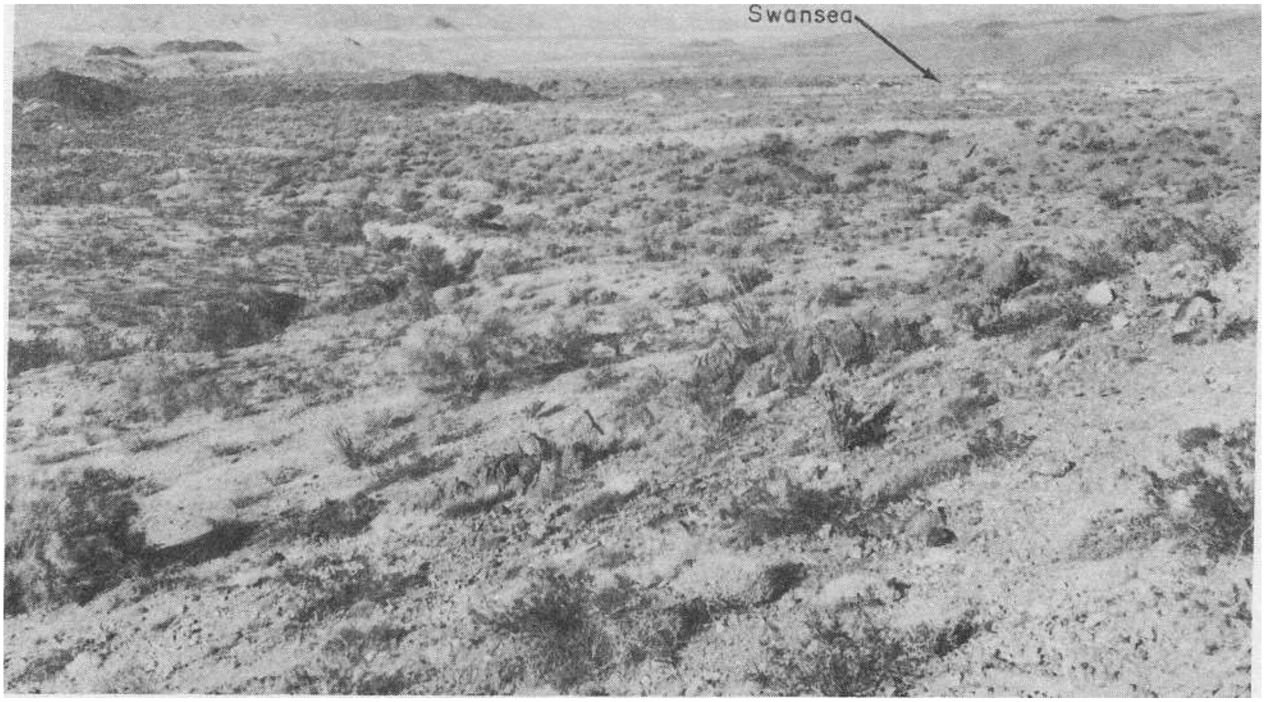

FIGURE 56. - Swansea and Old Clara-Signal Mining Co., T 10 N, R 15 W, Yuma County, Ariz.

The property was developed for copper and gold through 6 shafts and 5 levels that were inaccessible in 1961. The deposits are within an area 2,500 feet long and as much as 150 feet wide. There has been no production as iron ore to date.

Samples of mill tailings, almost entirely specularite, contained 57.8 to 61.0 percent iron, 0.07 to 0.13 percent copper, 0.8 to 1.2 percent sulfur, 4.8 to 8.2 percent silica, and 1.4 to 1.6 percent lime. The mill tailings were being shipped to Victorville, Calif., for use in manufacturing cement.

The Swansea mine area would add to total reserves that could be developed in the Buckskin Mountains area; however, the copper content presents a problem (4, pp. 60-65).

Dome Rock Mountains Magnetite

Magnetite (4, 38) is a prominent feature in part of the Mesozoic schist series in the Cunningham Mountain area (111, fig. 1) of the southern Dome Rock Mountains. The occurrence was noted at the old Cinnabar mine of Colonial Mining Co., approximately in sec 28, T 3 N, R 20 W, about 9 miles southwest of Quartzsite. The occurrence is reached by driving 12 miles south of Quartzsite on U.S. Highway 95, then 15 miles southwest and north to the end of the road at the Cinnabar mine.

At the Cinnabar mine, country rock consists of a series of fine-grained quartz-mica schists of sedimentary origin. Part of the schist sequence contains an abundance of finely crystalline magnetite, giving it a mottled appearance. Schists at the mine strike N 53° W and dip 15° to 45° NE (4, pp. 82-84; 38, p. 27).

Granite Wash Mountains Cupreous Magnetite

Cupreous magnetite (113, fig. 1) occurs as a contact metamorphic replacement on the Yuma Copper and Iron Dike group of claims being developed by C. R. King and T. H. Crawford, approximately in secs 24, 25, 29, and 30, T 6 N, R 14 W, in the rugged Granite Wash Mountains of the Harcuvar range. The deposit is in the Harcuvar-Ellsworth mining district, 5.5 miles northeast of McVay and 6.5 miles north of Vicksburg.

Magnetite (fig. 57) partly replaces a bed of yellow, crystalline lime-stone in a Precambrian complex of metamorphosed sediments, sedimentary schists, and granite gneiss-schist and Tertiary quartz monzonite intrusives. The

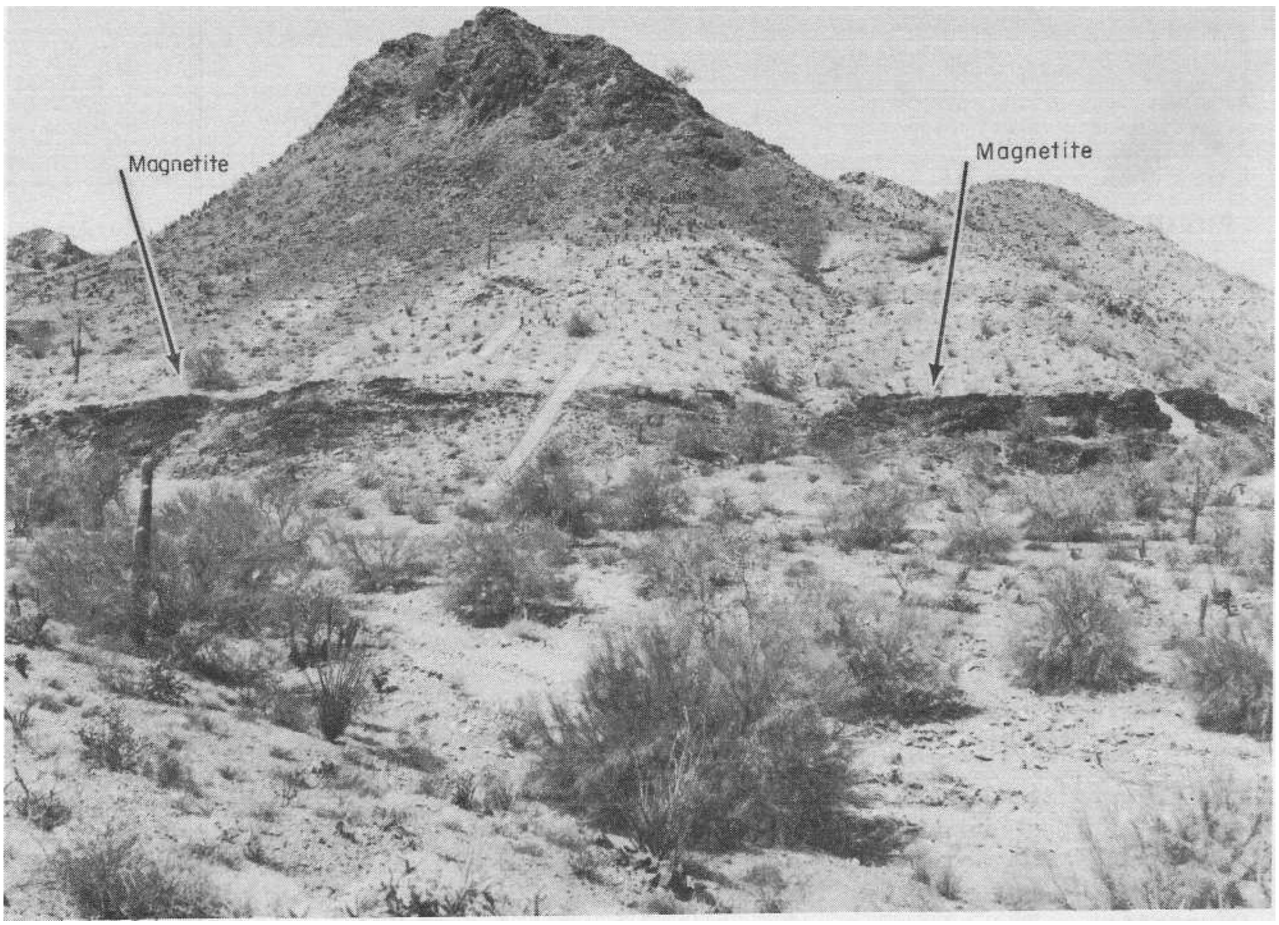

FIGURE 57. - Cupreous Magnetite Outcrop (Arrows), Yuma Copper Co., T 6 N, R 14 W, Yuma County, Ariz.

magnetite is associated with copper sulfides and their oxidation products, pyrrhotite, pyrite, garnet, actinolite, calcite, and quartz. The magnetite can be traced (fig. 57), as masses and disseminations as much as 50 feet thick, in an interrupted pattern along its north strike for several thousand feet. Dip is 15° to 35° W. A character sample of the magnetite taken by the Bureau in 1960 contained 58.4 percent iron, 0.2 percent titania, 0.3 percent manganese, 0.13 percent phosphorus, 0.14 percent sulfur, and 12.2 percent silica.

The deposit has been developed for copper by several small cuts, pits, shallow shafts, and an adit level. In 1961 underground exploration by King and Crawford indicated a cupriferous pyrrhotite-magnetite deposit, estimated to contain 50 percent iron, 0.75 to 1.6 percent copper, and 0.04 ounce gold a ton (4, pp. 95-96).

Harcuvar Mountains Hematite

Many ledges of impure siliceous hematite, some of considerable thickness, occur at Cunningham Pass (114, fig. 1) and in the vicinity of the Cunningham Pass copper mine in the Harcuvar Mountains, in T 7 N, R 12 W, about 9 miles north of Wenden. The deposits are small (4, p. 119).

Hope (Bauer-Kelly) Alluvial Magnetite

Titaniferous magnetite sand (116, fig. 1) is prominent in the alluvium of the southwest peneplain from the Little Harquahala Mountains in T 4 N, R 14 W. The alluvial deposits are about 2.5 miles south of Hope and U.S. Highway 60-70, in the valley and dry-wash areas of secs 2, 3, 9, 10, 11, 12, 13, 14, 15, 16, 17, 21, and 22 in T 4 N, R 14 W.

The magnetitic alluvium of the area was located by Paul Bauer, D. W. Kelly, and others of Wickenburg and Quartzsite. The deposit has been superficially explored with test pits and bulldozer trenches to depths from 6 to 10 feet. A sampling by Arizona Metals Co., R. R. Langley, president, indicates a 3 to 4 percent magnetite content with local concentrations as much as 10 per-cent magnetite. Screening and magnetic concentration tests yielded a concentrate containing as much as 68 percent iron and 0.9 percent titania. Magnetic separation of 20- to 30-mesh screened material reportedly yielded a concentrate containing 62 to 65 percent iron and 1 percent titania. Another trial resulted in a final concentrate reported as 66.11 percent iron, 0.9 to 1.01 percent titania, 0.008 percent sulfur, and 0.19 percent phosphorus.

Tank Mountains Magnetite, Hematite, Limonite, Jarosite

Magnetite, hematite, limonite, and jarosite occur in a lenticular vein filling a shear zone in granite on the Johnnie or Engesser prospect (127, fig. 1) in the northeastern part of the Tank Mountains, T 2 S, Rs 15 and 16 W., about 10 miles from Kofa and 30 miles from Clanton across desert terrain. The vein outcrop pinches to a few inches wide and swells as much as 3 feet wide. The vein strikes N 20° E, and dips 45° to 70° W. At the surface hematite is hard to pulverulent with some quartz and is flanked by like thicknesses of jarosite and limonite. Dump rock includes large aggregates of granular hematite, magnetite, and some pyrite and chalcopyrite. In depth iron grades into magnetite and considerable pyrite. Samples contained 37 to 56 percent iron.

The property is developed by a 200-foot deep shaft; 90 feet was accessible in 1960.

The deposit is considered small (74, pp. 124-125).

Trigo Mountains Hematite-Limonite

Hematite and limonite are reported (128, fig. 1) in an east-trending vein near the crest of the north end of the Trigo Mountains, approximately in T 1 S, R 22 W, 18 miles southeast of Blythe, Calif. The property is known as the E. E. Carlisle prospect. The vein is 3 to 4 feet thick and crops out about 500 feet. To the west the vein terminates against a fault, and to the east it grades into a quartz cemented breccia. A sample of the hematite taken by the Bureau in 1942 contained 63 percent iron.

Production in 1942 was about 100 tons, and the property was last operated by E. E. Carlisle of Blythe, Calif. The deposit is small.

Hematite occurs also on the southwest slope of the north Trigo Mountains (129, fig. 1), approximately in secs 5 and 6, T 1 N, R 21 W, inside the Yuma Test Station withdrawal. It is reached by driving 12 miles southeast of Ehrenberg on the Cibola Lake road, and 4 miles east along Trigo Wash. The deposit is reported as 2 to 4 feet thick and crops out in an interrupted pat-tern along a fracture in schist for a mile. Several shallow prospect pits and cuts expose the hematite along the outcrop. A sample of the better hematite contains 58 percent iron. Three claims along the outcrop were located by E. E. Carlisle of Blythe, Calif.

BENEFICIATION

General

Little is known about the metallurgical problems peculiar to low-grade iron deposits in Arizona. To arrive at some impression of the amenability of the iron-rich, low-grade materials to beneficiation, a few outcrop and character chip and grab samples were collected and sent to the Salt Lake City Metallurgical Research Center of the Bureau for pioneer appraisal and preliminary beneficiation testing. These studies were purely qualitative and preliminary because the samples formed part of a reconnaissance investigation and were not the results of any acceptable exploration program or fully representative metallurgical sampling. The samples, generally less than 50 pounds, were grab and chip collections spread over large areas. Results of preliminary tests on them should be considered only as a first impression. Samples from 16 localities and their chemical analyses are listed in table 28.

TABLE 28. - Localities and chemical analyses of Arizona test samples[1] for beneficiation amenability investigations

Test[2] sample No.	Location[3] No.	Locality: County	Locality: Deposit	Chemical analyses, percent: Fe	Mn	TiO_2	P	S	SiO_2	Cu
1....	1.....	Apache..	Lyman Reservoir (Red Cap)	16.0	0.04	0.53	0.01	0.11	66.4	-
			residual hematite.	44.6					20.4	0.44
2....	4......	Cochise.	Dragoon Mountains (Black		.70	.20	.02	.25		
			Diamond), cupreous magnetite-hematite.	40.5		9.3			25.4	
3....	31.....	Gila....	Iron King, taconite-semi-		.15		.08	.09		-
			taconite titaniferous hematite-magnetite.	31.8		7.5			37.8	
4....	36	do....	Pig Iron, taconite-semi-		.10		.04	.10		-
			taconite titaniferous hematite-magnetite.	54.8					19.3	
5....	13, 19, 22, 23, 35, 58 63.	Gila and Navajo.	Bottle Spring, Dry Creek,		.10	.25	.22	.02		-
			Gentry Creek and Mesa, Nail Ranch, Apache and Split Rock locations--Young-Canyon Creek area hematites.	25.5	2.3				46.3	
6....	48	Maricopa	Big Boulder-Iron Ridge, mag-			.26	.15	.11		-
			netite taconite.	28.7	1.9				46.5	
7....	50.....	do....	Hieroglyphic Mountains (Pikes			.10	.13	.05		-
			Peak), magnetite-hematite taconite.	44.9					19.4	1.75
8....	73.....	Pinal...	Slate Mountains-Lakeshore		.35	.15	.02	.15		
			cupreous magnetite.	50.2					21.7	
9....	65	Pima....	Quijotoa Mountains magnetite-		.20	.75	.12	.08		-
			hematite.	33.7	2.25				34.9	
10....	81, 82, 83, 102.	Yavapai.	Big Buck; Three Points; Black			.20	.27	.04		-
			Chief; Black Gold; Yaeger locations, Mingus Mountains; Black Hills; magnetite-hematite.	29.8	1.50				46.9	
11....	85, 86, 89, 96.	do....	Blue Bell mine and siding,			.33	.15	.04		-
			Copper Mountain, and Mayer-Stoddard magnetite-hematite taconite, vicinity of Mayer.	27.6					49.6	
12....	94.....	do....	Los Felice, magnetitic		.19	.23	.18	.08		-
			quartzite-schist (taconite), vicinity Cleator and Townsend Butte.	27.3					44.4	
13....	91, 84, 79, 97.	do....	Magnetite-hematite taconite;		.40	.45	.12	.13		-
			Goodwin, Blind Indian Creek, Longfellow Ridge, Ash Creek, Pine Creek areas.	25.6	2.35				51.5	
14....	100	do....	Stanton magnetite taconite...			.30	.19	.09		-
15....	103, 105, 107, 108, 117.	Yuma....	Black Chief, Black Jack,	31.3	3.30	.33	.07	.77	26.5	-
			Black Mule, Black Stud, Iron mine; hematites west of Bouse and at foothills of Plomosa Mountains.	24.5					38.5	2.51
16....	110, 121.	do....	Cupreous hematite; Brown		.15	.29	.06	.67		
			Mountain, Mineral Hill, and Mineral Wash area.							

[1]For summary of test results see table 46.
[2]Test samples are generally composites of individual samples from several sources.
[3]Location numbers refer to figure 1 and table 1.

Amenability Testing

Test Sample 1, Apache County Hematite

This character sample is of a residual hematite deposit in the vicinity of Lyman Reservoir (1, fig. 1), T 11 N, R 28 E. The deposits from which this sample and those following were taken are described in the chapter on iron occurrences by county.

Test sample 1 comprised earthy red hematite, having small quantities of specularite and limonite. Gangue minerals included quartz sand, illite clay, and chalcedony. Amenability of the sample to upgrading was tested by oil-emulsion flotation and wet magnetic separation of reduction-roasted crude ore. Preliminary tests of these methods of concentration were on material ground to minus 200-mesh and minus 325-mesh to secure maximum liberation and grade of product.

Material ground to minus 200-mesh size was tested by flotation in which a fuel oil-tall oil emulsion was used as the collector for the iron oxides. This method of concentration recovered only 59.9 percent of the iron in a product that contained 47.4 percent Fe and 24.9 percent SiO_2. Flotation was complicated because the earthy hematite slimed readily and consumed large amounts of reagent. Illite clay also formed slimes that coated the iron minerals and were difficult to disperse. Attempts to treat minus 325-mesh material were unsuccessful because of the large amount of slimes formed during grinding and subsequent conditioning and flotation. Desliming before flotation was not successful because of the excessive quantity of iron rejected with the slime.

Because most of the iron occurred as hematite, reductive roasting of minus 10-mesh ore followed by wet magnetic separation was employed on fractions ground through 200- and 325-mesh. Charges of the ground ore were heated in a rotating furnace for an hour with natural gas and steam at 625° C. The reducing atmosphere was maintained throughout the heating and cooling cycles. After cooling to room temperature the resulting calcine was separated into magnetic and nonmagnetic fractions using a Davis-tube magnetic separator. As slightly higher grade was obtained in treatment of the minus 325-mesh material, these data are reported in table 29.

TABLE 29. - Results of reductive roasting and magnetic separation on the Lyman Reservoir (Red Cap), residual hematite, Apache County, Ariz.

Products	Weight-percent	Chemical analysis, percent		Distribution, percent, Fe
		Fe	SiO_2	
Magnetic concentrate[1].........	27.0	52.8	18.6	87.5
Nonmagnetic tailing...........	73.0	2.8	-	12.5
Calculated heads..............	100.0	16.3	-	100.0

[1]Total analysis includes 0.52 percent TiO_2, 0.01 percent P, 0.05 percent S, and 0.2 percent Mn.

Table 29 indicates that reductive roasting followed by wet magnetic separation of minus 325-mesh material in a Davis tube magnetic separator resulted in a recovery of 87.5 percent of the iron as a concentrate containing 52.8 percent Fe and 18.6 percent SiO_2. Similar treatment of the minus 200-mesh material recovered 88.1 percent of the iron in a magnetic concentrate containing 50.0 percent Fe and 22.0 percent SiO_2.

Tests reported concentrates containing 63.1 percent Fe, 1.6 percent TiO_2, 3.0 percent Al_2O_3, and negligible amounts of S and P.

Test Sample 2, Cochise County Cupreous Magnetite-Hematite

A chip sample was taken from a cupreous magnetite-hematite replacement-type deposit at the Black Diamond mine in the Dragoon Mountains (4, fig. 1), T 18 S, R 24 E. Test sample 2 contained magnetite and hematite with some malachite in moderately coarse association with quartz and calcite. The amenability of the sample to upgrading was tested by magnetic separation of natural and reduced ore, oil-emulsion flotation of the iron minerals, and the copper segregation process to recover both the iron and the copper.

Wet magnetic separation, by Davis tube, of the ore sample ground to minus 100-mesh resulted in a recovery of 77.9 percent of the iron as a magnetic product containing 69.9 percent Fe, 0.17 percent Cu, and 3.9 percent SiO_2. Reductive roasting followed by wet magnetic separation recovered 94.6 percent of the iron in a concentrate containing 66.6 percent Fe, 0.25 percent Cu, and 4.2 percent SiO_2.

By oil-emulsion flotation of material ground to minus 100-mesh with one cleaning of the flotation rougher concentrate, 86.7 percent of the iron was recovered in the cleaned flotation concentrate, containing 55.4 percent Fe, 0.42 percent Cu, and 12.6 percent SiO_2. Attempts to recover the copper mineral before flotation of the iron minerals were unsuccessful because of low recovery.

The copper segregation process was investigated as a means of recovering both iron and copper minerals from a finely ground pulp as follows: A charge of minus 10-mesh ore, with 1 percent petroleum coke, 2 percent salt, and 2.4 percent water, was heated for an hour at 700° C in a rotary furnace. Natural gas and steam were passed through the furnace to insure a reducing atmosphere that was maintained throughout the heating and cooling cycles. After cooling to room temperature, the resulting calcine was ground to minus 100-mesh with enough lime to obtain a pH of plus 11. The metallic copper was floated with potassium amyl xanthate (KAX) as collector and methylisobutyl carbinol (MIBC) as frother. The copper rougher concentrate was filtered, dried, and chemically analyzed. The flotation rougher tailing, containing the bulk of the iron as artificial magnetite, was separated into magnetic and nonmagnetic fractions, using a Davis tube separator. Table 30 shows the results of the copper flotation and magnetic separation to recover the iron, as well as the amounts of reagents used in copper flotation.

TABLE 30. - Results of copper segregation, copper flotation, and wet magnetic iron separation on Black Diamond (Dragoon Mountains) cupreous magnetite-hematite ore, Cochise County, Ariz.

	Weight-percent	Chemical analyses, percent			Distribution, percent	
		Fe	Cu	SiO_2	Fe	Cu
Products:	4.6					
Copper rougher concentrate......	71.2	21.0	10.4	17.6	2.1	86.0
Magnetic iron concentrate[1]	24.2	61.5	.1	7.6	95.5	12.8
Nonmagnetic iron tailing........	100.0	4.5	.03	-	2.4	1.2
Calculated heads		45.8	.55	-	100.0	100.0
	Reagent consumption, pounds per ton					
	Grind	Copper rougher concentrates				
Reagents:						
Lime (CaO)[2]	8.0	1.2				
Potassium amyl xanthate (KaX)...	-	.24				
Methylisobutyl carbinol (MIBC)..	-	-				

[1]Total analysis includes 0.13 percent TiO_2, 0.01 percent P, 0.03 percent S, and 0.4 percent Mn.
[2]Resulting pH was 11.5.

Data in table 30 indicate that by the segregation process to recover cop-per followed by wet magnetic separation to recover the reduced iron minerals from the copper rougher tailing 86.0 percent of the copper and 95.5 percent of the iron was recovered. The copper was recovered as a low-grade rougher concentrate containing 10.4 percent Cu, 21.0 percent Fe, and 17.6 percent SiO . Undoubtedly the copper rougher concentrate could be upgraded with a flotation cleaning stage with only a small loss in overall recovery. The magnetic iron concentrate from the copper flotation tailing contained 61.5 percent Fe, 0.1 percent Cu, and 7.6 percent SiO_2.

Test Sample 3, Gila County Titaniferous, Hematite-Magnetite Taconite

A chip sample was taken of titaniferous hematite-magnetite taconite-semitaconite in the Precambrian Yavapai sequence on the Iron King group of claims (31, fig. 1), T 8 N, Rs 11 and 12 E.

Test sample 3 contained hematite, magnetite, ilmenite, quartz, sericite, chalcedony, garnet, and zircon. Hematite was the principal iron mineral in these outcrop samples, and most of the gangue was quartz. Mineral associations between the iron oxides and the quartz were extremely fine-grained, and it is doubtful that grinding through 325-mesh would provide satisfactory liberation of the iron minerals from the quartz gangue. Similarly, the ilmenite was extremely fine grained. Microscopic examination of specimens indicated a hematite-magnetite quartzite formation, probably a magnetitic quartzite originally; it was estimated as 40 percent magnetite, 100- to 200-mesh size; 25 percent hematite, approximately 500-mesh size; 30 percent quartz, 200-mesh size; and 2 percent feldspar, 300- to 400-mesh size. It must be remembered that this information was derived from small outcrop samples of a great area and could be considered only as an indication of the presence of iron.

Flotation and magnetic separation tests were made on this sample. The minerals were so closely associated that grinding through 325-mesh did not greatly improve the results obtained with a 100-mesh grind.

In oil-emulsion flotation of a charge of minus 10-mesh ore ground to minus 100-mesh, including multiple cleanings of the rougher concentrate, only 61.2 percent of the iron was recovered in a flotation concentrate that contained 55.2 percent Fe, 4.6 percent SiO_2, and 9.5 percent TiO_2. Most of the iron in the sample tested was hematite. Because of this, further tests consisted of reductive roasting of minus 10-mesh ore followed by wet magnetic separation on fractions ground through 100-, 200-, and 325-mesh. The procedure used for reductive roasting is similar to that described for area sample 1. Because similar results were obtained in the magnetic separation of the three sized samples, only the results obtained from the minus 100-mesh fraction were reported in table 31.

TABLE 31. - Results of reductive roasting and wet magnetic separation on titaniferous hematite-magnetite taconite, semitaconite iron formation on the Iron King claims, Gila County, Ariz,

Products	Weight-percent	Chemical analyses, percent			Distribution, percent	
		Fe	TiO_2	SiO_2	Fe	TiO_2
Magnetic iron concentrates[1]....	61.7	53.4	8.0	11.7	81.3	59.4
Nonmagnetic tailing	38.3	19.8	8.8	-	18.7	40.6
Calculated heads	100.0	40.5	8.3	-	100.0	100.0

[1]Total analysis includes 0.01 percent P, 0.03 percent S, and 0.2 percent Mn.

By wet magnetic separation of the reduced ore ground through 100-mesh (table 31) 81.3 percent of the iron was recovered in a magnetic product containing 53.4 percent Fe, 8.0 percent TiO_2, and 11.7 percent SiO_2. The amounts of TiO_2 in the concentrate, tailing, and calculated heads indicates unsuccessful liberation of the ilmenite from the other iron minerals. Little change in recovery and grade was achieved by grinding to minus 325-mesh. The magnetic iron concentrate obtained at this grind recovered 79.2 percent of the iron, containing 54.7 percent Fe, 8.4 percent TiO_2, and 10.2 percent SiO_2

Again it should be remembered that this is only a small outcrop sample from a large area.

Test Sample 4, Gila County Titaniferous Hematite-Magnetite Taconite

A chip sample was taken of titaniferous hematite-magnetite, taconite-semitaconite in the Yavapai sequence on the Pig Iron group of claims (36, fig. 1), T 8 N, Rs 11 and 12 E.

Test sample 4 appeared similar to sample 3 and was principally red earthy hematite with minor ilmenite, closely associated with quartz and some sericite, feldspars, biotite, and chlorite. Microscopic examination of rock fragments from the area indicated a composition of 40 percent magnetite of 100- to 200-mesh size, 25 percent hematite of 500-mesh or smaller size, 30 percent silica of 200-mesh size, and 2 percent feldspar of 300- to 400-mesh size.

This sample was tested by oil-emulsion flotation of the iron minerals and by wet magnetic separation of the reduced material. This sample, mineralogically similar to sample 3, differed in that grinding through minus 325-mesh improved the recovery of iron. Fine grinding, however, did not improve the grade of the magnetic iron concentrate importantly.

Flotation of a finely ground pulp, using oil-emulsion as the collector for the iron minerals, resulted in a recovery of 61.5 percent of the iron in a triple-cleaned concentrate containing 56.8 percent Fe, 9.4 percent TiO_2, and 3.7 percent SiO_2.

Most of the iron in this sample was hematite. Because of this, further tests consisted of reductive roasting and wet magnetic separation. To deter-mine the effectiveness of these means of concentrating the iron minerals in the sample, a charge of minus 10-mesh ore was heated for 1 hour at 625° C in a rotating furnace. Natural gas and steam were introduced into the furnace to maintain a reducing atmosphere throughout the heating and cooling cycles. After it was cooled to room temperature, the resulting calcine was ground through 100, 200, and 325-mesh, and wet magnetic separations were made employing a Davis-tube separator. The best results were obtained with the finest grind and are reported in table 32.

TABLE 32. - Results of reductive roasting and wet magnetic separation on titaniferous hematite-magnetite taconite, semitaconite iron formation on the Pig Iron claims, Gila County, Ariz.

Products	Weight-percent	Chemical analyses, percent			Distribution, percent	
		Fe	TiO_2	SiO_2	Fe	TiO_2
Magnetic iron concentrate[1]	56.7	53.0	8.1	13.2	90.4	67.5
Nonmagnetic tailing	43.3	7.4	5.1	-	9.6	32.5
Calculated heads	100.0	33.3	6.8	-	100.0	100.0

[1]Total analysis includes 0.01 percent P, 0.03 percent S, and 0.1 percent Mn.

Table 32 indicates that with wet magnetic separation of reduced ore ground to minus 325-mesh, 90.4 percent of the iron was recovered in a concentrate containing 53.0 percent Fe, 8.1 percent TiO_2, 13.2 percent SiO_2, and small quantities of P, 5, and Mn. Fine grinding was important in this sample since it increased recovery from 75 and 80 percent, obtained in grinds of 100-and 200-mesh, to 90.4 percent, obtained with a 325-mesh grind.

Test Sample 5, Gila and Navajo Counties Hematite

Composite chip samples of hematite were taken from the Bottle Spring, Dry Creek, Gentry Creek and Mesa, Nail Ranch, Apache and Split Rock locations in the Young-Canyon Creek area, Tps 8, 9, and 10 N, Rs 14 and 15½ E.

Replacements of Precambrian Mescal limestone associated with diabase intrusives (13, 19, 22, 23, 35, 58, 63; fig. 1).

Test sample 5 comprised a high-grade, compact to earthy, red hematite ore with some specularite and magnetite. Chalcedony, quartz, and sericite were present as gangue minerals. The sample is a composite of samples from several similar deposits covering a wide area. The sample required grinding through 200-mesh to effect satisfactory liberation of the iron minerals. Amenability testing included oil-emulsion flotation and wet magnetic separation of the reduced ore.

Oil-emulsion flotation of a charge of ore ground to approximately 80 per-cent minus 200-mesh was moderately successful. With the flotation concentrate, cleaned twice, 86.0 percent of the iron was recovered, containing 60.4 percent Fe, and 8.9 percent SiO_2.

Reductive roasting of minus 10-mesh hematite ore was followed by wet magnetic separation, employing a Davis-tube separator, on fractions ground through 200- and 325-mesh. The reductive roasting procedure was similar to that described under area sample 1. One hour was insufficient for complete reduction, and it was necessary to treat the material with natural gas and steam, in the furnace, for 2 hours. The results of wet magnetic separation of the fraction ground through 200-mesh are reported in table 33, since grinding through 325-mesh showed only a slight improvement.

TABLE 33. - Results of reductive roasting and wet magnetic separation on hematite ores of the Young-Canyon Creek area, Gila-Navajo Counties, Ariz.

Products	Weight-percent	Chemical analyses, percent		Distribution, percent, Fe
		Fe	SiO_2	
Magnetic iron concentrate[1]	90.3	60.4	11.6	99.2
Nonmagnetic tailing	9.7	4.4	-	.8
Calculated heads	100.0	55.0	-	100.0

[1]Total analysis included 0.28 percent TiO_2, 0.16 percent P, 0.02 percent S, 0.1 percent manganese, and 0.02 percent Cu.

As shown in table 33, by wet magnetic separation of reduced ore ground to minus 200-mesh, 99.2 percent of the iron was recovered in an artificial magnetite concentrate containing 60.4 percent Fe and 11.6 percent SiO_2. Treatment of reduced material ground through 325-mesh recovered 99.0 percent of the iron in a concentrate containing 61.2 percent Fe and 9.6 percent SiO_2. This test was made on a composite of many small samples from a large area.

Test Sample 6, Maricopa County Magnetite Taconite

A chip sample was taken of Big Boulder-Iron Ridge taconite in the Precambrian, Yavapai sequence (48, fig. 1), T 7 N, R 2 E.

Test sample 6 comprised moderately fine-grained magnetite with lesser amounts of very fine-grained brown hematite and limonite. Gangue minerals included quartz, sericite, and some opal. Microscopic examination of rock fragments indicated 10- to 25-percent magnetite of 30- to 100-mesh size; as much as 4 percent hematite, approximately 200-mesh size; 55 to 78 percent quartz of 200- to 400-mesh size; 3 to 5 percent spinel of 125- to 200-mesh size; less than 1 percent sphene of 240- to 1,000-mesh size; less than 1 per-cent apatite of 240- to 1,000-mesh size; and as much as 1 percent limonite and 4 percent kaolinite. The sample was a composite from a large taconite-like area and was tested by oil-emulsion flotation and wet magnetic separation of natural and reduced materials.

Moderate recovery of the iron minerals in a low-grade concentrate was achieved with flotation, using a tall oil-fuel oil emulsion as the collector in a finely ground pulp. This method resulted in recovery of 76.7 percent of the iron in a triple cleaned concentrate containing 49.1 percent Fe, and 17.1 percent SiO_2. Microscopic examination of the concentrate indicated that the low-grade was due to the diluting effect of manganese oxide minerals, sericite, and quartz.

Wet magnetic separation to recover only the magnetite was attempted, by Davis-tube separator, after grinding the sample to minus 200-mesh. Only 59.0 percent of the iron was recovered by this method in a magnetic concentrate containing 66.6 percent Fe and 3.2 percent SiO_2. Grinding to minus 325-mesh lowered recovery to 57.2 percent but increased the grade to 67.6 percent Fe with 2.6 percent SiO_2.

In an effort to obtain maximum recovery of both magnetic and nonmagnetic iron minerals, reductive roasting was tried. The procedure for reductive roasting was similar to that described for area test sample 1. Wet magnetic separation tests, employing a Davis-tube separator, were made on two charges of reduced ore ground through 200- and 325-mesh. Recovery of iron from the sample ground to minus 200-mesh was somewhat higher than that obtained with the 325-mesh grind, however, the grade of the iron product was lower. Table 34 illustrates the results obtained by magnetic separation of the minus 200-mesh reduced ore.

TABLE 34. - Results of reductive roasting and wet magnetic separation on Big Boulder-Iron Ridge magnetite taconite, Maricopa County, Ariz.

Products	Weight-percent	Chemical analyses, percent		Distribution, percent,
		Fe	SiO_2	Fe
Magnetic iron concentrate[1].......	42.8	57.6	13.2	93.5
Nonmagnetic tailing	57.2	3.0	-	6.5
Calculated heads	100.0	26.4	-	100.0

[1]Total analysis includes 0.3 percent TiO_2, 0.14 percent P, 0.05 percent S, an 3. 1 percent Mn.

By reductive roasting and wet magnetic separation of minus 200-mesh material, 93.5 percent of the iron was recovered in a magnetic concentrate that contained 57.6 percent Fe and 13.2 percent SiO_2. By grinding part of the reduced ore through 325-mesh before magnetic separation, 92.1 percent of the iron was recovered in a concentrate containing 58.8 percent Fe and 10.2 per-cent SiO_2.

Test Sample 7, Maricopa County Magnetite-Hematite Taconite

Description

A chip sample was used of Hieroglyphic Mountains-Pikes Peak taconite, Yavapai sequence (50, fig. 1), T 6 N, Rs 1 and 2 W.

Reconnaissance and preliminary microscopy indicate this low-grade iron deposit to be a taconite (fig. 22) consisting of bands and laminations of mixed iron oxides in a siliceous ground mass. The iron occurs as magnetite, martite, and hematite, as well as some limonite and goethite and a trace of pyrite. In addition, small amounts of manganese occur sporadically as hausmannite, pyrolusite, and manganiferous garnet. Minor amounts of spinel, ilmenite, apatite, feldspar, and sericite were also noted. Gangue is principally quartz. Microscopic examination reveals mineral grains of 1- to 50-microns size. Apatite occurs scattered as 100- to minus 200-mesh crystals. Mostly, the iron in the samples appeared as magnetite and martite. Crowding of the magnetite-martite crystals formed dark bands and massive appearing laminations of apparently high-grade ore, however, microscopic examination of these bands revealed considerable interstitial quartz of 100- to 350-mesh size, The hematite-limonite portion of the samples appears more abundant than the residual magnetite, however, the fine-grained magnetite, 1- to 20-microns size, appears uniformly distributed throughout all particles of crushed ore. The magnetite crystals occur singly, or in clusters ¼ inch or larger, mixed and interlocked with hematite-limonite and quartz. Octahedra of martite with centers of magnetite suggest that magnetite was the original source of iron in the deposit. According to Davis magnetic-tube tests on minus 10-mesh samples, about 1/3 of the deposit is magnetic.

Beneficiation Testing

Test sample 7 was tested by oil-emulsion flotation and by magnetic separation of natural and reduced fractions of the ore sample. Test material was ground through 325-mesh without achieving satisfactory liberation of the mineral components.

By flotation treatment of the sample with an emulsion of fuel oil and tall oil as collector for the iron minerals in a minus 325-mesh pulp, 78.0 percent of the iron was recovered. The iron concentrate, cleaned three times, contained 53.9 percent Fe and 11.7 percent SiO_2.

With wet magnetic separation of material ground through 325-mesh, only 39.5 percent of the iron was recovered from a concentrate containing 57.2 percent Fe and 15.4 percent SiO_2.

Wet magnetic separation tests were made on two charges of reduced ore ground separately through 200- and 325-mesh. The procedure for reductive roasting is described under test sample 1. Since test data for the two charges were approximately the same, only the results from the 200-mesh grind are reported in table 35.

TABLE 35. - Results of reductive roasting and wet magnetic separation on Hieroglyphic Mountains (Pikes Peak) hematite-magnetite taconite, Maricopa County, Ariz.

Products	Weight-percent	Chemical analyses, percent		Distribution, percent,
		Fe	SiO_2	Fe
Magnetic iron concentrate[s]	53.3	52.4	19.6	94.0
Nonmagnetic tailing	46.7	3.8	-	6.0
Calculated heads	100.0	29.7	-	100.0

Total analysis includes 0.26 percent TiO_2, 0.13 percent P, 0.03 percent S, and 1.7 percent Mn.

Table 35 indicates that pretreatment of the ore by a reducing-roast before wet magnetic separation resulted in recovery of 94.0 percent of the iron in a magnetic concentrate containing 52.4 percent Fe and 19.6 percent SiO_2. With the 325-mesh grind, 94.4 percent of the iron was recovered in a concentrate containing 52.1 percent Fe and 19.8 percent SiO_2.

Earlier Beneficiation Testing (20)

During 1943-44 the Bureau of Mines carried on beneficiation investigations on taconite samples furnished by Kaiser Steel Corp., from the Pikes Peak deposit (20) in the Hieroglyphic Mountains of Maricopa County, Ariz. Chemical analyses of three composites of the samples used in testing are compiled in table 36.

TABLE 36. - Analyses of composite samples, Hieroglyphic Mountains (Pikes Peak) deposit, Maricopa County, Ariz.

Composited material	Chemical analyses, percent						
	Fe	Mn	SiO_2	Al_2O_3	CaO	P	S
Surface trenches	30.6	2.7	37.6	4.7	1.0	0.14	0.04
Underground	32.5	3.9	34.1	3.9	1.2	.12	.06
Overall composite[1]......................	31.2	2.8	36.4	4.1	1.1	.13	.05

[1] 1/3-surface-trench composite and 2/3-underground composite.

Tests on the composite samples (20) included crushing, screening, log-washing, heavy-media separation, jigging, tabling, flotation, reductive roasting, and wet magnetic separation, giving the following results.

No significant concentration was effected by crushing, screening, and log-washing.

By coarse gravity concentration with heavy media (sink-float) and by jigging, (table A-4), 51.8 percent of the iron and 32.6 percent of the manganese was recovered in a concentrate containing 50.1 percent Fe, 2.5 percent Mn, 16.1 percent SiO_2, 0.15 percent P, 3.3 percent Al_20_3, 0.5 percent Can, and 0.04 percent S.

With gravity table concentration of the combined heavy-media and jigging middling, crushed through 20-mesh and sized on 48-mesh {table A-5), an additional 20.2 percent of the iron and 25.6 percent of the manganese was recovered in a concentrate containing 46.6 percent Fe, 4.5 percent Mn, 15.8 percent SiO_2, and 0.17 percent P. In combining heavy-media and jigging concentrates and the tabled middling concentrate, 72.0 percent of the iron and 58.2 percent of the manganese was recovered in a concentrate containing 49.1 percent Fe, 3.0 percent Mn, 16.0 percent SiO_2, and 0.15 percent P. After sintering at 1,175° C, the combined concentrates contained 52.3 percent Fe, 3.1 percent Mn, 17.1 percent SiO_2, 3.5 percent Al_20_3, 0.155 percent P, and 0.03 percent S.

Flotation of the combined heavy-media and jigging middling, ground to minus 100-mesh and 89 percent minus 200-mesh, resulted in recovery of 25.4 percent of the iron and 42.0 percent of the manganese, in a concentrate containing 49.0 percent Fe, 5.0 percent Mn, 14.2 percent SiO_2, and 0.24 percent P (table A-6). The combined heavy-media and jigging concentrates plus the middling flotation concentrate recovery was 77.2 percent of the iron and 74.6 percent of the manganese. The combined concentrates contained 49.7 percent Fe, 3.1 percent Mn, 15.1 percent SiO_2, and 0.18 percent P.

Wet magnetic separation of the heavy-media and jig middling, after crushing through 20-mesh and reduction roasting at 550° C with fuel oil, resulted in recovery of 29.7 percent of the iron and 28.3 percent of the manganese in a concentrate containing 51.6 percent Fe, 3.5 percent Mn, 16.3 percent SiO_2, and 0. 19 percent P (table A-7). Total recovery by combining the magnetic and gravity concentrates (table A-7) was 81.5 percent of the iron and 60.9 percent of the manganese in a concentrate containing 50.5 percent Fe, 2.9 percent Mn, 16.2 percent SiO_2, 3.4 percent Al_20_3, 0.17 percent P, and 0.04 percent S.

Flotation tests on the composite ore, ground through 65-, 100-, 200-, and 325-mesh indicated that grinding to 5 percent on 200-mesh gave optimum results. A typical test (table A-8) resulted in 80.3 percent recovery of the iron with 80.2 percent recovery of the manganese, in a concentrate containing 53.7 per-cent Fe, 5.0 percent Mn, 10.9 percent insolubles, and 0.15 percent P.

Wet magnetic separation tests on kilogram samples of inch composite ore given a reduction roast at 550° and 625° C and then ground to 48- and 100-mesh (tables A-9, A-10) resulted in recovery of 83.9 to 94.0 percent of the iron and 44.7 to 59.8 of the manganese, in concentrates containing 55.2 to 58.2 percent Fe, 3.2 to 3.6 percent Mn, 9.0 to 12.3 percent SiO_2, 0.13 to 0.15 per-cent P, and 2.0 to 2.5 percent Al_20_3 (20, pp. 24-39).

Test Sample 8, Pinal County Cupreous Magnetite

A grab sample was taken of Slate Mountains cupreous magnetite, Lakeshore mine, Transarizona Resources, Inc. {73, fig. 1), T 10 S, R 4 E.

Test sample 8 comprised relatively coarse-grained magnetite with some compact red hematite associated with chrysocolla. Gangue consists of quartzite, chalcedony, calcite, and minor amounts of opal and chlorite. The amen-ability of the sample to upgrading was tested by magnetic separation of natural and reduced ore, oil-emulsion flotation of the iron minerals, and the copper segregation method of concentration to recover both iron and copper.

Wet magnetic separation in a Davis-tube separator of natural ore ground to minus 100-mesh resulted in recovery of 89.6 percent of the iron in a magnetic concentrate containing 66.4 percent Fe, 0.4 percent Cu, and 2.6 percent SiO_2. Reductive roasting followed by wet magnetic separation resulted in recovery of 96.8 percent of the iron in a magnetic concentrate containing 61.8 percent Fe, 1.1 percent Cu, and 5.2 percent SiO_2. Copper present in the ore could not be recovered separately by wet magnetic separation of either the natural or reduced ore.

Oil-emulsion flotation of a charge of minus 10-mesh ore, ground through 100-mesh, with two cleanings of the rougher concentrate, resulted in recovery of 82.5 percent of the iron in a flotation concentrate containing 56.7 percent Fe, 0.6 percent Cu, and 11.2 percent SiO_2. Attempts to recover the copper mineral before floating the iron oxides were unsuccessful.

The copper segregation process was employed to recover copper and iron minerals from a finely ground pulp. A charge of minus 10-mesh ore with 1 percent petroleum coke, 2 percent salt, and 2.4 percent water, was heated for 1 hour at 700° C in a rotary furnace. Natural gas and steam were passed through the furnace to insure a reducing atmosphere throughout the heating and cooling cycles. After cooling to room temperature, the resulting calcine was ground to minus 100-mesh with enough lime (CaO) to develop a pH of plus 11. The metallic copper was floated with potassium amyl xanthate (KAX) as collector and methylisobutyl carbinol (MIBC) as frother. The copper rougher concentrate was filtered, dried, and analyzed chemically. The flotation rougher tailing, which contained the bulk of the iron as artificial magnetite, was separated into a magnetic iron concentrate and a nonmagnetic tailing, using a Davis-tube separator. Table 37 indicates results of the flotation test, the magnetic separation test, and the reagents used in flotation.

Copper segregation, flotation of the metallic copper, and magnetic separa-tion of the magnetite from the copper rougher tailing recovered 89.0 percent of the copper and 94.5 percent of the iron in the test sample. The copper was recovered in a rougher concentrate that contained 25.6 percent Cu, 17.0 per-cent Fe, and 27.2 percent SiO_2. Cleaning the copper rougher concentrate undoubtedly would raise its grade to plus 30 percent with only a small loss in overall copper recovery. The magnetic iron concentrate contained 63.9 percent Fe, 0.1 percent Cu, and 4.9 percent SiO_2.

TABLE 37. - Results of copper segregation, copper flotation, and magnetic iron-separation on cupreous magnetite-hematite ore at the Lakeshore mine, Pinal County, Ariz.

	Weight-percent	Chemical analyses, percent			Distribution, percent	
		Fe	Cu	SiO_2	Fe	Cu
Products:						
Copper rougher concentrate........	5.8	17.0	25.6	27.2	2.1	89.0
Magnetic iron concentrate[1]........	70.6	63.9	.1	4.9	94.5	5.1
Nonmagnetic tailing	23.6	7.0	.4	-	3.4	5.9
Calculated heads	100.0	47.8	1.7	-	100.0	100.0
	Reagent consumption, pounds per ton					
	Grind	Copper rougher concentrates				
Reagents:						
CaO[2]	8.0	-				
KAX	-	1.2				
MIBC	-	.24				

[1]Total analysis includes 0.21 percent TiO_2, 0.03 percent P, 0.05 percent S, and 0.4 percent Mn.

[2] pH of 11.4.

The copper segregation-flotation process was being used (22) by Transarizona Resources, Inc., at their Lakeshore mine to recover copper from the iron-rich ore.

Test Sample 9, Pima County Magnetite-Hematite

A chip sample was taken of magnetite-hematite in epidotized granite, Quijotoa Mountains (65, fig. 1), T 15 S, R 2 E.

Test sample 9 comprised magnetite and micaceous specular hematite and a little limonite in epidotized granite. Gangue minerals included quartz, chalcedony, epidote, hornblende, apatite, and some calcite. Spectrographic analysis indicated the presence of 0.1 to 1.0 percent vanadium, 0.01 to 0.1 percent nickel, and 0.001 to 0.01 percent copper and zirconium. The sample required grinding to 100-mesh to effect liberation of the mineral constituents, The sample was tested by oil-emulsion flotation of the iron minerals and wet-magnetic separation of natural and reduced ore fractions.

Oil-emulsion flotation of the ore ground to minus 100-mesh gave excellent results. The flotation concentrate, cleaned once, contained 63.1 percent Fe and 6.6 percent SiO_2, representing a recovery of 91.8 percent of the iron.

Wet magnetic separation of the natural ore ground to minus 100-mesh recovered 61.6 percent of the iron in a concentrate containing 66.0 percent Fe and 5.6 percent SiO_2.

To determine the effectiveness of reductive roasting and magnetic separation as a means of concentrating all of the iron minerals in the sample, a charge of minus 10-mesh ore was heated in a rotating furnace for 1 hour with natural gas and steam at a temperature of 625° C. The reducing atmosphere was maintained through the heating and cooling cycles. After cooling to room temperature, the calcine was ground to minus 100-mesh and then separated into a magnetic iron concentrate and a nonmagnetic tailing, employing a Davis-tube separator. Table 38 indicates the results of magnetic separation of the reduced ore.

TABLE 38. - Results of reductive roasting and wet magnetic iron separation on Quilotoa Mountains magnetite-hematite, Pima County, Ariz.

Products	Weight-percent	Chemical analyses, percent		Distribution, percent, Fe
		Fe	SiO_2	
Magnetic iron concentrate[1]........	70.9	66.4	4.6	93.2
Nonmagnetic tailing	29.1	11.8	-	6.8
Calculated heads	100.0	50.5	-	100.0

[1]Total analysis includes 0.23 percent TiO_2, 0.01 percent P, 0.03 percent S, 0.1 percent Mn, and 0.26 percent V.

As indicated in table 38, by wet magnetic separation of reduced ore, 93.2 percent of the iron was recovered in a magnetic concentrate containing 66.4 percent Fe and 4.6 percent SiO_2. Attempts to lower the iron content of the nonmagnetic tailing and to improve the recovery by grinding to minus 200-mesh resulted in a recovery of 91.6 percent of the iron in a concentrate containing 67.2 percent Fe and 3.5 percent SiO_2.

Test Sample 10, Yavapai County Magnetite-Hematite, Taconite-Jaspilite

Composite chip samples were tested of magnetite-hematite, taconite-jaspilite, Mingus Mountain-Black Hills area (81, 82, 83, 102; fig. 1), Tps 14 and 15 N, R 2 E. This sample was a composite from the Big Buck-Three Points, Black Chief, Black Gold, and Yaeger locations.

Test sample 10 comprised a fine-grained, siliceous magnetite-hematite iron formation. Gangue minerals included chalcedony with minor quantities of quartz, sericite, apatite, amphibole, and pyroxene. Petrographic study of sized fractions indicated that grinding to minus 325-mesh would give only partial separation of the mineral constituents. Spectrographic analysis indicated the presence of 1 to 10 percent manganese, 0.1 to 1.0 percent titanium, 0.01 to 0.1 percent cobalt, nickel, and copper, and 0.001 to 0.01 per-cent vanadium.

The sample was tested by oil-emulsion flotation of the iron minerals and wet magnetic separation of natural and reduced material. Because of the fine grain and close association of the iron oxides and gangue minerals, the material was ground through 325-mesh.

Flotation was not successful as a means of concentrating the iron minerals. With oil-emulsion as the collector for the iron minerals, recovery was only 66.1 percent of the iron in a triple-cleaned concentrate containing 43.8 percent Fe and 23.4 percent SiO_2.

Wet magnetic separation of natural ore ground to minus 325-mesh recovered only the magnetite, 51.0 percent of the total iron oxides, in a concentrate containing 50.0 percent Fe and 22.2 percent SiO_2.

Since flotation and magnetic separation of natural material proved unsatisfactory, reductive roasting followed by wet magnetic separation of material ground through 325-mesh was tried as a means of recovering all of the iron minerals. The procedure for reductive roasting was the same as for locality sample 9. Table 39 indicates results of magnetic separation of the reduced ore.

TABLE 39. - Results of reductive roasting and wet magnetic iron separation on magnetite-hematite, taconite-jaspilite, Mingus Mountain-Black Hills area, Yavapai County, Ariz.

Products	Weight-percent	Chemical analyses, percent		Distribution, percent,
		Fe	SiO_2	Fe
Magnetic iron concentrate-........	65.9	47.6	26.2	92.0
Nonmagnetic tailing	34.1	8.0	-	8.0
Calculated heads	100.0	34.1	-	100.0

'Total analysis includes 0.23 percent TiO_2, 0.23 percent P, 0.05 percent S, and 1.9 percent Mn.

Table 39 indicates that with wet magnetic separation of reduced ore ground to minus 325-mesh, 92.0 percent of the iron was recovered in a magnetic iron concentrate containing 47.6 percent Fe and 26.2 percent SiO_2. The concentrate is low-grade with a high-phosphorus content. Improvement in grade would require very fine grinding.

Test Sample 11, Yavapai County Magnetite-Hematite Taconite

Composite chip samples were tested of magnetite-hematite taconite, vicinity Mayer (85, 86, 89, 96; fig. 1), Tps 11 and 12 N, Rs 1 and 2 E. This sample was a composite from the Blue Bell Mine, Blue Bell siding, Copper Mountain, and Mayer-Stoddard location.

Test sample 11 is a composite of a very siliceous fine-grained magnetite-hematite iron formation with small quantities of specularite and limonite. Gangue minerals include quartz and chalcedony and minor quantities of biotite, muscovite, sericite, chlorite, garnet, spinel, apatite, and feldspar. Petro-graphic investigations of thin sections indicate that magnetite comprises 25 to 45 percent of specimens in 30- to 1,600-mesh size. Hematite comprises as much as 5 percent of the specimens in 20- to 1,200-mesh size. Psilomelane was noted in one thin section, comprising 4 percent of 800- to 1,400-mesh size. Quartz, the predominant gangue mineral comprises 45 to 68 percent of the specimens in 400- to 1,000-mesh size.

The sample was tested by flotation and wet magnetic separation. Flotation treatment of a minus 325-mesh pulp with an emulsion of fuel oil and tall oil as the collector for the iron minerals resulted in recovery of 82.6 per-cent of the iron in a concentrate containing 51.3 percent Fe and 21.4 percent SiO_2.

By wet magnetic separation of the natural sample in a Davis-tube separator only magnetite was recovered; nonmagnetic iron oxides were rejected in the tailing. Only 52.0 percent of the iron from a minus 200-mesh pulp in a magnetic concentrate containing 62.4 percent Fe and 8.9 percent SiO_2 was recovered by this method. In treating material ground to minus 325-mesh, 51.8 percent of the iron was recovered in a concentrate containing 64.4 percent Fe and 6.2 percent SiO_2.

Reductive roasting followed by wet magnetic separation of fractions ground to minus 200- and minus 325-mesh was investigated in an effort to improve grade and recovery. The procedure used for reductive roasting is described under locality sample 9. The best results were obtained with the 200-mesh grind and are reproduced as table 40.

TABLE 40. - Results of reductive roasting and wet magnetic separation on magnetite-hematite taconite, vicinity Mayer, Yavapai County, Ariz.

Products	Weight-percent	Chemical analyses, percent		Distribution, percent, Fe
		Fe	SiO_2	
Magnetic iron concentrate[s]	47.8	56.8	15.6	90.6
Nonmagnetic tailing	52.2	5.4	-	9.4
Calculated heads	100.0	30.0	-	100.0

'Total analysis includes 0.20 percent TiO_2, 0.06 percent P, 0.04 percent S, and 1.4 percent Mn.

Table 40 indicates that reductive roasting and wet magnetic separation of minus 200-mesh material recovered 90.6 percent of the iron in a concentrate containing 56.8 percent Fe and 15.6 percent SiO_2. Similar treatment of material ground to minus 325-mesh increased the recovery to 95.0 percent but reduced the grade of the resulting magnetic iron concentrate to 51.8 percent Fe.

Test Sample 12, Yavapai County Magnetitic Quartzite Schist

Composite chip samples were tested of magnetitic quartzite-schist (taconite) from the Los Felice-St. John Gold and Copper Co. property, vicinity of Cleator and Townsend Butte (94, fig. 1), T 11 N, R 1 E.

Test sample 12 is a composite of fine-grained, banded, magnetitic quartzite (taconite) with minor quantities of manganese and limonite. Petrographic investigation of thin sections indicated 37 to 55 percent of the specimens were magnetite of 200- to 280-mesh size, 25 to 60 percent were quartz of 35-to 250-mesh size, less than 1 percent were feldspar of 250- to 300-mesh size, less than 1 percent were biotite of 300-mesh size, as much as 5 percent were garnet of 100-mesh size, as much as 1 percent were spinel of 150-mesh size, less than 1 percent were sphene of 550-mesh size, and less than 1 percent were apatite of 280-mesh size. Spectrographic analysis indicated presence of 1 to 10 percent manganese; 0.1 to 1.0 percent titanium; 0.01 to 0.1 percent cobalt, nickel, and copper; and 0.001 to 0.01 percent vanadium.

Mineral components in the sample were so fine grained and intermixed that material ground through 325-mesh contained an excessive amount of silica in the iron concentrate.

Oil-emulsion flotation of a minus 325-mesh pulp recovered only 64.0 percent of the iron present in the sample. The flotation concentrate, triple cleaned, contained 51.2 percent Fe and 22.2 percent SiO_2.

By wet magnetic separation of natural ore with a Davis-tube concentrator only magnetite was recovered, leaving the nonmagnetic iron minerals in the tailing. This method recovered 65.7 percent of the iron from the 325-mesh ground material in a concentrate containing 60.4 percent Fe and 11.6 percent SiO_2.

Reductive roasting followed by wet magnetic separation was investigated as a means of recovering all of the iron minerals, magnetic and nonmagnetic. The procedure for reductive roasting is described under locality sample 9. Preliminary tests were made at coarser sizes; however, the best results were obtained in separation of reduced material ground to minus 325-mesh. Table 41 indicates the results obtained from this test.

TABLE 41. - Results of reductive roasting and wet magnetic separation on magnetitic quartzite schist (taconite), vicinity Cleator and Townsend Butte, Yavapai County, Ariz.

Products	Weight-percent	Chemical analyses, percent		Distribution, percent
		Fe	SiO_2	Fe
Magnetic iron concentrate'......	51.4	52.0	20.0	94.5
Nonmagnetic tailing	48.6	3.2	-	5.5
Calculated heads	100.0	28.3	-	100.0

"Total analysis includes 0.23 percent TiO_2, 0.24 percent P, 0.04 percent S, and 1.7 percent Mn.

Reductive roasting followed by wet magnetic separation of minus 325-mesh material resulted in recovery of 94.5 percent of the iron in a magnetic concentrate containing 52.0 percent Fe and 20.0 percent SiO_2. Liberation of the mineral components in this sample, to effect optimum separation, was not fully effective at minus 325-mesh, due to the finely crystalline structure of the minerals and to their intimate association.

Test Sample 13, Yavapai County Magnetite-Hematite Taconite

Composited chip samples were tested of magnetite-hematite taconite, Goodwin-Blind Indian Creek-Longfellow Ridge-Ash Creek-Pine Creek area (91, 84, 79, 97; fig. 1), Tps 10 and 11 N, R 1 W.

Test sample 13 is a composite of a siliceous, more or less fine-grained, banded quartzite (taconite) iron formation. Iron minerals are principally magnetite with minor amounts of hematite and limonite. Gangue minerals include quartz, amphibole, mica, epidote, garnet, chlorite, sericite, calcite, zircon, sphene, apatite, hornblende, and fluorite. Petrographic investigation of thin sections indicates that 15 to 80 percent of specimens is magnetite in 30- to 500-mesh size; about 1 percent is hematite of 600-mesh size; as much as 3 percent is limonite, too fine to measure; 25 to 70 percent is quartz of 30-to 350-mesh size; as much as 5 percent is feldspar of 300-mesh size; as much as 10 percent is hornblende of 150- to 300-mesh size, 1 to 5 percent is biotite of 80- to 600-mesh size, less than 1 percent is garnet of 600-mesh size; less than 1 percent is sphene of 1,500-mesh size, 1 percent is apatite of about 1,000-mesh size, 4 to 30 percent is epidote of 300- to 600-mesh size, about 2 percent is fluorite of 600- to 1,000-mesh size; as much as 5 percent is calcite, and less than 1 percent is kaolinite. Semiquantitative spectrographic analysis indicated presence of 0.1 to 1.0 percent manganese and titanium; 0.01 to 0.1 percent cobalt, copper, and nickel; and 0.001 to 0.01 per-cent vanadium and zirconium.

The sample was tested by oil-emulsion flotation, by wet magnetic separation of the natural ore, and by a combination of reductive roasting and wet magnetic separation. A study of sized fractions indicated optimum liberation at minus 200-mesh, and this grind was the basis of testing.

Flotation treatment of the ore, using a fuel oil-tall oil emulsion as collector for the iron minerals, in a minus 200-mesh pulp resulted in recovery of 70.5 percent of the iron in a triple-cleaned concentrate containing 51.6 percent Fe and 17.0 percent SiO_2.

The sample was tested also by grinding fractions of the ore through 200-and 325-mesh and separating them into magnetic iron concentrates and nonmagnetic tailings. Results of these separations were almost the same; with iron recovery the same in both tests and the grade of the minus 325-mesh concentrate slightly higher. Table 42 indicates the results obtained by wet magnetic separation of minus 200-mesh material.

The data in table 42 indicates that wet magnetic separation of the composite sample, by Davis tube separator, recovered 85.5 percent of the iron in a magnetic iron concentrate containing 60.2 percent Fe, and 11.6 percent SiO_2. Similar treatment of material ground to minus 325-mesh recovered 85.6 percent of the iron in a concentrate containing 61.6 percent Fe and 9.7 percent SiO_2.

The sample was tested further by a combination of reductive roasting and wet magnetic separation. Recovery was increased to 88.3 percent in a magnetic iron concentrate containing 58.6 percent Fe and 13.5 percent SiO_2.

TABLE 42. - Results of wet magnetic separation on a composite of samples of magnetite-hematite taconite in the Goodwin-Blind Indian Creek-Longfellow Ridge-Ash Creek-Pine Creek locality, Yavapai County, Ariz.

Products	Weight-percent	Chemical analyses, percent		Distribution, percent, Fe
		Fe	SiO_2	
Magnetic iron concentrate[1]........	40.0	60.2	11.6	85.5
Nonmagnetic tailing	60.0	6.8	-	14.5
Calculated heads	100.0	28.2	-	100.0

[1]Total analysis included 0.25 percent TiO_2, 0.04 percent P, 0.03 percent S, and 0.3 percent Mn.

Test Sample 14, Yavapai County Magnetite Taconite

Chip samples of Stanton magnetite taconite were tested (100, fig. 1), T 10 N, R 5 W.

Test sample 14 is a banded, fine-grained magnetitic quartzite with minor amounts of specular hematite, limonite, and manganese oxides. Gangue minerals comprise quartz, sericite, garnet, chlorite, diopside, and amphibole. Spectrographic analysis indicated presence of 1 to 10 percent manganese; 0.1 to 1.0 percent titanium; 0.01 to 0.1 percent cobalt, copper, and nickel; and 0.001 to 0.01 percent vanadium. Mineral content of the sample was calculated as 16 percent magnetite, 13 percent hematite, and 0.5 percent ilmenite.

The sample was tested by oil-emulsion flotation and magnetic separation of natural and reduced ore.

Oil-emulsion flotation of ore ground to approximately 75 percent minus 325-mesh recovered 81.6 percent of the iron in a concentrate containing 47.4 percent Fe and 22.6 percent SiO_2. Examination of the iron concentrate revealed manganese oxides, quartz, and sericite. The fine grinding achieved only partial liberation of the minerals from each other.

Wet magnetic separation of natural ore recovered only magnetite, leaving hematite and limonite in the nonmagnetic tailing. Test fractions were ground through 200- and 325-mesh. Wet magnetic separation of the minus 200-mesh test fraction recovered 51.0 percent of the iron in a concentrate containing 51.0 percent Fe and 21.9 percent SiO_2. The minus 325-mesh grind recovered 51.2 percent of the iron in a concentrate containing 53.0 percent Fe and 19.3 per-cent SiO_2.

Reductive roasting with wet magnetic separation was investigated. The procedure for reductive roasting is described under locality sample 9. Wet magnetic separation tests were made on fractions ground through 200- and 325-mesh. Results are reported for the minus 325-mesh grind in table 43.

TABLE 43. - Results of reductive roasting and wet magnetic separation on a composite of samples of Stanton magnetite taconite, Yavapai County, Ariz.

Products	Weight-percent	Chemical analyses, percent		Distribution, percent, Fe
		Fe	SiO_2	
Magnetic iron concentrate[1]........	47.6	50.4	23.1	91.4
Nonmagnetic tailing	52.4	4.3	-	8.6
Calculated heads..................	100.0	26.2	-	100.0

otal analysis includes 0.39 percent TiO_2, 0.11 percent P, 0.02 percent and 2.5 percent Mn.

Table 43 indicates a recovery of 91.4 percent of the iron from minus 325-mesh material. The concentrate was low grade, containing 50.4 percent Fe. Similar treatment of the 200-mesh grind recovered 89.4 percent of the iron in a magnetic concentrate containing only 48.2 percent Fe with 25.3 percent SiO_2.

Test Sample 15, Yuma County Hematite

Composite hematite samples west of Bouse and at foothills of Plomosa Mountains (103, 105, 107, 108, 117; fig. 1), Tps 6 and 7 N, Rs 17 and 18 W, were tested. This sample is a composite from the Black Chief, Black Jack, Black Mule, Black Stud and Iron Mine locations.

Test sample 15 is a composite of samples from hematite replacement deposits in Paleozoic sediments west of Bouse, Ariz. The fine-grained, red to brown hematites contain small quantities of magnetite and manganese oxides. Gangue minerals included quartz, chalcedony, feldspar, and minor amounts of sericite, barite, tourmaline, and calcite. Analyses under the description of the various deposits show 0.3 to 12.7 percent manganese, 0.2 to 0.8 percent titania, 0.12 to 0.2 percent phosphorus, and 0.09 to 1.24 percent sulfur.

The composited sample was tested by flotation and wet magnetic separation on reduced ore.

Oil emulsion flotation of material, ground 75 percent through 200-mesh resulted in recovery of 70.8 percent of the iron in a concentrate containing 42.2 percent Fe and 5.8 percent SiO_2. The iron flotation concentrate, triple-cleaned, contained 8.5 percent barium as barite and 9.0 percent CaO present as calcite. These diluents could not be rejected by cleaning.

Magnetic separation was confined to material given a reduction roast. The procedure for reductive roasting is described under locality sample 9.
Wet magnetic separation tests were made on material ground through 100-, 200-, and 325-mesh. Similar results were obtained with each grind, and it was apparent that only partial liberation of the iron minerals was achieved with the grinds employed. Table 44 indicates the results obtained with the minus 100-mesh grind.

TABLE 44. - Results of reductive roasting and wet magnetic separation on a com.osite of sam.les of the hematite re.lacements west of Bouse, Yuma County, Ariz.

Products	Weight-percent	Chemical analyses, percent		Distribution, percent,
		Fe	SiO_2	Fe
Magnetic iron concentrates[1]·······	57.0	52.8	13.2	91.6
Nonmagnetic tailing	43.0	6.4	-	8.4
Calculated heads..................	100.0	32.8	-	100.0

[1]Total analysis includes 0.33 percent TiO_2, 0.05 percent P, 0.22 percent S, and 1.8 percent Mn.

Table 44 indicates that reductive roasting and wet magnetic separation of minus 100-mesh material by Davis-tube separator resulted in recovery of 91.6 percent of the iron in a concentrate containing 52.8 percent Fe and 13.2 per-cent SiO_2. The concentrate also contained 1.0 percent barium and 2.0 percent CaO. By grinding through 325-mesh, 91.7 percent of the iron was recovered in a concentrate containing 50.6 percent Fe.

Test Sample 16, Yuma County Cupreous Hematite

A composite of cupreous hematite samples was tested from the Brown Mountain-Mineral Hill-Mineral Wash area (110, 121; fig. 1), Tps 9 and 10, N, R 1 7 W .

Test sample 16 is a composite of samples from hematite replacement depos-its in Paleozoic sediments of the Mineral Hill-Mineral Wash area, Yuma County, Ariz. Dense red hematite and specularite occur with the copper oxide minerals chrysocolla, brochantite, and malachite. The sulfide chalcopyrite was identified associated with quartz, but not with any iron minerals. Gangue minerals were principally quartz, chalcedony, feldspar, sericite, and small amounts of barite, calcite, and biotite. The iron and copper minerals were relatively a coarse grained form of complex copper-iron ore.

The sample was tested by selective flotation, the copper segregation process, and wet magnetic separation.

Selective flotation, in which the copper oxides were sulfidized with sodium sulfide and then floated with sodium isopropyl xanthate and the iron minerals were floated with an emulsion of fuel oil and tall oil resulted in recovery of 68.0 percent of the copper and 69.1 percent of the iron in separate concentrates. The copper concentrate contained 22.2 percent Cu and 15.8 percent Fe. The iron concentrate contained 47.4 percent Fe, 0.55 percent Cu, 3.7 percent Ba, 7.7 percent CaO, and 8.6 percent SiO_2.

The copper segregation process was investigated as a means of improving the copper and iron recoveries obtained by selective flotation. The procedure used for copper segregation followed by flotation to recover the reduced iron is described under locality sample 8. Table 45 indicates the results of copper flotation and magnetic separation on minus 100-mesh material for recovery of artificial magnetite and shows the amount of reagents used in copper flotation.

TABLE 45. - Results of copper seregation, copper flotation, and wet magnetic separation on a composite of samples of hematite replacements in the Mineral Hill-Mineral Wash area, Yuma County, Ariz.

	Weight-percent	Chemical analyses, percent			Distribution, percent	
		Fe	Cu	SiO_2	Fe	Cu
Products:						
Copper rougher concentrate.......	10.6	23.3	18.4	21.9	9.3	85.8
Magnetic iron concentrate[1]........	45.0	50.0	.5	18.0	85.0	9.9
Nonmagnetic tailing	44.4	3.4	.22	-	5.7	4.3
Calculated heads	100.0	26.5	2.27	-	100.0	100.0

	Reagent consumption, pounds per ton	
	Grind	Copper rougher concentrate
Reagents:		
Ca0[2]	8.0	-
KAX	-	1.2
MIBC	-	.24

[1]Total analysis includes 0.28 percent TiO_2, 0.06 percent P, 0.16 percent S, and 0.2 percent Mn.
[2]Maintained pH 10.8.

Table 45 indicates that the segregation process for recovery of copper followed by wet magnetic separation for recovery of reduced iron as artificial magnetite from the copper-rougher tailing resulted in recovery of 85.8 percent of the copper and 85.0 percent of the iron. The copper-rougher concentrate contained 18.4 percent Cu, 23.3 percent Fe, and 21.9 percent SiO_2. Cleaning the copper-rougher concentrate would raise the grade to more than 30 percent, giving only a small loss in overall recovery of copper. The magnetic concentrate contained 50. 0 percent iron, 0.5 percent Cu, and 18.0 percent SiO_2. Efforts to increase the grade of the magnetic concentrate by grinding the cop-per rougher tailing to minus 325-mesh resulted in recovery of 84.9 percent of the iron in a concentrate containing 52.1 percent Fe and 15.7 percent SiO_2.

Table 46 summarizes results of the above mentioned beneficiation testing on all 16 samples selected.

Other Beneficiation Testing

Leaching tests made by the Bureau on cupreous hematite (8) from the Mineral Hill area indicate that copper in the hematite can be removed to con-form to acceptable limits as a profitable coproduct. The cupreous hematite at Mineral Hill is comparable to the many other hematites represented at New Planet, Swansea, and other places in the Buckskin Mountains area of Yuma County.

TABLE 46. - Summary of results of beneficiation testing on Arizona iron samples

Test sample No.	Locality: County	Locality: Deposit	Treatment method	Mesh size	Concentrate recovery data, percent: Recovery Fe	Recovery Cu	Chemical analyses Fe	Chemical analyses Cu	Chemical analyses SiO_2
1....	Apache..	Lyman Reservoir (Red Cap), residual hematite.	B[1]	325	87.5	-	52.8	-	18.6
2....	Cochise.	Dragoon Mountains (Black Diamond), cupreous magnetite-hematite.	C[2]	100	95.5	-	61.5	0.1	7.6
					-	86.0	21.0	10.4	17.6
3....	Gila....	Iron King taconite-semitaconite, titaniferous hematite-magnetite.	B	100	81.3	-	53.4	-	11.7
4....	do....	Pig Iron taconite-semitaconite, titaniferous hematite-magnetite.	B	325	90.4	-	53.0	-	13.2
5....	Gila-Navajo.	Bottle Spring, Dry Creek, Gentry Creek and Mesa, Nail Ranch, Apache and Split Rock locations; Young-Canyon Creek hematites.	B	200	99.2	-	60.4	-	11.6
6....	Maricopa	Big Boulder-Iron Ridge, magnetite taconite.	B	200	93.5	-	57.6	-	13.2
7....	do....	Hieroglyphic Mountains (Pikes Peak), magnetite-hematite taconite.	B	200	94.0	-	52.4	-	19.6
8....	Pinal..	Slate Mountains-Lakeshore, cupreous magnetite.	C	100	{94.5	-	63.9	.1	4.9
					-	89.0	17.0	25.6	27.2
9....	Pima....	Quijotoa Mountains, magnetite-hematite.	B	100	93.2	-	66.4	-	4.6
10....	Yavapai.	Big Buck-Three Points, Black Chief, Black Gold, Yaeger locations; Mingus Mountain, Black Hills magnetite-hematite.	B	325	92.0	-	47.6	-	26.2
11....	do....	Blue Bell mine and siding, Copper Mountain, and Mayer-Stoddard; magnetite-hematite taconite, vicinity of Mayer.	B	200	90.6	-	56.8	-	15.6
12....	do....	Los Felice magnetitic quartzite schist (taconite), vicinity Cleator-Townsend Butte.	B	325	94.5	-	52.0	-	20.0
13....	do....	Magnetite-hematite taconite, Goodwin-Blind Indian Creek-Longfellow Ridge-Ash Creek-Pine Creek areas.	A[3]	200	85.5	-	60.2	-	11.6
14....	do....	Stanton magnetite taconite..........	B	325	91.4	-	50.4	-	23.1
15....	Yuma....	Black Chief, Black Jack, Black Mule, Black Stud, and Iron Mine, hematite west of Bouse and at foothills of Plomosa Mountains.	B	100	91.6	-	52.8	-	13.2
16....	do....	Cupreous hematite, Brown Mountain, Mineral Hill, and Mineral Wash area.	C	100	85.0	-	50.0	.5	18.0
					-	85.8	23.3	18.4	21.9

[1]B = wet magnetic separation of reduction roasted ore.
[2]C = copper segregation, copper flotation, wet magnetic separation.
[3]A = wet magnetic separation of natural ore.

Leaching tests on the cupreous hematite ore of Mineral Hill (8) show that as much as 95 percent of the copper can be extracted by flood leaching minus 3/8-inch feed with a 5-percent sulfuric acid solution for a period of 2.5 days. The acid consumption was nominal, and no difficulties were encountered in percolating the leach solutions through the ore bed.

Beneficiation of Magnetitic Alluvium

Early 1956 tests on the Omega, T 8 S, R 12 E, magnetitic alluvium by the Arizona Bureau of Mines, and others, indicated that the magnetite content was low and varied widely for samples and also, that concentrations of as much as 100 to 1 could be expected. Magnetitic alluvium with analyses of 0.47 percent to 4.99 percent iron yielded concentrates containing 61.6 to 64.8 percent iron. A grab sample, collected by the Bureau, of 1959 preliminary concentrates, contained 62.8 percent iron, 2.8 percent titania, 0.30 percent manganese, 0.39 percent phosphorus, 0.36 percent sulfur, and 4.2 percent silica. These concentrates were improved so that the analysis was better than 65 per-cent iron, and Arkota Steel Corp. reported (47) that grinding their magnetite concentrate to minus 200-mesh reduced titania to less than 0.3 percent and phosphorus to 0.03 percent.

During 1962, Arkota Steel Corp. mined and concentrated material from the low grade but very large magnetitic alluvium resources in T 8 S, Rs 11 and 12 E, for raw material iron used in their reduction and smelting facilities 2 miles north of Coolidge and on the Southern Pacific Railroad. The alluvium (64), averaging 5 to 7.5 percent iron and covering many square miles, was mined experimentally by open-pit methods and beneficiated to a high-grade concentrate. At the pit the alluvium was transported by conveyor belt to a series of inch-mesh screens. The screened alluvium continued through a rougher magnetic separator. The resulting magnetite concentrate was processed through a rotary dryer. From the dryer, the rougher concentrate was processed through a second magnetic separator and an impact crusher. The crushed material was passed through three high-frequency vibrating screens, and the minus 35-mesh undersize went to a third magnetic separator in a closed circuit with an impact crusher. The final, minus 35-mesh concentrate, averaging 65 percent iron, was trucked 25 miles to a 120-ton-per-day pelletizing plant at the reduction and smelting site near Coolidge. The magnetite concentrate was then either processed to pellets for reduction as such or was dried and sent directly to the retort for use in powder metallurgy. Magnetite concentrates or pellets were reduced to sponge iron by the Madaras direct-reduction process. Later in 1962 the plant was closed.

In the Madaras process, Arkota charged 16-ton batches of hot magnetite concentrates or concentrate pellets into a gas-tight sealed retort for reduction by re-formed natural gas at 1,800° to 1,850° F. After 2 hours, reduction was completed with the formation of 10 to 11 tons of sponge iron containing 4 to 6 percent sand. The batch was then ejected for refining as either sponge or electric furnace pig iron, and the retort was prepared for another charge.

Sampling and beneficiation tests have been carried on at numerous other magnetitic alluvium deposits in Arizona. Tests on the Fred Brown (Big Horn) magnetitic alluvium deposit T 4 N, R 9 W, Maricopa County, in 1961 by Arizona Metals Co., Ralph R. Langley, president, indicated an extensive deposit containing from 3 to as much as 10 percent magnetite and minor quantities of ilmenite. Preliminary screening and magnetic concentration tests yielded concentrates containing 65 to 69 percent iron and 0.3 to 0.8 percent titania.

Tests on the Hope-Bauer-Kelly magnetitic alluvium deposit, T 4 N, R 14 W, Yuma County, by Ralph R. Langley and associates, indicated a deposit containing from 3 to 10 percent magnetite. According to Mr. Langley, preliminary screening and magnetic concentration tests yielded concentrates containing 62 to 68 percent iron and 0.9 to 1.01 percent titania.

Tests on the Santa Margarita District magnetitic alluvium, Tps 8, 9, and 10 N, Rs 5 and 6 W, in Yavapai Country in 1961 by Magnet Mining Corp., Melvin H. Jones, president, indicated large areas containing 1.7 to 10.9 percent magnetite by weight, averaging 5.5 percent magnetite. Preliminary screening and magnetic separation tests yielded concentrates containing from 60.7 to 70 per-cent iron; 0.05 percent titania, 0.5 percent manganese, 0.24 percent phosphorus, and 11.20 percent silica.

Nonferrous Metallurgical Slags

Metallurgical slags in Arizona may some day be a source of large quantities of iron. The slags, containing about 30 to 50 percent iron, with some copper, zinc, and other elements are estimated as approaching an aggregate 100 million tons.

The first industrial-scale research on the reduction of iron oxides from slag by natural re-formed gas (5, 53) was by United Verde Copper Co., at Clarkdale in 1931. Iron in the granulated slag was 95 percent reduced to metal and was melted in an electric furnace. Steel produced, containing 0.75 to 1.5 percent copper, was satisfactorily forged and rolled. Results showed the feasibility of producing sponge iron from ferrous oxide slag.

Small-scale research, underway for several years at the Salt Lake City Metallurgical Research Center of the Bureau, has shown that about 90 percent of the iron in typical copper reverberatory slags can be recovered as an iron alloy by electric-furnace smelting. Limestone is used as flux, and coke or coal is used as the reductant. The metal produced will contain about 92 per-cent iron, 4 to 5 percent carbon, 1 to 3 percent silicon, and about 1 percent copper. The sulfur and phosphorus contents will depend on how much of these elements is present in the slag, the limestone, and carbonaceous reductant used. Bureau work also has shown that this high-carbon alloy can be readily converted to high-copper steel.

Smelting research by the Bureau has demonstrated the feasibility, and simplicity of decopperizing typical reverberatory slags by remelting with either limestone, pyrite and coke, or gypsum and coke. The reconstituted and decopperized slag, containing less than 0.1 percent copper, can be smelted with additional coke to produce cast iron of sufficiently low copper content for direct use or refining into steel.

At its Douglas Copper smelter, Phelps Dodge Corp. is operating a sponge-iron production plant, having a capacity of 25 tons per day. Sponge-iron, containing 65- to 75-percent iron, is produced from process converter slag. The sponge-iron replaces scrap iron in copper leaching operations.

Considerable research has been done by Gulf States Land and Industries, Inc. , on recovery of iron from copper slags at Clarkdale.

Sponge-Iron From Pyrite

The only operation that has produced metallic iron from Arizona minerals other than that of Phelps Dodge Corp., and the now idle Arkota Steel Corp., is the sponge-iron plant of Kennecott Copper Corp having a capacity of 39 to 42 tons per day. The plant uses pyrite and pyrite concentrates as a source of sponge iron and $S0_2$ gas. The latter is used as a source of sulfuric acid. Both the resulting sponge iron and sulfuric acid are necessary to the success of the Leach-Precipitation-Flotation (LPF) milling process.

Cupreous iron pyrite flotation concentrate--containing 34 to 46 percent iron, 1 to 1.7 percent copper, and 4 to 20 percent insolubles from the Hayden mill--are thickened to 70 percent solids and transferred to a fluid-bed reactor. The reactor develops SO_2 gas and a hematite calcine. The hematite calcine, coal, flue dust, and coke are fed to Bruckner-type rotary kilns at 1,500° to 1,800° F. Reduction to sponge iron takes place below the melting point of the charge. The hot sponge iron is discharged in a reducing atmosphere and cooled in gas-tight, Baker-type coolers. The cooled sponge iron, containing 35 to 50 percent iron, is comminuted to minus 28-mesh and is used in the LPF process (46, pp. 33-36).

ASSOCIATIVE RESOURCES

Raw materials other than iron ore and sources of energy are important considerations in the future developments of Arizona iron resources. The most important are the fluxes, limestone and dolomite, and the sources of energy, coal, petroleum, natural gas, electricity, and water. General information on each is presented.

Limestone and Dolomite

Limestone and dolomite resources, although not classified as reserves of determined quality, crop out as many Mesozoic, Paleozoic, and Proterozoic formations along the mountain ranges and canyons throughout Arizona. The rocks range in quality from pure calcite and dolomite to many impure varieties. They present a wide variety of physical and chemical characteristics. The highest quality limestones appear to be limited to the Mississippian Escabrosa and Redwall formations of northwest and southeast Arizona; however, good lime-stones and dolomites can generally be found in almost every county. Detailed chemical studies of these rocks have not been made; however, the following table 47 gives an idea of their quality.

TABLE 47. - Chemical analyses, Arizona limestones and dolomites

Geologic and geographic location	Analyses, percent CaO	MgO	SiO_2	Al_2O_3-Fe_2O_3
Mesozoic, Jurassic-Triassic:		0.3		
Glen Canyon group: Navajo sandstone (34), limestone lenses, 2 miles southwest of Kayenta, Coconino County, 16 samples.	45.7 to 55.3	to 1.3	-	-
Navajo sandstone (34), limestone lenses:	42.0	1.0		
12 miles east of Cameron			-	-
Tuba City	33.0	9.0	-	-
13 miles south of Kaibito	40.0	1.2	-	-
Cow Springs, 2 analyses	48.0	-		-
	41.5	1.0	-	-
Paleozoic:	(18.9	13.2	34.1	1.6
Permian: Kaibab limestone (23; 48), Grand Canyon area,	27.0	32.0	17.0	1.0
Coconino County, 4 analyses.	30.0	18.7	7.0	-
	48.7	-	11.1	.7
Carboniferous:	54.91		1.36	
Tornado limestone (57), Pinal County		.21		.22
Modoc limestone, Shannon and Modoc Mountains (41), Greenlee County,	46.2 to 53.5	.3 to 4.6	1.0 to 1.34	.92 to 2.70
Escabrosa limestone (56), Cochise County	55.80	.13	.06	.24
Naco limestone (56), Cochise County	53.68	.46	2.52	.24
Devonian:	31.65	18.65	3.11	1.55
Martin limestone (56), Pinal County				
Martin limestone (57), Cochise County	50.07	.55	8.52	.64
Morenci limestone (40), Greenlee County	46.8	.9	6.4	5.7
Ordovician: Longfellow limestone (41), Greenlee County, 27 analyses.	21.9 to 50.8	.7 to 11.0	4.7 to 30.0	.4 to 8.3
Cambrian:..	45.86	.48	11.80	3.23
Abrigo limestone (54), Cochise County..................	27.28	17.41	12.53	2.30
Paleozoic, undivided (4), Yuma County:	52.57		41.75	
Battleship Mountain limestone		.23		-
Planet limestone	44.63	2.11	36.98	-
Planet limestone flux	34.15	2.99	30.00	-
Redwall limestone (Mississipian) Grand Canyon area,	32.54	19.52	.82	.40
Coconino County, lower 80 ft (48).	55.50	.08	.48	.10
Temple Butte limestone (Devonian) (48), 75 ft thick,	22.95	15.01	24.41	1.83
Coconino County.	30.1	20.8	1.5	
Muav limestone (48) (Cambrian) Coconino County, upper 60				.80
ft.	54.1		1.4	1.3
Paleozoic, undivided (18):				
Gray limestone at San Carlos, Pinal and Gila Counties ...		-		
Pink dolomite, San Carlos damsite abutments and bluffs...	31.3	14.9	3.7	6.0
Blue limestone, Riverside damsite	52.1	-	4.7	1.4
Blue limestone, Queen Creek	50.5	-	4.1	5.8
Gray limestone, Queen Creek	31.1	-	34.6	1.3
Precambrian:	21.9	14.9	29.93	
Mescal limestone, Mescal Mountains, Pinal County (54, 57).				.42

(4, p. 27; 18, p. 378; 23, p. 39; 34, vol. 2, pp. 12-13, 21; 41; 40; 48; 54; pp. 139, 145; 56, p. 55; 57, pp. 6, 7, 9).

Table 48 lists the principal limestone-dolomite formations in the State. While little is known of their quality or the distribution of limestone or dolomite deposits of optimum quality, they are the basis of an enormous resource potential. Any new or projected industrial development using limestone and/or dolomite would of course explore these formations further to see if raw material would meet its particular specifications. Inspection of table 48 indicates that counties containing major iron occurrences also contain limestone and/or dolomite either within their borders or in adjacent counties.

TABLE 48. - Principal limestone-dolomite formations in Arizona

Formations	County	Approximate thickness, feet	Location	Reference
Limestones:				
Some scattered Permian.	Apache......	-	-	(16).
Horquila	Cochise......	2,115	Pedregosa Mountains...	(76).
Mural	do.........	500-700.....	Mule Mountains	(16; 54, 56 57; 76).
Abrigo	do.........	770.........	Bisbee and Gold Hills region.	(16, 76).
Escabrosa	do.........	600-800.....	do	Do.
Martin	do.........	340.........	do	Do.
Naco	do.........	1,500-3,000...	do	Do.
Concha	do.........	129	Gunnison Hills	(76).
Abrigo	do.........	844.........	Tombstone District....	(16; 76).
Martin	do.........	230.........	do	Do.
Escabrosa	do.........	786.........	do	Do.
Horquila............	do.........	1,000.........	do.........	Do.
Naco	do.........	Several hundred feet.	do	Do.
Dolomite:............ Epitaph.	do.........	783.........	do	Do.
Limestones:				
Colina	do.........	635.........	do...........	Do.
Abrigo	do.........	800.........	Dragoon Mountains.....	Do.
Escabrosa	do.........	729.........	do	Do.
Naco	do.........	Several hundred feet.	do...........	Do.
Martin	do.........	270.........	do	Do.
Black Prince.........	do.........	168.........	do	Do.
Carboniferous and Devonian.	do.........	-	Courtland	Do.
Abrigo	do.........	248.........	Dos Cabezas-Chiricahua Mountains.	Do.
Concha	do.........	730.........	do	Do.
Escabrosa	do.........	730.........	do	Do.
Martin	do	342.........	do	Do.
Colina	do.........	535.........	do...........	Do.
Horquila............	do.........	1,600.........	do	Do.
Abrigo	do.........	749	Whetstone Mountains...	Do.
Escabrosa	do.........	749.........	do...........	Do.
Martin	do.........	-	do	Do.
Naco	do.........	-	do...........	Do.
Horquila............	do.........	1,400.........	do	Do.
Upper Cambrian.......	do.........	435.........	Swisshelm Mountains...	(76).
Martin	do.........	615.........	do	Do.
Kaibab	Coconino.....	200-500	Covers half of county.	(16; 23; 48; 76).

TABLE 48. - Principal limestone-dolomite formations in Arizona (Con.)

Formations	County	Approximate thickness, feet	Location	Reference
Limestones:				
....	Coconino... (Con.)	400-1,000....	Cottonwood-Chinle tanks to Lee Ferry, Marble Hill, Ryan, Big Spring.	(16; 54; 76).
Bass	do......	335	South of Colorado River.	(16; 76).
Sandstone-limestone members:........... Navajo.	do......	-	Vicinity Kayenta, Tuba City, Cow Springs.	(34).
Limestones:				
Temple Butte	do......	0-100	Grand Canyon area ..	(16; 48; 76).
Muav	do......	400-475....	do	Do.
Escabrosa	Gila.......	550........	Christmas area......	-
Tornado	do.......	-	do	(16).
Martin	do......	-	Pinal Mountains.....	Do.
Carboniferous and Devonian, Redwall.	do.......	40	Along northern boundary of county between Naegelin and Pine.	Do.
Martin	do.......	325........	Mescal Mountains....	Do.
Tornado	do	1,000........	do	Do.
Mescal	do	225........	do	Do.
Martin	do	390	Mazatzal Mountains East Verde River.	(76).
Escabrosa	do.......	552	Dripping Spring Mountains.	(16; 76).
Martin	do.......	340........	-	-
Tornado	do.......	-	-	-
Martin	do.......	325	Miami-Globe district, and Pinal Mountains.	(16).
Tornado	do.......	1,000........	-	-
Abrigo	Graham.....	-	Northwest Gila Mountains and vicinity of Stanley Butte.	(16).
Martin	do.......	-	-	-
Tornado	do.......	-	-	-
Longfellow........	Greenlee...	200-400....	Clifton-Morenci district.	(16; Al; 40; 76).
Modoc	do	180........	-	Do.
Tule Spring.......	do.......	500........	-	Do.
Morenci	do.......	-	-	Do.
Martin	Maricopa...	300-450....	Vicinity of Roosevelt Dam and Cave Creek area.	(16; 76).
Redwall	do.......	175-300....	Roosevelt Dam, Black River, Salt River.	(76).
Kaibab	Mohave.....	500±	Northern half of county, Shivwits, Unkaret, and Kanab plateaus.	(16; 76).
Do	do.......	400-500.....	Grand Wash Cliffs, Virgin and Beaver Dam Mountains.	Do.
Pogonip	do.......	216.........	do.........	Do.
Muddy Peak........	do.......	550.........	do	Do.

TABLE 48. - Principal limestone-dolomite formations in Arizona (Con.)

Formations	County	Approximate thickness, feet	Location	Reference
Limestones:				
Redwall	Mohave .... (Con.)	-	Grand Wash Cliffs, Virgin and Beaver Dam Mountains.	(16).
Callville.........	do.....	-	Tps 27-31 N, Rs 10-15W	Do.
Kaibab	Navajo....	1-80.....	Between Hobson, Holbrook, and Heber.	(16; 76).
Martin	do.....	89	Oak Creek, SW part of county.	Do.
Supai	do.....	8-75	Vicinity of Cebecue, SW part of county.	Do.
Redwall	do.....	250.........	do.........	Do.
Abrigo	Pima and Santa Cruz	640.........	Tucson Mountains......	Do.
Martin	do.....	350.........	do	Do.
Escabrosa..........	do.....	600.........	do	Do.
Abrigo	do......	800	Santa Rita Mountains..	Do.
Do	do......	718.........	Waterman Mountains....	(76).
Martin	do.....	385.........	do.........	Do.
Concha	do......	510.........	Patagonia Mountains...	(16; 76).
Abrigo	do......	750.........	Santa Catalina Mountains.	Do.
Do	do......	300.........	Picacho, 16 miles NW of Tucson.	(16).
Carboniferous and Devonian.	do......	+400.........	Quijotoa Mountains, Brownell Mountains, and Sierra Blanca.	Do.
Martin	do......	440.........	Sierrita Mountains....	(16; 76).
Escabrosa	do......	550.........	do	
Martin	do......	300.........	Empire Mountains	(76).
Escabrosa..........	do......	600.........	do.........	Do.
Abrigo	do......	800.........	Growler Mountains.....	Do.
Naco group.........	do......	250.........	do.........	Do.
Abrigo	Pinal.....	195	Vekol Mountains	(16; 76).
Escabrosa	do......	435.........	do	Do.
Martin	do......	200.........	do.........	Do.
Naco	do......	360.........	do.........	Do.
Horquila	do......	520.........	do	Do.
Martin	do......	-	Mescal Mountains	(16; 54; 56; 57; 76).
Mescal	do......	-	do.........	-
Tornado	do......	-	do.........	-
Abrigo	do......	520	Slate Mountains	(16; 57; 76).
Martin	do......	-	do	-
Tornado	do......	-	do	-
Martin	do......	354.........	Superior region.......	(16; 76).
Tornado	do......	1,000.........	do.........	
Do	do......	-	Tortilla Range........	(16).
Martin	Yavapai...	465.........	Jerome district	(16; 76).
Redwall	do......	286.........	Extensively exposed along north boundary of County in Juniper Mountains, Black Mesa, and Clarkdale-Jerome areas.	(16).

TABLE 48. - Principal limestone-dolomite formations in Arizona (Con.)

Formations	County	Approximate thickness, feet	Location	Reference
Limestones:				
Kaibab	Yavapai (Con.).	-	T 18 N, Rs 3 and 5 E	(16; 76).
Limestones, dolomites, and marbles: Paleozoic.	Yuma......	-	Plomosa Mountains ...	(16).
Do	do.......	-	Buckskin Mountains....	(4; 16).
Do	do.......	-	Brown Mountains	(16).
Limestones:				
Martin	do	180-500	Harquahala Mountains at Martin Peak.	Do.
Do	do.......	-	Harcuvar Mountains....	Do.

Coal

Coal reserves in Arizona reportedly are large, and enormous reserves of coal are available in the neighboring States of New Mexico and Utah.

Coal (fig. 58) is prominent in several areas of Cretaceous rocks in eastern Arizona, as follows:

Black Mesa field:

The largest coal-bearing area (fig. 58), known as the Black Mesa field, comprises about 3,550 square miles in northern Apache, Navajo, and Coconino Counties. The coal-bearing formations are in the Cretaceous Dakota sandstone and Mesaverde group. The coals in the Dakota formation are classed as subbituminous B; on a natural basis its calorific value is between 7,700 to 9,000 Btu; moisture and ash free, the calorific value is between 10,200 and 11,100 Btu. The coal contains about 1.5 percent sulfur. Coal in the Mesaverde has a natural calorific value between 10,000 and 12,000 Btu; moisture and ash free, the calorific value is between 12,880 and 13,720 Btu. Sulfur ranges from 0.5 to 1.2 percent. Reserves are inferred at 8 billion to 2 billion tons (12, pp. 229-238; 34, pp. 50-63; 49, p. 8).

Pinedale-Showlow field:

South, in the vicinity of Pinedale and Showlow (fig. 58) in southern Navajo County, coal is prominent in Tps 10 and 11 N, Rs 18 and 19 E. Coal was noted also in T 7 N, R 23 E, in the southeast part of the Pinedale-Showlow coalfield, Navajo County, figure 58 (49, p. 8; 71, pp. 239-242).

Fossil Creek coal:

Coal was noted in Pennsylvanian Supai red beds in the Fossil Creek area of northwestern Gila County, approximately in T 12 N, Rs 7 and 8 E (fig. 58). The extent of the coal was indeterminate.

Deer Creek-Ash Creek coal:

Coal occurs also in the Deer Creek-Ash Creek area, approximately in T 4 S, Rs 16, 17, and 18 E, in Pinal County, between Christmas and Stanley (fig. 58). Reportedly these coals contain 35 to 54 percent ash, 27 percent fixed carbon, 37 percent volatile matter, and 2 percent moisture. The coalfield is about 3 miles wide and 10 miles long. Reserves are inferred as 30 million tons recoverable (11; 49; p. 8).

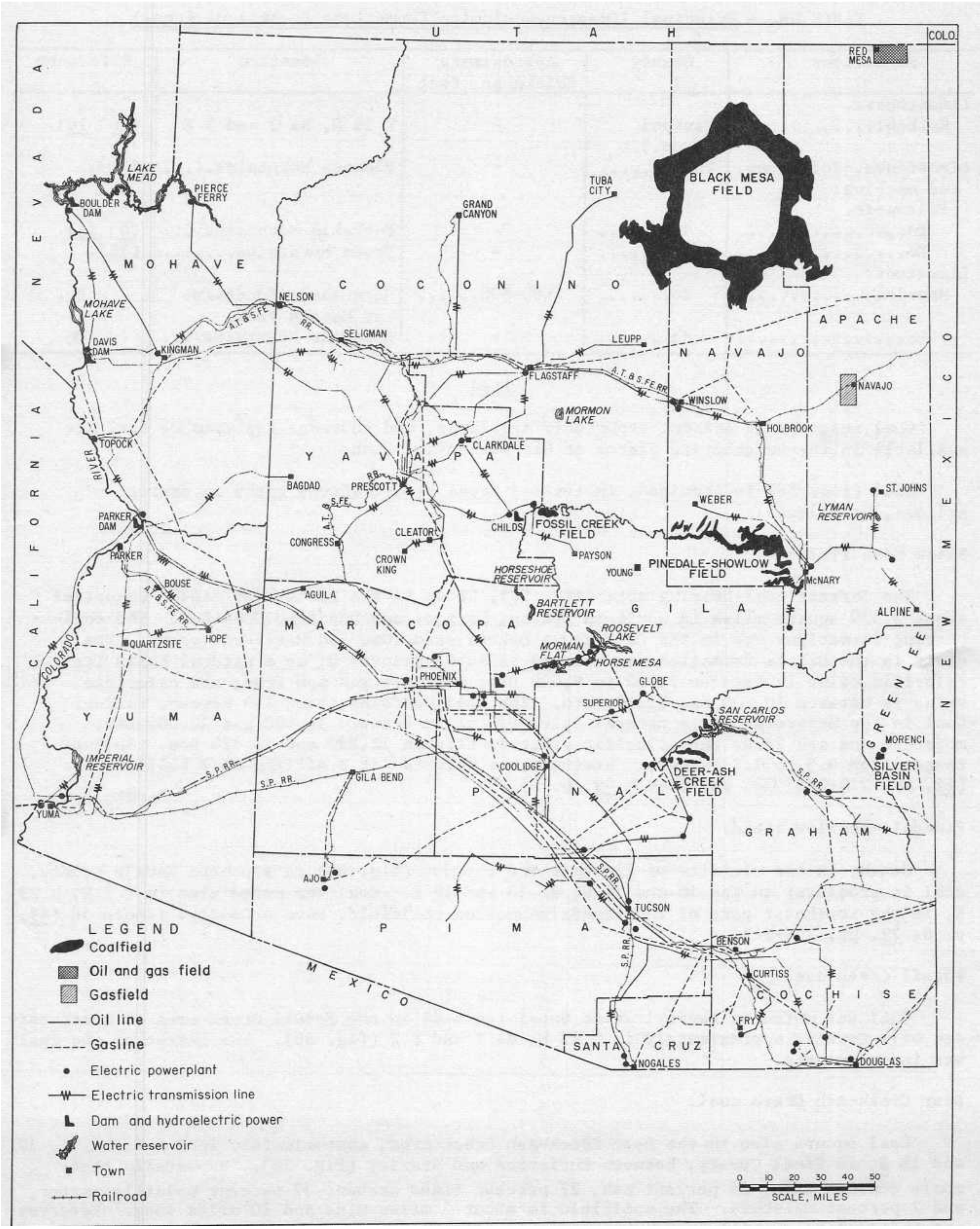

FIGURE 58. - Energy Sources in Arizona.

Silver Basin coal:

Coal is reported in the Cretaceous Pinkard formation 2.5 miles south of Morenci, along a tributary to Silver Basin Creek, approximately in T 4 S, R 29 E, Greenlee County (40, p. 13).

Coal from the Pinedale-Showlow field was investigated by the Bureau in 1945 as a reductant of iron oxides to metallic iron in the sponge-iron state (31), using hematite iron ore from the Fort Apache Indian Reservation. Preliminary tests indicated that Arizona coals would be a satisfactory reductant.

The relation of the many iron occurrences in Arizona to the State coalfields is shown by comparing figures 1 and 58. The four major iron resources are (1) the Apache Indian Reservation-Young area hematite-magnetite in Navajo and Gila Counties; (2) the Pig Iron-Iron King titaniferous hematite-magnetite taconite and semitaconite of the Sierra Anche in Gila County; (3) the magnetite-hematite taconite of Maricopa and Yavapai Counties, centering around Cleator; and (4) the hematite and cupreous hematite occurrences in the Buck-skin Mountains of Northern Yuma County. Table 49 gives the approximate distance and direction of the iron occurrences from the various coalfields.

TABLE 49. - Distance of major Arizona iron occurrences from State coalfields

No.	Iron resource area	Distance from major coalfields			
		Black Mesa	Pinedale-Showlow	Deer Creek-Ash Creek	Fossil Creek
1	Apache Indian Reservation-Young, hematite-magnetite area, Navajo and Gila Counties.	130 miles S.	30-50 miles SW.	100 miles N.	50 miles SE.
2	Pig Iron-Iron King, titaniferous hematite-magnetite taconite-semitaconite, Sierra Ancha, Gila County.	135 miles SSW.	30-80 miles W.	80 miles NW.	40 miles SE.
3	Maricopa and Yavapai Counties, magnetite-hematite taconites, centering around Cleator.	150 miles SW.	100-150 miles W.	130 miles NW.	50 miles W.
4	Northern Yuma County-Buckskin Mountains, hematite and cupreous hematite.	(1)	(1)	(1)	(1)

[1]Arizona coalfields are several hundred miles distant.

Petroleum and Natural Gas

Petroleum, natural gas, and natural gas liquids are important sources of energy in Arizona; however, the bulk of these is piped into the State (fig. 58). Discovery of oil and gas as of 1960 was limited to the Red Mesa area, T 41 N, Rs 28, 29, 30, and 31 E, in the northeast corner of Apache County and to gas only in Tps 19 and 20 N, R 26 E, in the center of Apache County.

The nearest refineries for Arizona crude oil are in northwestern New Mexico. Pipelines in the State distribute natural gas and refined oil products and are part of a transcontinental transport network.

The relation of the many iron occurrences in Arizona to the State oil and gas lines is shown by comparing figures 1 and 58. While oil and gas lines form a great network connecting and serving the major use areas of the present within Arizona, their use as suppliers of heat energy for iron resource developments would require installation of long auxiliary lines to iron resources and iron and steel developments. This is particularly so since large industrial requirements demand noninterruptible service. At present the nearest oil line is at Phoenix, about 50 to 100 miles from major iron resources. The nearest gasline to the hematite occurrences in the Apache Indian Reservation-Young area and the Pig-Iron Iron-King titaniferous hematite-magnetite in the Sierra Ancha in Navajo and Gila Counties is at Globe about 50 miles south. Another line passes through Flagstaff, Winslow, and Holbrook 90 to 120 miles north. A gasline is available to the northern Yuma County hematite and cupreous hematite area in the vicinity of Hope, House, and Parker.

Oil and gas requirements for large scale developments in the future iron industry of Arizona appear largely dependent upon sources outside the State--probably from New Mexico, Texas, and California.

Power

Arizona is served by a well distributed network of hydroelectric and steam-electric power generating plants and transmission lines, suited to handle increasing demands for electrical energy by urban, rural, industrial, mining, and metallurgical centers (fig. 58).

As of December 31, 1960, total installed electric generating capacity in Arizona was 2,482,000 kw distributed as 1,502,000 kw to fuel type plants and 980,000 kw to hydroelectric plants. Capacity of electric utility companies in the State totaled 2,265,000 kw.[8] Additional capacities were projected to 1965[9] as 671,000 kw for fuel type plants and 448,000 kw for hydroelectric plants (Glen Canyon).

The relation of many iron occurrences in Arizona to the State network of electric energy transmission lines is shown by comparing figures 1 and 58. Of course, power transmission lines would need to be extended to the sites of the various iron occurrences, depending on the magnitude and the operations developed. In general, electric energy lines (fig. 58) are now about 40 to 60 miles north, east, and west from the Apache Indian Reservation-Young

[8]U.S. Bureau of the Census. Statistical Abstract of the United States. 83d Ann. Ed., 1962, pp. 531-534.

[9]National Coal Association. Steam-Electric Plant Factors. 12th Ed. 1961, pp. 28-29 (tables 5 and 6).

hematite-magnetite area of Navajo and Gila Counties and about 50 miles south (Globe area) of the Pig Iron-Iron King titaniferous hematite-magnetite taconite-semitaconite area in the Sierra Ancha of Gila County. The magnetite-hematite taconite area of Maricopa and Yavapai Counties is within short distances to 30 miles of established electric energy lines at Prescott, Clarkdale, Cleator, Mayer, and Phoenix-Wickenburg. Electric energy is readily available (figs. 1 and 58) from nearby lines traversing the vicinity of the hematite and cupreous hematite area of northern Yuma County in the vicinity of Quartzsite, Bouse, and Parker.

Water

Arizona water consumption (evaporation or incorporation in a product) like those of its neighbors has been increasing tremendously as has its population. In the lower Colorado River Basin, comprising Arizona and parts of New Mexico, Utah, Nevada, and California, water consumption by the mineral industry has been estimated to increase from about 130,000 acre-feet in 1960 to over 320,000 acre-feet by the year 2000. The Arizona mineral industry uses twice as much new water as it consumes. The Arizona water supply is essentially derived from its dam-formed lakes and reservoirs and from deep wells. Arizona has drawn heavily on its aquifers and ground water basins in populous areas--exceeding natural replenishment by more than 2 million acre-feet annually.

Development of additional water supplies to keep abreast of increasing demands of the State include the Salt River development in Maricopa County; the Gila River development in Pinal and Graham Counties; the Aqua Fria River development in Maricopa-Gila Counties; and the Little Colorado-Colorado River developments, present and future, in Coconino and Mohave Counties and along the California-Arizona boundaries of Mohave and Yuma Counties. Present sup-plies appear adequate, however, if optimistic growth projections for the future are realized, water requirements of the State will be of increasing concern. Of course, present water supplies can be extended by reclaiming and reusing waste waters. This is common practice at taconite operations where as much as 95 percent of the process water is continually reclaimed.

Water requirements, of necessity, would vary depending mainly on the type and size of beneficiation facilities. However, since the trend is towards increasingly higher iron content of concentrates used as blast furnace feeds, all ores or iron-rich materials will probably require beneficiation in the future.

Firm estimates of water requirements are presently impossible; however, in Minnesota, Erie Mining Co.[10] uses about 16,000 gpm per million annual tons of pelletized-concentrate plant capacity in their concentrator, and Reserve Mining Co.[11] uses about 28,000 gpm per million annual tons of total plant capacity of pelletized concentrates.

[10]Thompte, W. L., H. P. Whaley, and F. P. Morawski. The Story of Erie Mining Company. Min. Eng., v. 15, No. 5, May 1963, pp. 39-54.

[12]Engineering and Mining Journal. Reserve's New Taconite Project. V. 157, No. 12, December 1956, pp. 75-102.

As Arizona and surrounding States increase in population and industrial developments, it is possible that waters now used for agricultural purposes may be diverted to urban and industrial use. A new industry may also acquire water rights or privileges in the less-populated and isolated areas that are the location of iron oxide resources.

The water supply problem has been of concern to Arizona and all its neighbors, and studies towards its solution are in progress by the U.S. Department of the Interior and the Corps of Engineers. Water resource development studies by various agencies of the States and the Federal Government are now in progress to alleviate this problem.

Under present conditions water necessary for iron industry developments in the vicinity of the major resource locations would have to be purchased or developed in the various local watersheds, streams, and aquifers and transported to use sites. In the Apache Indian Reservation--Young hematite-magnetite area of Navajo and Gila Counties, water developments would probably be in the Canyon, Oak, Cherry, and Tonto Creek drainages. In the Pig Iron-Iron King-Sierra Ancha, titaniferous hematite-magnetite taconite-semitaconite area, water supplies might be developed in the Spring and Tonto Creeks drain-ages. In the magnetite-taconite area of Maricopa and Yavapai Counties, process waters might be obtainable from the Aqua Fria River drainage and the Lake Pleasant Reservoir. Water from the Bill Williams River, Parker Dam, and wells in the area might be obtainable for a local operation in the hematite-cupreous hematite area in the Buckskin Mountains of Northern Yuma County.

Water for many Arizona mining and mineral-concentrating operations, is pumped long distances; most operations reuse the water. The cost of water for large operations in Arizona has been partly estimated to be (35, 36) from $0.04 to $0.60 per thousand gallons for new water and $0.036 per thousand gallons for reclaimed water. The Arizona Department of Mineral Resources has published partial costs of water for the State copper industry (35, 36, 37). A recent publication on Arizona water by Gilkey and Beckman[12] is recommended for additional background.

IRON RESOURCE DEVELOPMENT, ECONOMIC BACKGROUND

Arizona Population and Employment

Arizona has a population of 1,302,160 according to the 1960 census. Projections have raised it to 2 million by 1970, 3 million by 1980,[13] and 3.859 million by 2000.[14]. More optimistic projections report a potential of about 10 million people for Arizona by the 2020.[15] This appears to be an attractive

[12]Gilkey, M. M., and Robert T. Beckman. Water Requirements and Uses in Arizona Mineral Industries. BuMines Inf. Circ. 8162, 1963, 97 pp.

[13]Valley National Bank, Phoenix, Arizona Statistical Review. 17th Ann. Rev., September 1961, p. 5.

[14]Bureau of Labor Statistics; Outdoor Recreation Resources Review Commission. Study. Rept. 23, 1965, p. 6 (table A-2).

[15]Based on data from State and local government agencies, banks, telephone company, and consultants.

market for a wide range of materials and products, since development of markets in the West is a contingent function of population expansion. Table 50 gives the distribution of employment among the population of Arizona.

TABLE 50. - Wage and salary employment in Arizona, April 1961[1]

Industry	Employment	Employment percentage	
		Total nonagricultural	Total employment
Manufacturing	49,900	12.0	11.0
Mining and quarrying	15,300	3.8	3.4
Contract construction	32,800	8.0	7.3
Transportation, communications, and public utilities	24,200	6.2	5.4
Wholesale-retail trade	83,700	20.7	18.6
Finance, insurance, real estate	16,500	4.1	3.7
Service	49,800	12.3	11.0
Miscellaneous (proprietors and unpaid family and domestic workers)	61,100	15.1	13.6
Government (nonmilitary)	72,100	17.8	16.0
Agricultural	44,800	-	10.0
Total employment	449,700	100.0	100.0
Total nonagricultural and nonmilitary employment	404,900	-	-
Total population (1961 estimate)	1,374,000	-	-

[1]Basic economic data. Employment Security Comm. Ariz. August 1961, p. 5.

The distribution indicates that wholesale and retail trade (18.6 percent) and government (16.0 percent) are the largest employers in Arizona. Transportation, communications and utilities; finance, insurance, and real estate; and service and miscellaneous account for 33.7 percent. In contrast, manufacturing employs only 11.0 percent and mining and contract construction engage 10.7 percent of the total employed. Of 449,700 people employed as of April 1961, mining and manufacturing accounted for only 14.4 percent.

Population growth to the present, while phenomenal in percentage, appears insufficient to sustain a strong industrial base. This will undoubtedly change in the long-range.

Status of Arizona Iron and Steel Industry

While Arizona has about 10 foundries and many small fabricated structural steel, plate, and sheet metal shops distributed through the State it has no large iron-ore smelting and steelmaking industry. These firms secure their material requirements from steel plants in California, Colorado, Texas, Utah, and the East and will continue to do so until local operations become more competitive. Arizona is estimated to consume more than 300,000 tons of iron and steel annually, most originates outside the State. Comparison of figures 1 and 2 illustrates the relation of Arizona iron occurrences to the established iron smelting industry of the West. Figure 2 shows the location of blast furnaces in Western United States and from this illustration it should be noted that Arizona is part of a great area, having established and vertically integrated iron and steel complexes that will influence the raw materials market potential of the State, jointly and severally.

As late as 1962, natural iron oxides, basis of the iron and steel industry, found little use in the raw materials economy of Arizona--production totaling only a few thousand tons. Before 1962, iron ore mined in Arizona had been high of quality and very small in tonnage and for specialized and sporadic markets other than those for metallic iron.

An idea of the minor importance of local iron ore in the economy is shown by the terminations of class 1 railroads within Arizona during 1952-60, table 51.

TABLE 51. - Iron ore terminations class 1 railroads in Arizona, 1952-60

Year	Tons	Year	Tons
1952..........	5,042	1957...........	335
1953..........	1,933	1958...........	729
1954..........	4,291	1959...........	395
1955..........	6,843	1960	342
1956..........	3,554		

Table 52 shows the tonnage of iron and steel products terminated in Arizona by class 1 railroads during 1953-60. Although these data can include products that are terminated on one line and transshipped by rail to another State, the tonnage of transshipped goods should be comparatively small, less than 10 percent. Data on the tonnages of iron and steel products shipped to Arizona consumers by truck were more complete for 1956 than for previous years. Table 53 gives these data as a composite comparison; this can be assumed as a comparative percentage for estimates of total iron and steel entering the State.

Terminations of pig iron and steel billets, bloom, and ingots are small; the limited foundry and other metal processing and forming industries and the abundance of scrap metal, restricting the consumption of these materials. From table 52 it should be noted that manufactured iron and steel, pipe and fittings, nails, and wire account for the bulk of iron and steel products terminated in Arizona. Tables 52 and 53 indicate a present annual market for about 300,000 tons of iron and steel products. This will of course be greatly increased if projections for the future are realized. To be successful, any large scale developments of the potentially enormous iron resources of Arizona cannot be limited to the State raw-material requirements but must be directed toward the iron and steel industry of the entire Western United States in competition with all other Western sources and imports. Export markets may be developed also, as witness exports of Nevada and California iron ores to Japan.

TABLE 52. - Iron and steel products terminated in Arizona by class 1 railroads 1953-60, in short tons[1]

Commodity group or class	1953	1954	1955	1956	1957	1958	1959	1960
Pig iron............	57	56	59	108	131	52	142	-
Iron and steel billet, bloom, and ingot	-	50	-	-	-	-	94	43
Iron and steel, bar, rod, and slab......	1,081	331	923	670	26	494	1,224	430
Iron and steel, n.o.s	63	-	77	8	7	6	455	952
Iron and steel, nails and wire, woven and unwoven, n.o.s	11,488	11,691	13,600	14,795	12,622	12,019	14,677	14,438
Manufactured iron and steel	80,820	79,846	86,076	94,651	114,655	62,845	99,744	99,112
Iron and steel pipe and fittings, n.o.s	29,815	21,085	58,556	91,761	151,652	31,457	83,056	31,022
Total...........	123,324	113,059	159,291	201,933	279,093	106,873	199,392	145,997

[1]Data from annual reports of class 1 railroads to State Public Utilities Agencies. These data represent waybill rather than shipment destination and should be interpreted according to waybill practices. For example, when traffic is rebilled at an intermediate point, there will be a waybill terminated at that point, and another waybill will originate there--even though the shipment is a through one.

TABLE 53. - Shipments of steel products to Arizona in 1956 by railroads and motor freight

	Tons	Percent
Carrier:		
Class 1 railroads	201,993	75
Common carrier motor freight	68,652	25
Total	270,645	100

Western United States Trade Area

For the purpose of this publication, the Western United States trade area is assumed as all states west of the Mississippi River.

Population and Gross National Product

Population and Gross National Product (GNP) are probably the most important generalized clues to the future consumption of iron ores, iron, and steel in Western United States. Increases in future consumption of iron ore, iron, and steel depend on large increases in population, GNP, and industrialization. Historically projections of National and Western population and GNP have been a continual rise. Projections into the future (table 54), based on the past, indicate that population in Western United States is expected to more than double by the year 2000 and (table 55), will rise from $482.1 billion in 1959 and $1,018.4 billion by 1976 to $2,007.0 billion in the year 2000.

TABLE 54. - Population projections for Western United States,[1] 1960 to 2000,[2] in thousands

Locations	Actual	Projections[3] [4]	
	1960	1976	2000
Iowa	2,758	3,266	4,514
Missouri	4,320	5,003	7,015
North Dakota	632	695	890
South Dakota	681	796	1,083
Nebraska	1,411	1,719	2,368
Kansas	2,179	2,592	3,727
Arkansas	1,786	1,406	1,469
Louisiana	3,257	4,114	6,204
Oklahoma	2,328	2,341	2,874
Texas	9,580	13,281	20,730
Montana	675	908	1,351
Idaho	667	828	1,221
Wyoming	330	393	578
Colorado	1,754	2,580	4,101
New Mexico	951	1,255	2,084
Arizona	1,302	2,144	3,859
Utah	891	1,297	2,116
Nevada	285	523	929
Washington	2,853	3,844	6,224
Oregon	1,769	2,415	3,920
California	15,717	23,744	41,272
Totals:			
Western United States	56,126	75,144	118,529
All United States	179,323	230,019	350,477

[1]-Western United States is assumed to be all states west of the Mississippi River.
[2]National Planning Association, Bureau Labor Statistics, U.S. Dept. of Labor. Outdoor Recreation Resources Review Commission Study Report 23, 1965.
[3]Includes Armed Forces stationed herein but not abroad.
[4] Percent increase: 1960-1976, 33.4; 1976-2000, 57.1; 1960-2000, 101.0.

As population grows, Western markets may become large enough to encourage development of large, low-grade iron resources in Arizona and other places in the West.

Transportation

The coming of the railroads made it economically feasible to tap great resources of the West and brought about a realization that the resource potential of the East was not a sufficiently broad base for the National economy--considering the tremendous demands of the greatly expanding West.

Figures 1 and 2 presents the locations of Arizona iron resources, Western blast furnaces, and railroads. Although smaller and additional iron-ore smelting units may be feasible in the future, blast furnaces are considered the basic consumers of iron oxides. Their locations and need for raw material will influence greatly the development of iron resources in Arizona and the West. Since iron-oxide ores and concentrates are a bulky, low-cost, and extremely competitive commodity, low, bulk-transportation costs are a necessity. The location of railroads and the distances between the established iron and steel industry, which is the chief market, and the iron-oxide resources of the West, including Arizona, is important. Table 56 illustrates the approximate railroad-mile distances between certain iron resources, blast furnaces, and seaports in Western United States and reflects partly the difficulty in developing some iron resources for other than local purposes. It must be remembered, however, that iron ore from Nevada is shipped to the Pacific coast for export to Japan.

TABLE 55. - Gross national product, annual rates of increase, and projections--1900 to 2000[1]

Year	Gross national product, billion dollars[2]	Average annual rates of increase, percent	
		Years	Rate
1900..........	77.8		
1915..........	125.3	1900 to 1915	3.3
1929..........	203.6	1900 to 1929	3.4
1939..........	211.5	1915 to 1939	2.2
1948..........	327.9	1929 to 1955-57	3.0
1955-57.......	450.4	1948 to 1959	3.6
1959..........	482.1	1955-57 to 1976	4.2
1976..........	1,018.4	1955-57 to 2000	3.5
2000..........	2,007.0	1976 to 2000	2.9

[1]Adapted from Bureau of Labor Statistics, Outdoor Recreation Resources Review Comatission Study. Rept. 23, 1962, table D-21, p.178.
[2]In 1959 dollars.

Many western iron resources, including those in Arizona, would require extensive branch lines--some quite long--from the existing mainline railroad network (figs. 1 and 2).

Unless railroad rates can be reduced to assist in making prices of the potentially large iron resources of Arizona competitive, other means of transport or more local developments may be required before they can be used, granting technology and demands are favorable.

To give an impression of the variations in freight rates as applied to iron ores and concentrates of Western United States, table 57 is presented as a comparison between approximate freight charges and the ton per mile cost equivalents. The considerable variations should be noted. Of course, large and regular shipments of beneficiated iron ores and very high-grade agglomerated iron concentrates are subject to negotiation between shippers and the railroads.

TABLE 56. - Approximate railroad miles between certain Western United States iron resource areas, smelter locations, and seaports

Destination	Export ore, Wabuska, Nev.	Atlantic City, taconite, Winton Jct., Wyo.	Montana, iron ore, Stanford, Mont.	Kaiser Steel Corp., Eagle Mt. iron mine vicinity of Indio, Calif.	Vicinity Pea Ridge, Sullivan, Mo.	Black Hills, taconite, Rapid City, S. Dak.	Vicinity N. Mex., taconite, Ghana, N. Mex.	Cedar City, Utah, hematite and magnetite	Fierro-Hanover, Silver City Dist., N. Mex., magnetite hematite	Sunrise, Wyo., hematite
Chicago, 111.[1]	1,997	1,281	1,423	2,215	329	868	1,244	-	1,516	-
Pueblo, Colo.'.......	1,191	512	938	1,309	836	534	225	780	624	377
Geneva, Utah"........	570	280	671	792	1,441	918	851	260	1,263	-
Fontana, Calif.'	733	962	1,558	84	1,962	1,602	1,310	530	1,773	-
Galveston, Tex.[2]	2,297	1,535	1,854	1,644	819	1,345	1,059	1,976	952	..
Houston, Tex.'	2,242	1,480	1,799	1,589	764	1,290	1,004	1,919	897	-
Los Angeles, Calif.[2]	677	1,019	1,607	129	2,011	1,658	1,359	670	772	-
San Diego, Calif.[2]	803	1,093	1,590	255	2,094	1,732	1,442	795	854	-
San Francisco, Calif.[2]	323	977	1,507	598	2,139	1,616	1,661	1,086	1,176	-
Seattle, Wash.[2]	827	1,061	925	1,400	2,223	1,700	1,856	1,359	1,965	-

'Smelter location. [2] Seaport.

TABLE 57. - Comparison of approximate long-ton railroad freight rates and ton-mile equivalents in Western United States[1]

Origins, vicinity of iron resource areas	Chicago area, Ill. Freight charge, dollars	Chicago area, Ill. Ton-mile rate, cents	Pueblo, Colo. Freight charge, dollars	Pueblo, Colo. Ton-mile rate, cents	Geneva, Utah Freight charge, dollars	Geneva, Utah Ton-mile rate, cents	Houston, Tex. Freight charge, dollars	Houston, Tex. Ton-mile rate, cents	Galveston, Tex. Freight charge, dollars	Galveston, Tex. Ton-mile rate, cents	Fontana, Calif. Freight charge, dollars	Fontana, Calif. Ton-mile rate, cents	San Diego, Calif. Freight charge, dollars	San Diego, Calif. Ton-mile rate, cents	San Francisco, Calif. Freight charge, dollars	San Francisco, Calif. Ton-mile rate, cents	Seattle, Wash. Freight charge, dollars	Seattle, Wash. Ton-mile rate, cents
Arizona: Ajo .... Bouse...... Globe...... Humboldt... Phoenix.... Snowflake..	[2]24.58 [2]24.58 [2]24.58 [2]24.58 [2]24.58 [2]25.70	1.32 1.29 1.45 1.40 1.36 1.62	[2]18.63 [2]18.63 [2]18.63 [2]18.63 218.63 [2]19.30	1.89 1.91 2.27 2.24 2.00 2.97	[3]28.00 [2]12.23 [3]31.84 [2]15.51 [3]25.76 [3]28.90	2.60 1.50 2.42 1.55 2.68 2.54	[2]18.63 [2]18.63 [2]18.63 [2]18.63 [2]18.63 [2]19.30	1.45 1.40 1.72 1.41 1.56 1.70	[2]18.63 [2]18.63 [2]18.63 [2]18.63 [2]18.63 [2]19.30	1.40 1.35 1.64 1.36 1.49 1.62	[3]14.78 [2] 6.576. 57 [3]21.06 [3]17.25 [2]13.20 [3]19.49	4.00 2.22 3.06 3.47 3.53 3.17	[3]17.25 [3]15.68 [2]23.07 [3]19.49 [2]17.56 [3]22.18	3.46 3.65 2.81 3.10 3.47 2.98	[2]26.93 [2]11.67 [2]16.40 [2]13.33 [2]12.75 [3]25.31	3.04 1.80 1.44 1.56 1.63 2.62	[3]36.96 [3]33.38 [3]41.22 [3]36.74 [3]35.62 [3]38.53	2.21 2.33 2.13 2.10 2.27 2.20
California: Indio......	[2]19.38	.88	[2]18.63	1.43	[2]22.40	2.83	[2]18.63	1.17	[2]18.63	1.13	[2]37.63	4.48	[2] 4.48	1.76	[2] 9.99	1.68	[3]32.48	2.32
Missouri: Sullivan...	[3]11.87	3.60	[3]19.71	2.30	[3]25.14	1.74	[3]19.26	2.52	[3]19.26	2.33	[3]25.14	1.28	[3]25.14	1.20	[3]25.14	1.18	[3]25.14	1.13
Montana: Stanford...	[4]13.53	.95	[4] 9.66	1.03	[3]20.61	3.07	[3]34.94	1.39	[3]34.94	1.90	[3]32.93	2.12	[3]34.72	2.19	[3]31.36	2.09	[4] 9.81	1.07
New Mexico: Hanover- Silver City. Chama......	[2]18.03 [3]37.63	1.19 3.03	[4] 5.04 [3]16.35	.81 7.27	[3]30.91 [3]35.62	2.45 4.19	[2 4] 10.93 [3]38.81	1.18 3.87	[24] 10.55 [3]35.39	1.11 3.34	[3]21.73 [3]38.81	1.23 2.96	[3]23.97 [3]38.81	2.93 2.69	[3]28.90 [3]38.81	2.46 2.34	[3]41.44 [3]38.81	2.11 2.10
Nevada: Wabuska....	' 17.30	.9	[3]18.63	1.6	[2]7.73	1.34	[2]18.63	.84	[2]18.63	.82	[2]6.94	.95	[3]1.03	2.9	[2]5.89	1.82	[2]13.23	1.60
South Dakota: Rapid City...	[5]6.89	.80	[3]15.01	2.81	[3]24.86	2.84	[3]26.21	2.00	[3]26.21	1.95	[3]23.80	2.60	[3]23.80	1.37	[3]23.80	1.47	[3]23.80	1.77
Utah: Cedar City...	-	-	[5]6.54	.84	[5]2.78	1.07	-	-	-	-					°			-
Wyoming: Winton Jct... Sunrise...	[3]26.88 -	1.11 -	[3]17.02 [5]3.96	3.32 1.05	[5]2.80 -	1.0 -	[3]28.90 -	1.95	[3]23.90 -	1.90	[3]25.76	2.68	[3]28.00	2.56	[3]25.31	2.60	[3]27.55	2.60 -

[1]Many rates in this table are based on minimum shipments of 60 to 100,000 net tons. Negotiated rates for large and regular shippers might be lower, possibly about 1 cent or less per ton-mile.
[2]Original short-ton rate converted to long-ton equivalents.
[3]Original quoted rate in hundredweight converted to long-ton equivalents.
[4]Original rates quoted per long ton.
[5]Negotiated rate.

Presently, major Arizona cities are served by railroad transportation. The Southern Pacific railroad passes through the southern and central parts of the State; the Atchison, Topeka & Santa Fe Railroad crosses the northern and central parts of the State, going east and west across Western United States. North, the West is linked by the Western Pacific, Southern Pacific, Union Pacific, Chicago, Milwaukee, St. Paul & Pacific, and the Great Northern railway systems.

Western Iron and Steel Industry

The established iron and steel industry and export trade are the present principal source of markets for iron ores and concentrates within Western United States. The size of the present market for iron ores and concentrates can be obtained from observing the distribution and capacity of blast furnaces within the West, since they convert these basic raw materials to pig iron--considered the first stage of new iron and steel. Table 58 gives the blast furnace operators, the number of furnaces, the annual capacity in short tons, and the distribution by States. Present capacity of Western blast furnaces totals 5,649,400 short tons. It takes 3,869 lb[16] of ore, mill scale, sinter, slags, and scrap to make 2,000 lb of pig iron, approximately a 2 to 1 ton ratio.

TABLE 58. - Capacity of iron blast furnaces in Western United States, Jan. 1, 1960[1]

States	Number of blast furnaces	Total annual capacity, short tons	Operators
Texas	1	540,000	Sheffield Division Armco Steel Corp., Houston.
	1	385,000	Lone Star Steel Co., Lone Star.
Colorado	4	922,400	Colorado Fuel and Iron Corp., Pueblo.
Utah......................	3	1,321,500	Columbia Geneva Division, U.S. Steel Corp., Geneva.
	2	482,700	Columbia Geneva Division, U.S. Steel Corp., Ironton
California	4	1,997,800	Kaiser Steel Corp., Fontana.
Totals:			
Western United States	15	5,649,400	
All United States....	263	96,520,630	

[1]American Iron and Steel Institute. Directory of Iron and Steel Works of the United States and Canada. 29th ed., 1960, pp. 444 and 448.

Since blast furnaces use varying qualities and quantities of iron ore and scrap, they are estimated to use about 1 short ton of ore and/or concentrates per ton of pig iron produced; the rest being a variety of scrap products. On

[16]U.S. Steel Corporation. The Making, Shaping, and Treatment of Steel. 7th ed., 1957, pp. 223, 254.

this basis, Western blast furnaces would require about 6 million long tons of ore annually. Exports to Japan in 1963 are expected to be about 2 million tons. In addition, relatively small tonnages of high-grade, direct-shipping iron ore are used in open hearth steel and electric furnaces. Other markets include using iron oxides as an ingredient in manufacturing low-heat portland cements (5 percent FeO) ; as ship ballast and heavy aggregate; for paint pigment; in manufacturing ferroalloys; in heavy-media separations; as foundry sands; and as an ingredient in drilling muds. These and other industries would probably absorb another million tons annually. Thus, the present market for iron-ores and concentrates is approximately 9 million long tons annually. Of course, if present population and GNP projections are realized or exceeded, the market would also increase. The above estimate is based on using high-quality direct-shipping and beneficiated iron ores and agglomerated concentrates, such as pellets, briquettes, and sinter as furnace feed. Actual consumption of iron resources, which are lower grade, would of course be much greater. An example is the conversion of taconite, having 20 to 35 percent iron content, to concentrates containing more than 65 percent Fe; wherein from 3 to almost 4 tons of resource are necessary to produce 1 ton of concentrate or furnace feed.

Another indication of the size of the present iron and steel market for iron ore and concentrates--including scrap--is the steel capacity of furnaces in Western United States (table 59). Development of a competitive synthetic scrap (sponge iron) may be a possibility in the future. Table 60 illustrates the variety of basic steel products and capacities available to the industries of the West. Table 61 presents the relationship of prices between iron ore, the product of the blast furnace-pig iron, and finished steels for the United States--these relationships apply also to the West; of course, within these averages, special iron ores and concentrates can and do vary greatly in prices, depending upon their qualities. Examples of these are taconite concentrate pellets at about $12 per long ton, and special rolled and drawn products, averaging about $320 per short ton ($358.40 per long ton). Examples of the prices[17] in the West and adjacent Minnesota are (1) $7.22 to $7.65 per long ton for direct shipping Utah and Minnesota hematite, $4.64 for miscellaneous limonite, and $5.25 per long ton for magnetite; (2) $8.17 per long ton for Minnesota iron ore concentrates, $6.43 for miscellaneous hematite ore concentrates, $9.38 for miscellaneous limonite concentrates, and $13.24 per long ton for miscellaneous magnetite concentrates from other states; and (3) from $11.65 per long ton for Minnesota iron ore agglomerates to an average of $12.14 per long ton for other States. The average National value for usable iron ore, excluding byproduct ore, was $8.99 per long ton in 1961.

Western Iron Resources

Most iron ore must be processed through the blast furnaces and steel mills to become a salable product. The value of iron ore and concentrates is therefore reflected through this sequence of processes. Values placed on Arizona and Western iron resources will be a reflection of advantages in relation to their location to the Western iron and steel producing industry,

[17]Holliday, R. W., and Helen E. Lewis. Iron Ore. BuMines Mineral Yearbook 1961, v. 1, pp. 663.

potential as furnace feeds of optimum quality, and competitive price position. This kind of information about Arizona iron resources is presently largely unknown or of a conjectural nature.

TABLE 59. - Annual steel capacity, ingots and steel for castings in Western United States, Jan. 1, 1960, short tons[1 2 3]

States	Open hearth		Bessemer		Basic oxygen process		Electric	
	No.	Capacity	No.	Capacity	No.	Capacity	No.	Capacity
Missouri...........	4	420,000	-	-	-	-	2	420,000
Oklahoma...........	-	-	-	-	-	-	1	140,000
Texas	13	1,825,000	-	-	-	-	12	699,080
Colorado...........	17	1,800,000	-	-	-	-	-	-
Arizona............	-	-	-	-	-	-	2	60,000
Utah	10	2,300,000	-	-	-	-	-	-
Washington.........	-	-	-	-	-	-	6	401,000
Oregon	-	-	-	-	-	-	3	150,000
California	30	2,727,500	-	-	3	1,440,000	8	628,000
Totals:								
Western United States.......	74	9,072,500	-	-	3	1,440,000	34	2,498,000
All United States.......	906	126,621,630	32	3,396,000	12	4,157,400	301	14,395,940

[1]Net capacities after deduction of 8.7 percent for operating time lost for holidays, rebuilding, relining, and repairs.
[2]Does not include foundries that normally produce only for castings.
[3]American Iron and Steel Institute. Directory of Iron and Steel Works of the United States and Canada. 29th ed., 1960, pp. 453, 454, 456, 458, 461, and 462.

Development of Arizona iron will depend upon its competitive position with other Western iron-ore resources. This position will depend upon the location, size, quality, and rate of depletion of the deposits; expansions within the industry; and export trade. Table 56 gives the approximate rail-road distances from selected Western iron resources to blast furnace locations and seaports. Table 62 gives the approximate reserves of Western iron ore and taconite, other than in Arizona, and some data about their iron content. This table illustrates the abundance of Western iron ores and their size. These ores would materially affect the competitive status of Arizona iron resources wherever economic advantages exist. Table 63 gives the quality of iron ores and concentrates being produced in the West. Their quality would have to be matched or exceeded by Arizona iron ores to be competitive.

Many deposits in Wyoming, Utah, Nevada, Texas, and California are already in production and subject to gradual depletion. Table 64 illustrates approximately the annual rate of depletion of Western iron resources and their principal uses.

TABLE 60. - Annual capacity of hot rolled steel products in Western United States, total and distribution by States, Jan. 1, 1960, net tons[1]

States	Total hot rolled products	Rails, long joint or splice bars and tie plate bars, and wheels and axles (rolled)	Structural shapes, steel piling (rolled), and plates	Hot rolled sheets	Hot rolled strip	Hot rolled bars	Wire rods	Skelp	Blanks, tube rounds, or pierced billets for seamless tubes
Iowa	-		-			-	-		
Missouri	726,000	-	52,000	-	-	415,000	259,000	-	-
North Dakota........	-	-	-	-	-	-	-	-	-
South Dakota........	-	-	-	-	-	-	-	-	-
Nebraska	-	-	-	-	-	-	-	-	-
Kansas	-		-	-	-	-	-	-	-
Arkansas									-
Louisiana									
Oklahoma...........	134,000	-	-	-	-	134,000	-	-	-
Texas	1,864,900	-	853,700	-	-	248,100	62,500	655,000	-
Montana	-	-	-	-	-	-	-	-	-
Idaho	-	-	-	-	-	-	-	-	-
Wyoming									-
Colorado	1,348,500	478,000	67,000	-	2,500	150,000	275,000	-	300,000
New Mexico..........	-	-	-	-	-	-	-	-	-
Arizona									
Utah	1,919,940	-	765,700	650,050	-	1,990	-	-	-
Nevada	-	-	-	-	-	-	-	-	-
Washington..........	244,000	9,000	58,000	-	-	177,000	-	-	-
Oregon	125,000	-	16,500	-	-	93,500	-	-	-
California	3,531,760	14,300	841,360	429,000	9,660	976,080	230,460	537,500	-
Totals: Western United States	9,894,100	501,300	2,654,260	1,079,050	12,160	2,195,670	826,960	1,192,500	300,000
All United States	113,785,590	2,521,160	19,640,280	39,512,570	2,656,110	18,349,130	7,340,480	6,070,920	5,836,180

States	Blooms and billets (forging or export)	Other hot rolled products	Cold finished bars	Pipes and tubing	Wire and wire products	Sheets (cold rolled, galvanized, and long terne)	Hot dipped tin and terneplate and tinplate	Strip cold rolled and galvanized	Splice bars, other rail joints, tie plates, track spikes	Coils of cold reduced block plate and tinplates
Iowa	-	-	-	-	-	-	-	-	-	-
Missouri	-	-	-	-	402,500	-	-	-	24,000	-
North Dakota.......	-	-	-	-	-	-	-	-	-	-
South Dakota	-	-	-	-	-	-	-	-	-	-
Nebraska............	-	-	-	-	-	-	-	-	-	-
Kansas	-	-	-	-	-	-	-	-	-	-
Arkansas............	-	-	-	-	-	-	-	-	-	-
Louisiana...........	-	-	-	-	-	-	-	-	-	-
Oklahoma............	-	-	-	-	-	-	-	-	-	-
Texas	-	45,600	-	1,558,000	210,800	-	-	-	-	-
Montana	-	-	-	-	-	-	-	-	-	-
Idaho	-	-	-	-	-	-	-	-	-	-
Wyoming	-	-	-	-	-	-	-	-	-	-
Colorado	1,000	75,000	-	240,000	457,400	-	-	-	220,000	-
New Mexico.........	-	-	-	-	-	-	-	-	-	-
Arizona	-	-	-	-	-	-	-	-	-	-
Utah	-	-	-	533,100	-	-	-	-	-	502,200
Nevada	-	-	-	-	-	-	-	-	-	-
Washington.........	-	-	4,000	-	-	-	-	-	13,000	-
Oregon	15,000	-	-	-	-	-	-	-	-	-
California	9,700	-	112,000	1,132,800	499,950	516,730	2,127,120	80,000	45,070	483,700
Totals: Western United States	25,700	120,600	116,000	3,463,900	1,570,650	516,730	2,127,120	80,000	302,070	985,900
All United States	731,300	300,100	4,175,600	16,502,960	12,489,340	26,367,640	16,418,380	3,871,630	1,180,970	10,827,360

[1]American Iron and Steel Institute. Directory of Iron and Steel Works of the United States and Canada. 29th ed., 1960, pp. 466 to 505.

TABLE 61. - National average of prices of iron-ore, pig-iron, and finished steel, 1951 through 1961[1]

Year	Usable iron ore, per long ton	Pig-iron, per short ton	Finished steel, per short ton	Year	Usable iron ore, per long ton	Pig-iron per short ton	Finished steel, per short ton
1951	$5.46	$46.75	$124.90	1956	$7.76	$54.60	$154.62
1952	6.09	48.43	129.36	1957	8.31	58.17	165.36
1953.......	6.76	49.83	135.78	1958...........	8.61	59.33	172.86
1954.......	6.99	49.93	125.88	1959	8.69	59.29	177.14
1955.......	7.11	50.68	141.98	1960	8.72	59.28	173.14

[1]F.o.b. mine or plant.

TABLE 62. - Approximate iron resources[1] in Western United States other than in Arizona

State	Reserves		Potential		References
	Millions of long tons	Fe content, percent	Millions of long tons	Fe content, percent	
Arkansas	Small...	24 to 59...	-	-	(13, table 4).
Iowa	0.5..	37	-	-	Do.
Missouri (Pea Ridge, Bourbon, Boss,Ironton).	65....	Less than 40 to more than 58,	Large, several hundred.	-	Fine, M. M., D. W. Frommer. Experiments in Concentrating Iron Ore from the Pea Ridge Deposit, No. Min. Eng., vol. 11, No. 3, March 1959, p. 325. Beall, John V. What's Behind the Mining Boom in Southeast Missouri. Min. Eng., vol. 15, No. 7, July 1963, p. 76 Staff, Bureau of Mines. Mineral Facts and Problems. BuMines Bull. 585, 1960, p. 412.
Oklahoma.......	-	-	2.72	45 to 62	(13, table 4).
South Dakota...	-	-	About 500 as taconite	-	Do.
Texas	160.74.	40........	57.56	-	Do.
California	73.11.	25 to 67...	More than 2.4.	-	California Department of Mineral Resources. Mineral Commodities of California. California Dept. Min. Res. Bull. 176, 1957, p. 247, (table 1). (13).
Colorado.......	12....	-	9.25	38 to 55	(13, table 4). Staff, Bureau of Mines. Mineral Facts and Problems. BuMines Bull. 585, 1960, p. 412.
Idaho	2....	50 to 62...	Small......	-	Do.
Montana	12.9..	27 to 59...	Large, 60..	-	Do.
Nevada	38....	47 to 63...	Large, possibly 2,000.	-	Engineering and Mining Journal. Vol. 163, No. 5, May 1962, p. 116. Staff, Bureau of Mines. Mineral Facts and Problems. BuMines Bull. 585, 1960, p. 412.
New Mexico	25.96.	25 to 60...	117.15 and 100 taconite,	20 to 38	(13, table 4). Staff, Bureau of Mines. Mineral Facts and Problems. BuMines Bull. 585, 1960, p. 412.
Oregon.........	7....	39 to 59...	2	-	Do.
Utah	350.95.	45 to 52...	150........	-	Do.
Washington.....	8.22.	38 to 60...	24.........	35 to 60	Do.
Wyoming........	[2]230....	30 to 55...	268	[2]20 to 45	(13, table 4; 52, p. 8). Pinnell, D. B., and J. A. Marsh. Summary Geological Report on the Titaniferous Iron Deposits of the Laramie Range. Colo. Mng. Assoc. Meeting, Jan. 30, 1954, 10 pp.
Louisiana	-	-	Limonite-siderite in Claiborne and Union parishes, extent unknown.	-	Grandone, Peter, and Leo W. Hough. Louisiana. BuMines Minerals Yearbook 1961, 1962, p. 485.

[1]These resources may be greatly expanded by additional search and discoveries.
[2] Includes agnetite, taconite, titaniferous magnetite, and hematite.

TABLE 63. - Quality of iron ores and concentrates produced in Western United States[1]

State	Mine	Location	Type of analysis	Fe	P	SiO_2	Mn	Al_2O_3	CaO	MgO	S	Loss on ignition	Moisture
Missouri....	Schroeder Mining Co.,	Koshkonong,	Dry	53.46	0.051	9.76	0.08	-	-	-	0.179	-	-
	limonite.	Mo.	Natural	{51.27	-	-	-	-	-	-	-	-	5.40
Texas	Armco Steel Corp. Sheffield Division,	Rusk, Tex.......	do....	43.67 {41.36	.325	16.03	-	9.58					
	limonite.				.308	15.17	-	9.07	-	-	-	-	5.65
New Mexico..	Jones mine, Dotson	Socorro,		-	-	-	-						
	Minerals Corp., magne-	N. Mex.	do....	{62.00	.063	4.50	.11	.55	-		.107	2.98	
	tite concentrates.		do.,..	61.80		10.60			0.20	0.34			
Wyoming	Atlantic City, magne-	Atlantic City,			.009		-	.39			.004	-	-
	tite taconite.	Wyo.		{61.10	-	10.50	-	-	-	-	-	-	1.20
Utah	Columbia Mining Co.,	Pinto district,	do...		.184	8.30	-	-	-	-	.066	-	-
	non-Bessemer.	Utah.		{52.26	.177	8.00	-	-	-	-	.064	-	3.58
Do..........	Excelsior, blast furnace	do..........		150.39 55.10	.33	9.20	-	-	-	-	.022		
	ore, Utah Construction & Mining Co.		do....		-	-	-	-	-	-	-	-	2.60
Do	Excelsior, open hearth	do..........		58.10	.24	7 20	-				015	-	-
	ore, Utah Construction & Mining Co.		do....	-									2.60
Nevada	Export, The Standard	Gabbs and	do	{62.00	.030	5.00	.10	.70	1.00	6.00	.700	-	-
	Slag Co.	Wabuska, Nev.	" "	-	-	-	-	-	-	-	-	-	3.00
Do	Nevada, lump ore,	Pershing	do.,..	{62.00								-	
	Iron Castle.	County, Nev.		62.00	.200	-	-	-	-	-	.015	-	-
California..	Iron Age, lump ore,	29 Palms,		-	-	-	-	-					-
	Iron Age Mining	Calif.	do....	{65.50_	.032	3.10	.07	-	1.20	-	.018	-	.50
	Association.			{59.00		6.25			2.40				
Do	Iron Age fines.	do..........											
	Iron Age Mining Association.		do....		.032		.07	-		-	.018	-	.80
Do	Eagle Mountain.	Eagle Mountain,	ddo	-	-	-	-	-	-	-	-		
	Kaiser Steel Corp.	Calif.		{56.49	.054	7.85	.06	1.23	1.51	3.10	.562	-	2.70

[1]American Iron Ore Association. Iron Ore, 1962. Table VI-Grade Names and Analyses, pp. 83, 84.

TABLE 64. - Approximate annual rates of depletion of Western United States iron ores, 1961-62, with origins, destinations, and principal uses

Resource area	Locations	Rate of depletion in annual long tons	Principal uses
Missouri....	Various.......	[2]346,000.........	Various, including blast furnace feed.
South Dakota	Black Hills...	34,000..........	Cement manufacture.
Texas[1]......	Various.......	-	Blast furnace feed.
Montana.....	do.........	About 20,000....	Cement manufacture.
Idaho.......	do.........	About 8,000.....	Iron and steel industry, manufacture of cement.
Wyoming[1]....	Sunrise and Atlantic City.	About 1,000,000.	Blast furnace feed, manufacture of iron and steel.
Colorado[1]...	Various.......	About 30,000....	Paint pigment, manufacture of iron and steel.
New Mexico[1].	Hanover, Fierro, Silver City.	9,000...........	Blast furnace feed, production of iron and steel, and as heavy aggregate.
Arizona.....	Various.......	Small...........	Paint pigment, manufacture of iron and steel.
Utah........	Cedar City District.	About 3,000,000..	Blast furnace feed, production of iron and steel.
Nevada.....	Gabbs, Wabuska, etc.	About 1,000,000..	Export, Western iron and steel mills, and cement industry.
Oregon[1].....	Various.......	About 1,000.....	Cement manufacture, iron and steel industry.
California[1].	do.........	-	Blast furnace feed, manufacture of iron and steel, cement manufacture, ferroalloys foundries, ballast, export to Japan.

[1]California, Wyoming, Texas, New Mexico, Colorado, Arizona, and Oregon have an undistributed depletion of about 10 million long tons annually.
[2]Depletion will be increased by about 4 million tons annually when the Meramec Mining Co. Pea Ridge mine goes into production in 1964.

Status of Arizona Iron Resources

Reserves and Resource Potential

Total iron reserves (table 3) have been estimated as 14.144 million tons of hematite ore, averaging 46 percent Fe, for the Fort Apache Indian Reservation in Navajo County; 1.25 million tons of hematite ore, averaging 60 percent Fe, for the Buckskin Mountains area of Yuma County; and 100 million tons of magnetite-hematite taconite, averaging 30 percent iron for the Hieroglyphic Mountains area of Maricopa County. The reserves potential of these and other areas in Arizona are considered enormous, as shown in table 65. While the estimates of table 3 are indicated and inferred reserves, they nevertheless represent considerable exploration detail. Most of the iron resources potential represented in table 65 are based only on reconnaissance inferences too generalized to be the basis of reserves estimates. Comparison of tables 62 and 65 shows how Arizona iron resources supplement those in the entire Western United States, giving an idea of their quality. It should be noted that, on the basis of reconnaissance, the low-grade taconite and jaspilite iron resources potential is in the billions of tons. The approximate distances, by railroad, from established blast-furnace-smelting centers and seaports is shown in table 66. Many smaller sources of iron oxides are discussed in the text.

TABLE 65. - Reserves and resource potential at principal Arizona iron occurrences, millions of tons

Locations	Total reserves	Fe, percent	Inferred resource potential	Production of iron ore
Gila County:				
Iron King taconite	-	39.0 to 42.0	More than 1,000	None.
Pig Iron taconite	-	18.6 to 36.7	1,000	Do.
Northern Gila County hematite, replacement in mescal limestone. Bottle Spring, Gentry Creek and Mesa, Nail Ranch, Bear Creek, Shell Mountain, Rock Creek, Frog Pond area, between Young and the Gila-Navajo county line.	-	35.4 to 64.2	More than 100..	Do.
Zimmerman-Asbestos Points magnetite.	-	30 to 68....	Several	-
Maricopa County:				
Magnetite-hematite taconite. Hieroglyphic Mountains (Pikes Peak).	100	30.0	-	-
	-	28.7 to 31.2	More than 100..	None.
Big Boulder-Iron Ridge...	-	24.6 to 33.1	More than 100..	Do.
Navajo County: Fort Apache	{14.144	46	-	Do.
Indian Reservation: Apache, Chediski, Cow Creek, Oak Creek, Split Rock, Gentry and Rock Creeks areas.	-	20.0 to 67.9	More than 100..	Do.
Pima County: Quijotoa Mountains: Horseshoe Basin and other locations.	-	43.7 to 55.7	About 100	Do.

TABLE 65. - Reserves and resource potential at principal Arizona iron occurrences, in millions of tons (Con.)

Locations	Total reserves	Fe, percent	Inferred resource potential	Production of iron ore
Pinal County: Florence-Oracle Junction-Red Rock alluvium.	-	0.5 to 20 in magnetite sand.	Very large, across many square miles.	Small for experimental purposes. 1
Yavapai County:				
Black Hills magnetite....	-	26.9 to 37.4 Fe with 0.9 to 4.5 percent Mn.	large.........	None.
Magnetite-hematite taconite: Lynx Creek, Mayer, Stoddard, Blue Bell, Cleator (Los Felice), Blind Indian, Arrastra, and Ash Creek, and Stanton areas.	-	20.6 to 30.9 Fe with as much as 11 percent Mn.	Enormous possibly several thousand.	Do.
Seligman, Juniper Nountains hematite.	-	58.3 to 68.4	1	Small.
Santa Margarita District, alluvial titaniferous magnetite.	-	1.9 to 10.9 percent magnetite by weight, averaging 5.5 percent magnetite.	Large.........	None.
Yuma County: Plomosa and Buckskin Mountains: Mineral Hill, New Planet, Planet Peak, Brown Mountain, Swansea, etc.	[1]1.25 [2]4.5	60.0........ 15.5 to 67.8	- As much as 100.	Do. Small.
Cochise, Gila, Greenlee and Pima Counties: Copper slags.	-	33 to 50....	Approaching 100.	Do.

[1]New Planet Mine area, 1945.
[2]Mineral Hill, Marvel Mining Co., 1962.

TABLE 66. - Approximate railroad miles between Arizona iron resources,) smelter locations, and seaports

Destination	Maricopa County; taconite; Pikes Peak and Big Boulder, vicinity of Phoenix	Yavapai County; taconite; Blue Bell, Lynx Creek, etc., vicinity Humboldt and Prescott	Navajo-Gila Counties; hematite; Fort Apache Indian Reservation and vicinity of Snowflake, Ariz., nearest rail point; more than 50 miles distant
Chicago area, I11[2]	1,812	1,764	1,584
Granite City, I11[2]	1,627	1,579	1,399
Pueblo, Colo[2]	930	830	649
Geneva, Utah[2]	960	1,002	1,138
Fontana, Calif[2]	374	497	613
Los Angeles, Calif[3]	424	547	662
San Diego, Calif3	506	629	745
San Francisco, Calif[3]	786	859	964
Seattle, Wash[3]	1,575	1,749	1,753
Galveston, Tex[3]	1,248	1,372	1,185
Houston, Tex[2]	1,193	1,317	1,130

Destination	Yuma County; hematite; vicinity of Bouse	Pima County; Quijotoa Mountains magnetite-hematite; railroad at Ajo about 50 miles northwest	Gila County; Pig Iron-Iron King; titaniferous hematite and magnetite; railroad at Globe 50 miles south
Chicago area, I11[2]	1,912	1,863	1,702
Granite City, I11[2]	1,727	1,678	1,517
Pueblo, Colo2	977	984	823
Geneva, Utah2	822	1,078	1,317
Fontana, Calif2	297	367	689
Los Angeles, Calif[3]	346	417	739
San Diego, Calif[3]	429	499	821
San Francisco, Calif[3]	649	886	1,143
Seattle, Wash[3]	1,437	1,675	1,932
Galveston, Tex[3]	1,386	1,342	1,138
Houston, Tex[2]	1,331	1,287	1,083

)All iron resources would require spur railroad connections to link them to main lines. Some, like hematite deposits in Navajo and Gila Counties and titaniferous taconites Pig Iron-Iron King of Gila County would be more than 50 miles long.

[2]Smelters. [3]

Seaports.

Exploration Status

The search for iron ore in Arizona is increasing, indicated by The Colorado Fuel and Iron Corp explorations for hematite on Fort Apache Indian Reservation in southwest Navajo County and by numerous private interests in the adjoining Young area of Gila County; exploration of the Zimmerman Point-Asbestos Peak area of Gila County, where Arizona Iron Mine, Inc., of Phoenix, Ariz. has inferred several million tons of magnetite on drilling information; exploration of the Buckskin and Plomosa Mountains area of northern Yuma County--particularly Mineral Hill where Marvel Mining Co., of Salt Lake City, Utah, has drilled an estimated 4.5 million tons of hematite; and exploration of the low-grade magnetitic alluvium of the Florence-Oracle Junction-Red Rock area of Pinal County.

Little or no attention has been directed toward investigating low-grade taconite and jaspilite iron occurrences in Arizona, other than staking claims and investigations and estimates of potential iron resources in this report--based on a few samples miles apart--which may or may not be characteristic of the deposits or the best parts of them. These are considered mere preliminaries to those necessary before their real value can be established.

Further investigations necessary to properly evaluate the large low-grade iron resources of the State should include: (1) Mapping iron formations and more detailed studies of the most favorable areas; (2) exploratory core drilling of the better areas established by (1); (3) beneficiation research to determine critical problems and methods for their solution; (4) bulk sampling of selected deposits to develop methods of processing and cost data; and (5) economic investigations to determine the competitive position of Arizona developed iron oxide products in the Western United States and export markets.

Present Developments

Production of iron ore in Arizona remains very small. By far the greatest production of iron in the State is synthetic scrap-sponge iron for the Leach-precipitation-flotation process of recovering copper from its ores. Development in the Arizona iron resource industry in the next few years will probably remain small. Ore mined will be high grade and of small tonnage. Some deposits are being explored and developed; however, a large mining venture requires considerable successful exploration and development before it reaches the production stage. Even if an attractive and large enough deposit were found and development work were begun immediately, it would take from 3 to more than 5 years before the mining and/or processing plant could be placed in full operation. With this in mind, any large-scale development of Arizona iron, within the next few years, appears unlikely.

Long-Range Considerations

Under present circumstances the earliest long-range, large-scale iron ore development in Arizona will probably be large deposits of hematite in the Fort Apache Indian Reservation area of Navajo County and the adjoining Young area of Gila County, as the results of long-time exploration by The Colorado Fuel and Iron Corp., and others. These deposits are comparable, approximately, with the hematites of Sunrise, Wyo., and the Cedar City district of Utah. They would be mined by underground and open-pit methods as conditions warrant. Part of the ore may be of direct-shipping quality and part or all may require beneficiation to furnace feeds of optimum quality.

A second development may be the potentially large hematites and cupreous hematites of northern Yuma County.

The least known iron resources, the taconites and jaspilites will be a very long-range development, dependent on the successful solution of many exploration, beneficiation, metallurgical, and economic problems. At this stage these resources are in a position comparable to the very earliest investigations of Minnesota taconites.

General Long-Range Developments

In general, long-range development of Arizona iron resources will depend mostly on its competitive position with the many other sources of iron ore in Western United States (tables 62 and 65); however, other factors of prime importance must be considered. Some of these factors are: (1) Expanding markets, due to increasing population and industrialization; (2) depletion of competitive iron reserves; (3) changeovers of the iron and steel industry to synthetic scrap and to the very highest iron content concentrates and agglomerates; and (4) advances in technology and the possible lowering of unit transportation and energy costs.

At present, data on reserves, quality, and metallurgical amenability are inadequate for evaluating the future place in the iron and steel economy of Western United States; however; there are indications that potentially enormous resources do exist. The largest resource available will be the low-grade iron occurrences in the State. Because of this, it is anticipated that when large quantities of iron ore are demanded and mined, a prime consideration will be inclusion and beneficiation of low-grade fractions of deposits and the potentially enormous low-grade deposits.

Exploitation and Operators

Whether future resource exploitation will be by independent mine opera-tors or by vertically integrated steel makers is uncertain. The largest opera-tors in the iron and steel business in the West are The United States Steel Corp., Columbia-Geneva Division, Geneva, Utah; The Colorado Fuel and Iron Corp., Pueblo, Colo.; Kaiser Steel Corp., Fontana, Calif.; The ARMCO Steel Corp., Sheffield Division, Houston, Tex.; and the Lone Star Steel Co., of Lone Star and Daingerfield, Tex. These steel producers, directly or through contractual mining arrangements, control their sources of iron ore. Control over the source of iron raw materials stems from the desire to maintain strict metallurgical control over the feed to the blast furnaces. This control is of vital importance if high-quality steel is to be produced competitively.

In the past, small iron-ore purchases have been made by the major steel producers from independent mine operators. However, in recent years, because of more exacting specifications for finished steel and increasing economic pressures that have compelled Western steelmakers to engage in increased mining activity for blast furnace feed, steelmakers seldom purchase small lots of iron-ore concentrate. Thus, any large-scale development of Arizona iron resources would appear to depend mainly on the activities of large integrated steel producers or on large-scale custom mining companies closely affiliated with the iron and steel industry.

Figure 2 shows the location of blast furnaces in Western United States. From this illustration it can be noted that most Arizona iron deposits are within a 500-mile radius of steel plants in California, Utah, and Colorado--Texas being more distant. It would appear that if Arizona iron resources are to be developed by existing steelmakers, this development would possibly originate with concerns in Colorado, California, Utah, and Texas. There is also a possibility that consideration may be given to establishing a mining and metallurgical enterprise devoted solely to furnishing very high-quality concentrates and agglomerates for both western and foreign markets.

Implications of Technologic Change

In spite of an indicated oversupply of iron ores throughout the world of iron and steel, new developments and expansions in raw materials supplies have been the rule for more than 10 years. Steelmakers are increasingly aware of the savings and greatly increased capacities of blast furnaces, made possible by using very high-grade agglomerates. Thus, while there is an oversupply of direct-shipping ores, there is also the paradox of a shortage of very high-grade blast furnace feed, currently represented by plus 65 percent Fe pellets or agglomerates. This is particularly apparent by such recent developments as the great taconite-pellet industry of Minnesota and its multimillion tons expansions, the Meramec Mining Co. Pea Ridge magnetite-pellet development in Missouri, the U.S. Steel Corp. magnetite taconite-pellet development in Wyoming, and the Kaiser Steel Corp. announcement of a west coast pellet plant. The trend toward increasingly high-iron-content furnace feeds and the very large investments necessary for beneficiating and agglomerating (pelletizing) plants should direct attention to the potentially enormous low-grade iron deposits of Arizona and the West.

The ever present problem of transportation costs has long plagued the iron and steel industry. While great strides have been made in reducing bulk transportation costs, much more remains to be done. Some of the newer considerations include using unitrains, shuttle trains, and pipelines. Another is production of semifinished iron and steel locally and transportation of these higher value and lower bulk products to steel mills. The products could take the form of synthetic scrap-sponge iron, prereduced and self-fluxing pellets, and direct-reduction (D-R) and electric furnace products from mine-site locations.

The development and improvement of direct-reduction (D-R) processes for production of pig iron and sponge iron could hasten exploitation of Arizona iron resources. D-R plants have been operated commercially in Mexico, Sweden, and Germany. Existence of these plants indicates that when economic conditions are favorable and adequate raw materials are available, D-R processes can be used successfully to produce iron and steel and in some cases might be a competitor to blast-furnace steel--at least in specialties or the less competitive types of local iron and steel demands. At present, sponge iron is used in the leach-precipitation-flotation (LPF) process of recovering copper from Arizona ores.

Direct-reduction processes may have an advantage depending on local conditions. Application of D-R technology to situations where the market requires less than blast-furnace tonnages of iron; where there is a definite need for a flexible operation relative to startups, shutdowns and variable tonnage of output; or where special types of ore or product are involved can be listed as advantages.

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APPENDIX

TABLE A-1. - Ore zone data, Bureau of Mines core drilling (1942-43)
East Apache hematite deposit, Navajo County, Ariz.

Drill hole fig.25	Hematite thickness, feet	Depth to top of ore zone	Iron percent	Remarks
1....	19.3	405.9	51.23	Stopped in hematite and ferruginous
	21.7	451.6	50.90	sandstone.
2				Some local hematite below ore zone.
3.....	9.4	266.4	40.95	Do.
4.....	9.0	625.7	-	Do.
5.....	21.8	134.4	46.17	Do.
6.....	6.2	284.7	36.42	Some local hematite above ore zone.
7.....	-	-	-	Hole stopped above ore.
8.....	20.6	408.1	45.56	Some local hematite below ore zone.
9.....	16.5	358.0	40.73	Includes bands of ferruginous material.
10.....	9.0	349.0	46.23	Ferruginous to barren chert, sandstone,
	5.0	276.9	44.09	mudstone below ore zones.
11.....				Low-grade hematite and ferruginous sand-
	25.0	236.9	48.70	stone and chert below ore zone.
12.....				Do.
13.....	11.5	218.0	46.89	Ferruginous jasper and sandstone above ore
	7.0	532.0	35.36	zone.
14.....				Ferruginous chert and sandstone below ore
	7.0	494.0		zone.
15.....			-	Hematite zone.
	9.7	515.2	-	Low grade hematite zone.
16	10.4	506.1	-	Hematite ore to low-grade hematite.
17.....	5.5	423.7	38.94	Ferruginous chert breccia below ore zone.
18.....	18.3	456.0	40.78	Do.
19.....	16.3	402.0	48.83	Do.
20.....	11.2	256.8	52.12	Do.
21.....	20.2	256.8	41.25	Local narrow lenses of hematite with ferru-
	5.0	266.8	43.86	ginous chert and sandstone above ore zone.
22.....				Specular hematite ore.

TABLE A-2. - Mining claims at Mineral Hill, Yuma County, Ariz.

Claims surveyed for patent		Unpatented claims	
Name	Patent survey No.	Name	Description
Apex	2785	Cobre 1-4.....	Lode location.
Copper Glance	2785	Cobre fraction	Do.
Copper King	2785	Bobbie........	Do.
Copper Prince	2785	Annex 1-3.....	Do.
Greater Jerome	2785	Bessie Belle..	Do.
Mohave Chief	2785	Extension 1-4.	Do.
Norma.....................	2785	Joe 1 and 2...	Placer claims in W½W½
Queen of Copper...........	2785		sec 2, T 10 N, R 17 W
Cavern....................	2981		
Continental-1,2,9,10,11	2981		

TABLE A-3. - Patented mining claims at New Planet, Yuma County, Ariz.

Ahonika	Byron Hill 1-11	Mark Hanna	Otis 1-3
Ashley	Comet	McCarn	Palmetto
Barton	Copper Hill 1-6	Mesa 1-3	Partridge 1-4
Bill Williams	Crompton 1-4	New York	Planet 1-22
Blue Bird	Ella Belle 1-2	Oddoletta 1-2	Sentinel
Boston	Iron Hill 1-2	Odora 1-2	Smelter Gulch
Brookeville 1-5	Kimball	Opal 1-5	Wisconsin
Bunker Hill	La Mexicana	Orange	

TABLE A-4. - Results of coarse-gravity concentration by heavy media[1] and jigging (20, p. 26) on Hieroglyphic Mountains (Pikes Peak), hematite-magnetite taconite, Maricopa County, Ariz., 1943

Products	Weight-percent	Chemical analyses, percent				Distribution, percent		
		Fe	Mn	SiO_2	P	Fe	Mn	SiO_2
Plus 3-mesh sink concentrate...	10.3	47.0	1.5	22.4	0.14	15.7	6.6	6.0
Plus 6-mesh jig concentrate....	9.4	51.9	2.4	13.5	.16	15.8	9.5	3.3
Plus 20-mesh jig concentrate...	12.2	51.4	3.2	12.7	.14	20.3	16.5	4.0
Combined middling..............	37.5	30.5	3.5	33.5	-	36.9	56.9	32.5
Combined tailing	30.5	11.5	.8	13.1	-	11.3	10.5	54.5
Calculated heads	100.0	30.9	2.4	36.9	-	100.0	100.0	100.0
Combined iron concentrates[2]....	31.9	50.1	2.5	16.1	.15	51.8	32.6	13.3

[1]Heavy media; ferrosilicon-water at 3.21 sp gr followed by 2.78 sp gr.
[2]Analysis included 3.3 percent Al_2O_3, 0.5 percent CaO, and 0.04 percent S.

TABLE A-5. - Results of table concentration of coarse-gravity concentration middling (20, pp. 26-27) on Hieroglyphic Mountains (Pikes Peak) hematite-magnetite taconite, Maricopa County, Ariz., 1943

Products	Weight-percent	Chemical analyses, percent				Distribution, percent		
		Fe	Mn	SiO_2	P	Fe	Mn	SiO_2
Iron concentrate	13.4	46.6	4.5	15.8	0.17	20.2	25.6	5.5
Tailing	11.7	19.0	2.4	52.1	-	7.2	11.8	15.8
Slime-untreated	12.4	23.6	3.7	34.7	-	9.5	19.5	11.2
Calculated heads	37.5	30.4	3.6	33.4	-	36.9	56.9	32.5
Combined iron concentrates[1].....	45.3	49.1	3.0	16.0	0.15	72.0	58.2	18.8
Combined sintered concentrates[2].	-	52.3	3.1	17.1	0.155	-	-	-

[1]Composite of coarse-gravity and table concentrates from reprocessing the middling.
[2]Total analysis included 3.5 percent Al_2O_3 and 0.03 percent S.

TABLE A-6. - Results of flotation of coarse-gravity middling[1] (20, p. 27), on Hieroglyphic Mountains (Pikes Peak), hematite-magnetite taconite, Maricopa County, Ariz., 1943

Products	Weight-percent	Chemical analyses, percent				Distribution, percent		
		Fe	Mn	SiO_2	P	Fe	Mn	SiO_2
Cleaned iron concentrate	16.6	49.0	5.0	14.2	.24	25.4	42.0	5.9
Cleaner tailing	12.6	20.0	1.7	47.2	-	8.1	11.1	12.0
Rougher tailing	8.3	13.1	.9	59.0	-	3.4	3.8	14.6
Calculated middling	37.5	30.3	3.0	35.3	-	36.9	56.9	32.5
Combined gravity and flotation concentrates..	48.5	49.7	3.1	15.1	.18	77.2	74.6	19.2

[1]Minus 100-mesh pulp, 89 percent through minus 200-mesh floated with a fuel oil-tall oil emulsion. Emulsion consisted of 75 percent water, 16 percent No. 2 fuel oil, 8 percent tall oil, and 1 percent petroleum sulfonate.

TABLE A-7. - Results of reductive roasting and wet magnetic separation of coarse-gravity middling[1] (20, p. 28) on Hieroglyphic Mountains (Pikes Peak), hematite-magnetite taconite, Maricopa County, Ariz., 1943

Products	Weight-percent	Chemical analyses, percent				Distribution, percent		
		Fe	Mn	SiO_2	P	Fe	Mn	SiO_2
Magnetic iron concentrate	18.4	51.6	3.5	16.3	.19	29.7	28.3	7.7
Nonmagnetic tailing	16.5	12.1	3.8	57.2	-	7.2	29.1	24.8
Loss on ignition	2.6	-	-	-	-	-	-	-
Calculated heads	37.5	30.7	3.4	33.2	-	36.9	57.4	32.5
Combined gravity and magnetic concentrates...	50.3	50.5	2.9	16.2	.17	81.5	60.9	21.0

[1]Crushed through 20-mesh for roasting at 550° C. Calcine ground through 100-mesh for magnetic separation.

TABLE A-8. - Results of flotation of composite surface and underground ore[1] (20, pp. 28-29), on Hieroglyphic Mountains (Pikes Peak), hematite-magnetite taconite, Maricopa County, Ariz., 1943

	Weight-percent	Chemical analyses, percent				Distribution, percent		
		Fe	Mn	Insoluble	P	Fe	Mn	Insoluble
Products:								
Iron concentrate.......	47.2	53.7	5.0	10.9	0.15	80.3	80.2	12.3
Cleaner tailing 4......	2.8	30.0	2.4	42.3	.17	2.7	2.3	2.8
Cleaner tailing 3......	3.4	18.0	1.6	63.5	-	1.9	1.0	5.2
Cleaner tailing 2	7.0	13.8	1.4	67.0	-	3.1	3.3	11.2
Cleaner tailing 1......	5.3	12.0	1.4	67.4	-	2.0	2.5	8.5
Rougher tailing	34.3	9.2	.8	73.2	.17	10.0	9.9	60.0
Calculated heads	100.0	31.6	2.9	41.9	-	100.0	100.0	100.0

	Reagent consumption, pounds per ton					
	Conditioning	Cleaners				Total
		1	2	3	4	
Reagents:						
Sulfuric acid..........	4.0	4.0	4.0	2.0	2.0	16.0
Sodium fluoride........	2.0	2.0	2.0	2.0	2.0	10.0
Collector emulsion[2]....	20.0	2.5	2.5	2.5	2.5	30.0
pH	7.0	6.3	5.3	6.7	5.2	

[1]Ground to 5 percent on 200-mesh.

[2]Collector emulsion comprised 16 percent No. 2 fuel oil, 8 percent tall oil, 1 percent petroleum sulfonate, and 75 percent water.

TABLE A-9. - Results of reductive roasting with natural gas' and wet magnetic separation of composite surface and under-ground ore (20, pp. 30-31) on Hieroglyphic Mountains (Pikes Peak), hematite-magnetite taconite, Maricopa County, Ariz., 1943

Products	Weight-percent	Chemical analyses, Dercent			Distribution, percent	
		Fe	Mn	SiO_2	Fe	Mn
Reduced ore ground to 48-mesh:	56.0	55.5	3.6		94.0	59.8
Magnetic concentrate...........				11.9		
Nonmagnetic tailing	44.0	4.5	3.1	-	6.0	40.2
Calculated heads...............	100.0	33.1	3.4	-	100.0	100.0
Reduced ore ground to 100-mesh:	53.4	58.2	3.5		93.4	55.7
Magnetic concentrate[2]...........				9.0		
Nonmagnetic tailing	46.6	4.7	3.2	-	6.6	44.3
Calculated heads	100.0	33.3	3.4	-	100.0	100.0

'Ore held at 625° C for one-half hour.
[2]Total analysis included 0.13 percent P and 2 to 2.5 percent Al_2O_3.

TABLE A-10. - Results of reductive roasting with fuel oil' and wet magnetic separation of composite surface and under-ground ore (20, pp. 30-31) on the Hieroglyphic Mountains (Pikes Peak), hematite-magnetite taconite, Maricopa County, Ariz., 1943

Products	Weight-percent	Chemical analyses, -Dercent			Distribution, percent	
		Fe	Mn	SiO_2 a	Fe	Mn
Reduced ore ground to 48-mesh:						
Magnetic concentrate[2]..............	49.6	55.2	3.5	12.3	86.2	50.4
Nonmagnetic tailing................	50.4	8.7	3.4	-	13.8	49.6
Calculated heads	100.0	31.8	3.4	-	100.0	100.0
Reduced ore ground to 100-mesh:	46.1	57.8	3.2		83.9	44.7
Magnetic concentrate...............				9.1		
Nonmagnetic tailing	53.9	9.5	3.4	-	16.1	55.3
Calculated heads	100.0	31.7	3.3	-	100.0	100.0

'One-fourth inch size ore held at 550° C for 1 hour.
[2]Total analysis included 0.15 percent P and 2 to 2.5 percent Al_2O_3.