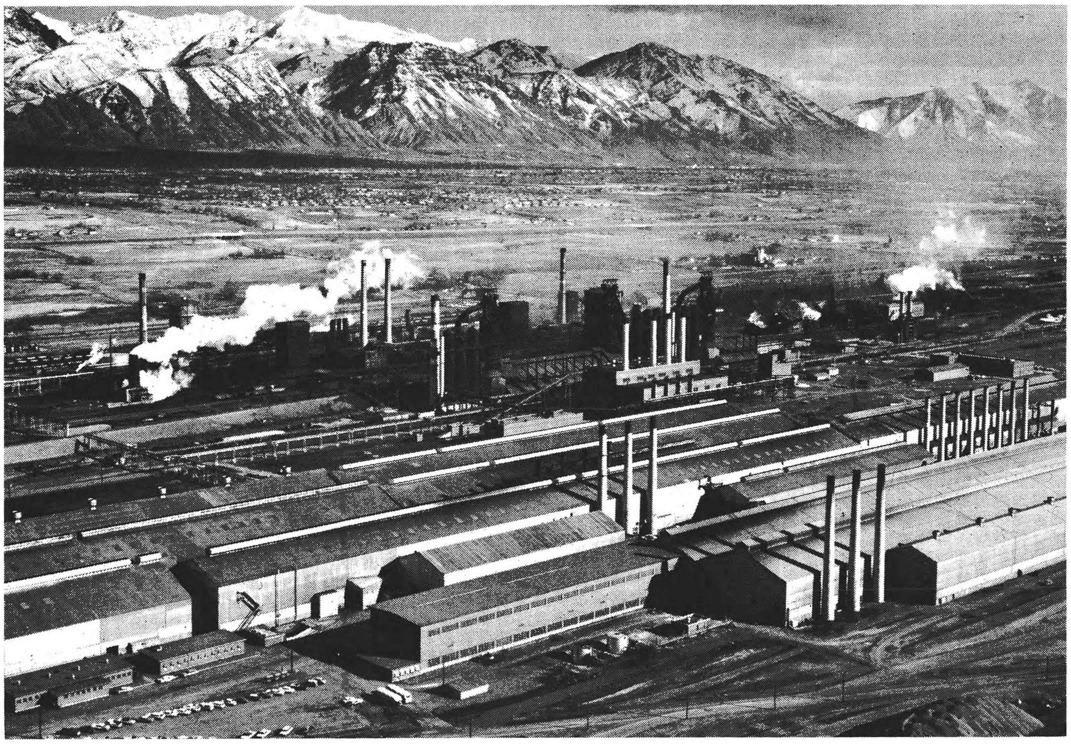
IRON DEPOSITS OF UTAH

by
Kenneth C. Bullock



Geneva Works, U. S. Steel Corporation, near Provo. Courtesy of U. S. Steel Corporation.

UTAH GEOLOGICAL AND MINERALOGICAL SURVEY
affiliated with
THE COLLEGE OF MINES AND MINERAL INDUSTRIES
University of Utah, Salt Lake City, Utah

BULLETIN 88 | **PRICE $4.50** | **DECEMBER 1970**

CONTENTS

ILLUSTRATIONS

Frontispiece: Geneva Works, U. S. Steel Corporation, near Provo, Utah. Courtesy of U. S. Steel Corporation.

Page

Table

IRON DEPOSITS OF UTAH

by

Kenneth C. Bullock[1]

ABSTRACT

Utah is the fifth ranking state in the nation in iron ore production. Small surficial iron occurrences discovered in fifteen counties were used for flux, ocher and other minor uses. Two iron deposits in Washington County with moderate ore potential have not been developed commercially. The only large iron production in the state has come from the Iron Springs district in Iron County.

Iron Springs district, on the east edge of the Basin and Range province in southwest Utah, is the largest iron-producing district in the western states. Ore bodies lie 12 to 20 miles west of Cedar City. Several open pit mines in operation are controlled by three major iron-producing companies. Iron ore was discovered in 1849; commercial production started in 1923.

Deposits in the Iron Springs district are clustered along the margins of three intrusions of quartz monzonite porphyry. They are oval in plan, 3 to 5 miles in diameter, and are aligned in a northeast direction. Jurassic, Cretaceous and Tertiary sedimentary strata and Tertiary volcanic rocks flank the intrusions. Concordance with the intrusive bodies has been overemphasized. Margins of two intrusions are complexly folded and faulted.

Principal iron ore minerals are hematite and magnetite. The ore occurs as contact metasomatic-hydrothermal replacements and breccia fillings mainly in Jurassic limestone, but also in younger strata and porphyry. Small fissure veins of magnetite occur in all three porphyry intrusions. From 1923 through 1968 the Iron Springs district produced 78,000,000 long tons of iron ore. Estimates based on drilling operations, geophysical data and geologic information indicate a probable ore potential in the district to be more than 300,000,000 long tons.

ACKNOWLEDGMENTS

The writer wishes to express appreciation to the Utah Geological and Mineralogical Survey, William P. Hewitt, director, for financial support and publication of this report, to Stephen R. Wilson, U. S. Bureau of Mines, and to the three iron mining companies operating in the Iron Springs district, Iron County, for the opportunity to examine properties, for information, and for some of the photographs used in this report.

[1]Professor of geology, Brigham Young University, Provo, Utah.

HISTORY OF THE IRON INDUSTRY IN UTAH

Iron ores in Utah were first discovered in 1849 in the Iron Springs district in Iron County, and major iron production from this district began in 1923. During the past half century the Iron Springs district has become the largest iron-producing district in the western states, making Utah the fifth state in the nation in iron ore production. The Utah iron mining industry may be divided into five stages in time over the past 120 years.

The first stage, from 1849 through 1884, marked by Mormon pioneer efforts to produce iron from Iron County deposits, was doomed to failure principally because of lack of funds and good coking coals and of competition of cheaper imported iron products after the completion of the transcontinental railroad through Utah. Only a few thousand tons of iron ores were mined and processed into finished products.

The second stage, starting about 1869 with the coming of the railroads to Utah and continuing until about 1922, marked the development of the nonferrous mining industry in Utah and the use of iron ores, chiefly limonite gossans, for fluxing purposes in the smelting of lead, copper, zinc, silver and gold ores. Several hundred thousand tons of fluxing iron ores were used during this time by Utah smelters. Small amounts of magnetite and hematite ores are still being used today.

The third stage of iron mining in the state, the Ironton Works stage, was a 20-year period from 1923 to 1942, marked by the completion of the Ironton blast furnace near Provo. Ore production from the Iron Springs district averaged 230,585 long tons annually, all of it shipped to Ironton. Iron mining was conducted by Utah Iron Ore Corporation and Columbia Iron Mining Company during this period.

The fourth stage began with World War II and extended to 1961 with the wartime construction of a huge steel plant at Geneva, near Provo, now known as the Geneva Works and owned by the U. S. Steel Corporation. Production in the Iron Springs district averaged 3,108,820 long tons annually during this time. Columbia Iron Mining Company, a subsidiary of U. S. Steel, greatly increased its shipments of ore to the Geneva and Ironton Works. CF&I Steel Corporation began production from its properties in the Iron Springs district in 1943 and made shipments of ore to its furnaces at the Minnequa Works, Pueblo, Colorado. Utah Construction and Mining Company started independent iron ore production from its properties in 1944 from the Iron Springs district. Its principal sales were made to the Kaiser Works at Fontana, California, and later to foreign markets. In 1958 they made a long-term contract with U. S. Steel to ship ore to the Geneva Works.

In the fifth stage, after 1961, iron ore production from the Iron Springs district was curtailed because the Geneva Works used about 1.5 million gross tons annually of taconite ores from U. S. Steel Corporation's operation at Atlantic City, Wyoming. Since 1962 the average annual iron ore production from the Iron Springs district has been slightly more than 2 million long tons. Taconite ores will continue to compete with iron ore production in Iron Springs district, since taconite concentrates average more than 60 percent iron content and Iron Springs district ores have averaged about 52.7 percent since 1923.

Iron occurrences in the Iron Springs district are clustered about three igneous intrusives in the form of limestone replacement bodies, breccia fillings and replacements, and fissure fillings in porphyry. The district will continue to be the only major iron producing district in Utah in the future. The Iron Springs district produced nearly 78 million long tons of iron ore from 1923 through 1968. The estimate of ore potential, based on drilling operations, geophysical data and geologic information, still exceeds 300 million tons, and additional ore bodies may be discovered in the district. In the future the iron ores may require increasing amounts of beneficiation to meet competition of taconite ores from Wyoming and Montana.

The study of Utah iron ore deposits shows that of the 29 counties in the state, 12 have few or no deposits, 15 have small surficial occurrences with small economic value, one has a moderate ore potential, and one county has major deposits and ore potential. Washington County has two deposits with moderate ore potential in the Bull Valley district. Iron County contains important iron deposits, all in the Iron Springs district. The main portion of this report is devoted to the Iron Springs and Bull Valley districts; the 15 counties with small deposits are discussed also.

BEAVER COUNTY

Beaver Lake Mountains Deposits

Beaver Lake Mountains deposits lie in the north third of the range near the base of Lime Mountain, about 14 miles by road northwest of Milford. The principal iron occurrences are on Bat Ridge in sec. 16, at Black Rock mine in sec. 19, and Skylark mine in sec. 20, all in T. 26 S., R. 11 W. (figure 1). Black Rock mine is held by assessment work by Hampton C. Burke of Milford.

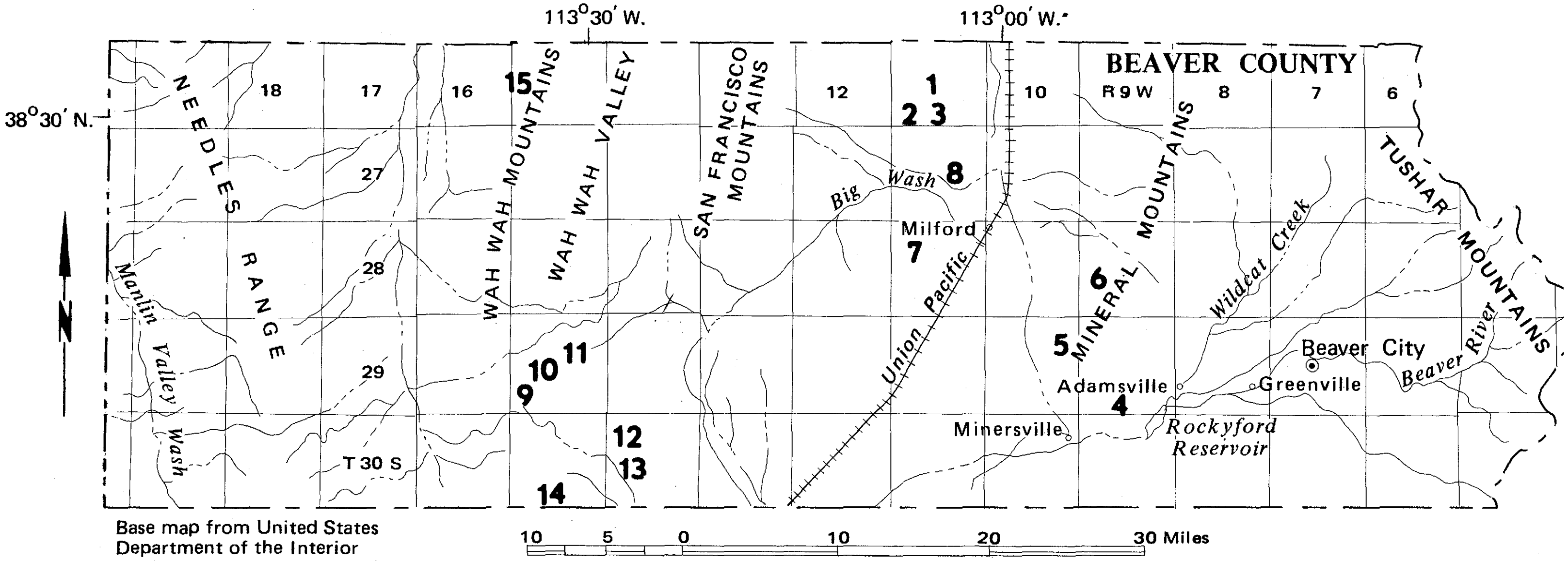
Beaver Lake Mountains form a low circular mass of hills with low relief, reaching 1,700 feet on Lime Mountain in the north portion of the range. This area is composed of Paleozoic strata that have been folded, thrust and cut by high-angle faults (Barosh, 1960). The strata near Skylark and Black Rock mines on the south flank of Lime Mountain are metamorphosed and probably are Ordovician Fish Haven and Silurian Laketown dolomites. Near the mines the strata are white to light gray in color and contain small amounts of tremolite. Undifferentiated Paleozoic carbonate rocks occur along Bat Ridge east of Lime Mountain.

The Tertiary quartz monzonite that intruded the Paleozoic strata is medium gray, medium-grained and granular in texture. It forms outcrops and boulders that disintegrate into arkosic grus. The intrusion altered the sedimentary carbonate rocks for varying distances from its contact, and in places has produced some mineralization. The alteration consists of rather extensive bleaching of dolomite, forming generally white to light gray recrystallized dolomite. Tremolite is occasionally present. The mineralization consists of a narrow sporadic zone usually less than 10 feet wide containing skarn minerals and some localized iron minerals.

Bat Ridge iron occurrence consists of a lens of magnetite and calcite, at the central part on the north side of the ridge. Adjacent to the igneous contact is a massive magnetite zone nearly 10 feet wide, followed by an 8-foot zone containing about 20 percent ore. The ore zone is mostly covered by float, but the mineralization extends for about 100 feet along the contact. No development work has been done here. A little farther on the northeast side of the ridge is a skarn zone similar to that at Skylark mine. Garnet and chlorite are abundant, and magnetite is limited. An adit penetrates this skarn zone parallel to the contact for about 150 feet. The Copper Mountain mine shaft is sunk into a skarn zone farther east. A few hundred tons of iron ore may be available from Bat Ridge.

Black Rock mine, near West Spring, about one-half mile west of the Skylark mine, is in a pipelike ore body of remarkedly pure specular hematite, that measures about 10 feet in diameter at the shaft collar. The deposit occurs near the intrusive contact, entirely within the carbonate rock. A 300-foot shaft was sunk in the hematite ore. Several hundred tons of ore were shipped to nearby smelters during the late nineteenth century. Nearly 200 tons are stockpiled at the mine, and perhaps several hundred additional tons are yet unmined. The stockpile contains nearly pure specular hematite.

Skylark mine has a mineralized zone about 20 feet wide and slightly longer at the shaft collar and lies in a small roof pendant of carbonate rock, nearly surrounded by quartz monzonite. The ore appears in a tactite-type rock containing magnetite and hematite. Other minerals present are epidote, quartz, calcite, cuprite, chalcopyrite, chlorite, garnet and limonite. A



Base map from United States Department of the Interior Geological Survey "State of Utah" 1959. 1:500,000

Figure 1. Beaver County iron occurrences.

1. Bat Ridge prospect, Beaver Lake Mountains
2. Black Rock mine, Beaver Lake Mountains
3. Skylark mine, Beaver Lake Mountains
4. Creole mine, Mineral Range
5. Cave mine, Mineral Range
6. The Iron mine, Mineral Range
7. Copper King mine, Star Range
8. Old Hickory, Montreal, Bawana and Maria mines, Rocky Range
9. Blawn Mountain prospects, Wah Wah Mountains
10. Blawn Wash Iron mine, Wah Wah Mountains
11. Dry Canyon prospects, Wah Wah Mountains
12. Emma mine, Wah Wah Mountains
13. Iron Duke prospects, Wah Wah Mountains
14. King Iron prospects, Wah Wah Mountains
15. Wah Wah Pass prospects, Wah Wah Mountains

few tons of iron ore were produced for fluxing at the nearby smelters in the late nineteenth century, and several tons of ore are stockpiled at the mine. Iron ore potential of the three occurrences is less than 5,000 tons. Chemical analyses of the ores are given in table 1.

Mineral Range Deposits

Creole mine lies four miles northeast of Minersville in the Lincoln mining district on the southwest end of Mineral Range, in sec. 29, T. 29 S., R. 9 W. (figure 1). A graded road extends northeast from Minersville for 3½ miles to where the road forks. The mine lies one-half mile along the right fork and is owned by Croff Oil Company of Salt Lake City.

Creole mine is a contact metasomatic deposit localized along a limestone and quartz monzonite contact. The mine was originally developed for lead-silver ore and later was worked chiefly for copper. In 1907 about 200 tons of limonite gossan were mined and used as a flux for smelters at Milford. Gold, silver, and copper were found. Nevada Massachusetts Company acquired a lease on the property in 1942 for the purpose of removing tungsten ore. In 1943 about 200 tons of tactite ore, containing disseminated scheelite ore, were mined. In 1966-67, 16 diamond drill holes showed a nonferrous ore zone ranging from 7 to 35 feet thick. About half of the holes penetrated a capping of limonite gossan or magnetite or a combination of both.

Sedimentary rocks near the Creole mine are Talisman quartzite, Pennsylvanian in age, and Kaibab limestone, Permian in age. The quartzite is gray to pink in color and weathers to a dark gray. It contains some limestone beds. The Kaibab limestone measures 700 feet thick (Earll, 1957), and is medium-bedded to massive, tan to light gray, with an abundance of chert which occurs in lenses, nodules and thin beds in limestone, and is light to medium gray in color.

The Tertiary quartz monzonite which intrudes the sedimentary rocks is medium gray to pink in color and weathers to gray and brown. It is composed of pink to flesh-colored orthoclase, white plagioclase and varying amounts of quartz, biotite and hornblende. It is cut by occasional aplite dikes.

The intrusive metamorphosed the limestone rocks, producing a tactite zone and mineralizing the host rocks. The principal minerals in the tactite are garnet, vesuvianite, epidote, tremolite, quartz, calcite and opal. The zone varies in width from less than one foot to more than 100 feet and lies adjacent to the intrusive contact. Primary ore minerals are magnetite, pyrite, chalcopyrite, bornite, scheelite and galena, and secondary minerals are limonite, malachite, azurite, cerussite, chrysocolla, copper pitch and manganese oxides. Where ore minerals are present they are intimately associated with tactite. The ore minerals and tactite are often capped by limonite gossan or magnetite, or a limonite zone overlain by magnetite. Mixtures of magnetite, tactite and sulfides are common.

The Creole property was developed by a steep inclined shaft with drifts, adits and recent drilling operations east of the mine. Drilling indicated a rather extensive nonferrous ore zone, overlain in part by limonite or magnetite or both. A limonite gossan zone exposed at the main workings is up to 10 feet thick. This zone is generally overlain by magnetite whose occurrences are localized, with irregular to lenticular outlines. Surface outcrops of magnetite are 50 feet long and less than four feet wide, except at one point where a magnetite-tactite zone measured nine feet wide. On the main working level of the mine a lenticular body of magnetite measures 12 feet thick.

One of several magnetometer profiles showed a fairly large anomaly, but profiles only 50 feet on either side showed no particular extension of this ore body. From surface and underground observations and from the geophysical data, the ore potential of the Creole mine is estimated to be less than 25,000 tons. Chemical analyses of the magnetite ores from the Creole mine are given in table 1.

Cave mine lies on the west side of Mineral Range in the Bradshaw mining district, nearly 10 miles by road southeast of Milford, in sec. 12, T. 29 S., R. 10 W. (figure 1). It lies a short distance south of Cave Canyon Wash along a steep mountain front at about 6,400 feet. The mine is accessible from Utah Highway 21, seven miles southeast of Milford, thence east nearly three miles along a poor dirt road. The property is owned by Croff Oil Company of Salt Lake City.

Ore was found in a cave in 1859, but little was done with it until 1875-76 when ore was shipped to the Milford smelter. The ore consisted of a series of cave-filling deposits along a fissure and replacement bodies in adjacent dolomite and dolomitic limestone. The ore, composed of limonite gossan and cerussite which contained gold and silver, was an oxidized residual of primary sulfides. Oxidation shrank the deposits and created void spaces above the ore in some caves. Ore was sometimes found on cave floors covered by fallen roof material. It was richest at and just above the floor, decreasing in values upward, and barren or essentially barren at the top. Some high-grade ore was produced; it was sold for a maximum of $800 per ton, but the average price was in the order of $25 to $30 per ton. Several hundred tons of ore were shipped in 1880, then little was done until 1900. Since this date Cave mine has yielded 1,400 tons of iron ore used as smelter flux.

The Cave mine deposits occur in Mississippian Redwall limestone, perhaps a thousand feet or more

Table 1. Analyses of iron ores in Utah, by county.

Location	Number of Samples	Fe	SiO_2	S	P	Mn	Cu
		Percentages					
BEAVER COUNTY							
Bat Ridge prospects, Beaver Lake Mtns.	1	48.6	7.6	0.044	0.02	0.098	
Black Rock mine, Beaver Lake Mtns.	1	57.2	1.4	0.044	0.16	0.06	
Skylark mine, Beaver Lake Mtns.	1	37.3	9.4	0.08	0.017	0.03	
Creole mine, Mineral Range	9	54.2	4.2	0.11	0.23	0.116	
Cave mine, Mineral Range	2	50.3	3.4	0.21	0.068	0.042	
The Iron mine, Mineral Range	1	51.3	8.6	0.76	0.025	0.43	
Copper King mine, Star Range	2	39.78	14.15	0.32	0.09	0.31	
Old Hickory mine, Rocky Range	2	46.5	12.5	0.05	0.26	0.13	
Bawana mine, Rocky Range	2	42.73	13.6	0.27	0.30	0.91	
Maria mine, Rocky Range	2	49.33	8.8	0.30	0.13	1.11	
Mill tailings concentrate, Rocky Range	3	68.4	6.0	0.48	0.26	0.87	
Iron Queen mine, Blawn Mtn., Wah Wah Mtns.	3	50.8	4.3	0.06	0.08	0.09	
Blawn Wash Iron mine, Wah Wah Mtns.	1	46.0	9.4	0.18	0.17	0.36	
Dry Canyon prospects, Wah Wah Mtns.	1	48.4	11.2	0.30	0.39	0.04	
Emma mine, Wah Wah Mtns.	1	55.1	10.4	0.30	0.11	0.81	
Iron Duke prospects, Wah Wah Mtns.	2	39.0	13.7	0.14	0.59	1.65	
King Iron prospects, Wah Wah Mtns.	2	45.6	8.4	0.16	0.06	0.20	
Red claim, Wah Wah Pass prospects, Wah Wah Mtns.	1	57.6	3.0	0.25	0.01	0.01	
West claim, Wah Wah Pass prospects, Wah Wah Mtns.	1	46.0	1.8	0.51	0.01	0.01	
BOX ELDER COUNTY							
Copper Mtn. mine, Pilot Range	3	48.9	13.4	0.12	0.18	0.12	
Tecoma mine, Pilot Range	3	41.7	10.4	0.02	0.03	1.57	

Table 1 (continued).

Location	Number of Samples	Fe	SiO_2	S	P	Mn	Cu
			Percentages				
West outcrop, Wasatch Iron & G.M.C. prospects, Wasatch Mtns.	3	50.4	18.4	0.04	0.06	0.06	
East outcrop, Wasatch Iron & G.M.C. prospects, Wasatch Mtns.	2	45.7	25.2	0.05	0.14	0.05	
CACHE COUNTY							
Magnetite ore, Deadman Gulch prospect, Bear River Range	1	57.5	5.76	0.06	0.12	0.01	
Hematite ore, Deadman Gulch prospect, Bear River Range	1	39.8	11.2	0.32	0.09	0.10	
Surface outcrops, Mineral Point mine, Bear River Range	2	67.1	4.1	0.05	0.02	0.03	
50-foot level, Mineral Point mine, Bear River Range	3	62.6	4.47	0.01	0.01	0.02	
Storage ore bins, Mineral Point mine, Bear River Range	2	61.5	9.39	0.01	0.01	0.02	
Shaft along fault contact, Mineral Point mine, Bear River Range	2	55.0	16.6	0.04	0.03	0.01	
DAGGETT COUNTY							
Rock Springs sandstone, Spring Creek prospects, Antelope Flat	2	21.2	51.4	0.04	0.10	0.14	
Quaternary iron bed, Spring Creek prospects, Antelope Flat	2	24.1	47.6	0.02	1.70	0.06	
Birch Creek prospect, Uinta Mtns.	2	36.4	39.3	0.09	0.56	0.06	
GRAND COUNTY							
Batchelor Basin prospects, La Sal Mtns.	3	48.2	20.2	0.47	0.05	0.01	
IRON COUNTY exclusive of Iron Springs district							
Iron Peak prospects, Markagunt Plateau	14	62.4	4.9	0.006	0.03	0.36	
JUAB COUNTY							
Little Oak Creek prospects, Canyon Range Limonite ore	2	45.5	8.0	0.01	0.04	0.04	

Table 1 (continued).

Location	Number of Samples	Fe	SiO_2	Percentages S	P	Mn	Cu
Little Oak Creek prospects, Canyon Range Hematite ocher	2	41.0	15.3	0.11	0.07	0.10	
Iron Blossom mine, Drum Mtns.	2	58.2	5.2	0.20	0.02	0.03	
Black Jack Iron mine, East Tintic Mtns. East outcroppings	1	50.5	12.6	0.18	0.52	0.17	
Black Jack Iron mine, East Tintic Mtns. Main outcroppings	2	53.6	7.3	0.18	0.42	0.15	
Dragon mine, East Tintic Mtns.	2	56.0	4.5	0.20	0.45	0.16	
Lockheed mine, Sheeprock Mtns. Surface samples	4	58.2	8.7	0.14	0.09	0.25	
Lockheed mine, Sheeprock Mtns. 70-ft. level, 375-lb. sample	1	60.1	5.2	4.45	0.14	0.01	
MILLARD COUNTY exclusive of Cricket Mtns.							
Iron Mine Pass prospects, Beaver Mtns. West prospect	2	53.8	2.9	0.09	0.29	2.52	
North Fork prospect, Pavant Range	2	51.2	4.8	0.23	0.24	0.02	
Widemouth Canyon prospect, Pavant Range 80-ft. shaft	3	46.5	1.8	0.09	0.02	0.26	
Widemouth Canyon prospect, Pavant Range Surface outcroppings	3	35.3	1.4	0.14	0.01	0.02	
Twin Peaks prospect, Twin Peaks	7	60.7	3.8	0.013	0.019	0.15	
MORGAN COUNTY							
Queen of the West mine, Wasatch Mtns. Main shaft, gossan ore	2	56.6	4.6	0.05	1.06	0.12	
Queen of the West mine, Wasatch Mtns. Surface gossans	3	50.2	4.1	0.07	0.27	0.10	
Queen of the West mine, Wasatch Mtns. Magnetite outcrops	2	48.2	2.7	0.80	0.50	0.11	
SALT LAKE COUNTY							
Big Cottonwood mine, Wasatch Mtns. Metallurgically tested ore	50 lbs.	37.35	18.2	0.96	0.01		1.67

Table 1 (continued).

Location	Number of Samples	Fe	SiO_2	S	P	Mn	Cu
Big Cottonwood mine, Wasatch Mtns. High-grade magnetite	2	56.1	6.8	0.27	0.34		0.16
SEVIER COUNTY							
Krotki Iron deposit, Antelope Range, Stalactitic massive ore	5	57.7	4.77	0.08	0.024	1.27	
Krotki Iron deposit, Antelope Range, Ocherous ore in tuff	3	51.2	1.60	0.04	0.028	1.48	
TOOELE COUNTY							
Iron Claims prospect, Deep Creek Range	2	41.4	24.2	0.01	0.015	0.29	
Gold Hill barite-limonite prospect, Deep Creek Range	3	37.7	27.2	0.25	0.19	0.02	
Iron King mine, Sheeprock Mtns.	5	61.3	6.54	0.02	0.03	0.09	
Consolidated Lela prospects, Stansbury Mtns.	3	60.1	11.3	0.45	0.02	0.01	
Skull Valley Indian Reservation prospects, Stansbury Mtns.	3	46.4	29.8	0.50	0.09	0.01	
UINTAH COUNTY							
Black Canyon prospects, Uinta Mtns.	2	25.6	35.8	0.78	0.07	0.04	
Cow Hollow prospect, Uinta Mtns. Hematite ore	2	52.6	4.8	0.24	0.02	0.02	
Cow Hollow prospect, Uinta Mtns. Gossan ore	2	29.2	5.4	1.60	0.04	0.02	
Dry Fork prospects, Uinta Mtns. Hematite ore	2	33.2	40.8	0.74	0.02	0.06	
Mosby Park prospect, Uinta Mtns.	2	42.8	22.4	0.07	0.40	0.05	
Pope Iron mine, Uinta Mtns.	6	53.2	2.21	0.29	0.04	0.06	
Wild Mountain prospects, Uinta Mtns.	2	29.9	47.2	0.06	0.02	0.06	
UTAH COUNTY							
Iron King mine, East Tintic Mtns.	4	46.8	6.45	0.10	0.39	5.60	

Table 1 (continued).

Location	Number of Samples	Fe	SiO_2	Percentages S	P	Mn	Cu
Diamond Fork prospect, Wasatch Mtns.	2	44.8	19.4	0.10	1.98	0.03	
WASATCH COUNTY							
Ferry Iron mine, Uinta Mtns.	6	57.2	20.1	0.05	0.02	0.07	
WASHINGTON COUNTY exclusive of Pilot deposits							
Buckey claims, Bull Valley district	3	50.6	15.2	0.034	0.39	0.12	
Cove Mountain deposits, Cove Mountain, Bull Valley district	20	44.7	31.6	0.39	0.05	0.18	
Farnsworth prospects, Mastodon claims, Bull Valley district	3	62.3	9.26	0.21	0.015	0.10	
Farnsworth prospects, Low Down claims, Bull Valley district	2	56.5	9.8	0.02	0.042	0.25	
Farnsworth prospects, High Up claims, Bull Valley district	3	58.2	4.72	0.03	0.023	0.31	
Soft Iron prospects, Bull Valley district	5	44.7	16.5	0.076	0.19	0.24	
Emma mine, Mineral Mtn.	3	38.6	11.8	0.01	0.03	0.30	

in thickness in the Mineral Range (Earll, 1957). It consists of cherty gray limestone and dolomite that weathers light to medium gray and is thin- to thick-bedded. An igneous intrusion of quartz monzonite outcrops below the Cave mine and cuts the Redwall limestone. An abundance of tactite minerals has developed in places along the igneous contact.

The Redwall limestone was cut by faults of unknown but small magnitudes where primary ore mineralization took place. Oxidation of pyrite and galena converted these minerals into a spongy limonite and limonite ocher deposit containing cerussite and some gold and silver. Mine workings consist of a series of adits at varying elevations along the fissures, connecting drifts and raises. The oxide zone containing limonite and goethite gossan appears to have been largely depleted. Local miners say additional ore is available in the mine but the ore potential is probably small. Chemical analyses of Cave mine ore are given in table 1.

The *Iron mine* property, on McGarry Knoll on the west side of Mineral Range, lies seven miles southeast of Milford in sec. 20, T. 28 S., R. 9 W. (figure 1). The area is accessible from the Pass road that traverses the Mineral Range between Milford and Beaver. The property lies one mile northeast of a telephone booster station on the Pass road near the western mountain base. The property has been known as the PH and L mine, P and H mine, and The Iron Mine; the latter term is used on the Adamsville topographic quadrangle map. The property is held by E. W. Hood of Beaver.

McGarry Knoll is a prominent hill of bedrock nearly 150 feet high surrounded by Quaternary alluvium. A bedrock outlier consists mainly of Permian Kaibab limestone, Triassic Moenkopi Formation and a small exposure of quartz monzonite rock. Sedimentary formations strike northwest and dip steeply toward the east. The quartz monzonite intrusive forms a limited outcrop on the west side of the hill at the mine workings.

Kaibab limestone in the Mineral Range is a medium-bedded to massive, tan to light gray limestone, about 700 feet in thickness; it contains an abundance of chert. It is overlain by the Triassic Moenkopi Formation and consists of about 1,500 feet of red, brown and yellow calcareous sandstone and sandy shale, gray limestone, and red-brown to maroon sandy shale.

Along the southwest side of the knoll a quartz monzonite intrusive has cut the Kaibab limestone. A small contact metasomatic deposit of tactite with some magnetite has developed. A 50-foot shaft on the south end of the Knoll contained very little magnetite; the main mineralization occurs about 500 feet farther north along the southwest side of the outcrops. A tactite zone which can be traced intermittently for about 300 feet has a width up to 20 feet, and contains at least one layer of magnetite with a maximum thickness of two feet. The magnetite occurs as a replacement along a favorable limestone bed. The adjacent limestone has been marbleized to some extent. Of the three small workings, two prospect holes are less than ten feet deep and show little magnetite; the third operation consists of a short caved adit and an excavation 20 feet deep and 40 feet long that parallels the strike of the Kaibab limestone beds. The best exposure of tactite is shown in this pit. Outcrops of magnetite are small, but one layer can be traced about 40 feet and averages one foot thick. This property contains less than 100 tons of magnetite ore. A chemical analysis of the ore is given in table 1.

Star Range Deposits

Copper King mine lies five miles west of Milford, in the SW¼ sec. 5, T. 28 S., R. 11 W. (figure 1). The mine is accessible via Utah Highway 21, five miles west of Milford, then south two miles on a dirt road. The property consists of 13 patented mining claims owned by Eugene N. Davie of Milford.

Mineralization at Copper King is a contact metasomatic type. Talisman quartzite, Pennsylvanian in age, has been intruded by Tertiary quartz monzonite porphyry. Limited copper, iron and tungsten mineralization occurs along the contact. The Talisman quartzite consists of nearly 1,100 feet of fine-grained brown to pink orthoquartzite with some lenses of limestone and gypsum (Baer, 1962). The quartz monzonite porphyry contains about equal parts of orthoclase and plagioclase and 25 percent quartz. It has intruded and lies northwest of the Talisman quartzite outcrops.

The deposit consists of partial magnetite replacements in carbonate lenses of Talisman quartzite, with primary bornite, and secondary azurite, malachite and cuprite. Scheelite can be found along the mineralized contact. The property was originally developed for its copper content.

Iron mineralization can be traced intermittently for about 400 feet along the contact. Lenses up to 10 feet wide are exposed, and one shaft exposes magnetite to a depth of 110 feet. One exposure shows small amounts of magnetite across a width of nearly 50 feet. The property has been developed by four shafts and several prospect pits. Based on surface exposures and development work, the ore potential is estimated as ranging from 5,000 to 10,000 tons of magnetite ore. Chemical analyses of the ores are given in table 1.

Rocky Range Deposits

Rocky Range iron occurrences all lie at the south end of the range in secs. 22 and 23, T. 27 S., R. 11 W., about five miles northwest of Milford (figure 1). These deposits are the *Old Hickory, Montreal, Bawana,* and *Maria* mines. Bawana and Maria operations belong to the Cerro Verde group and were first operated by the American Mining Company, later by the West Toledo Mining Company, for their copper mineralization.

Rocky Range is composed of a belt of Triassic sedimentary rocks which have been intricately intruded by Tertiary igneous rocks. The Triassic Moenkopi Formation has a varied lithology in its 2,200-foot thickness (Hobbs, 1945). The lower portion is dark gray marine limestone and green shale, nearly 350 feet thick. Red, brown and green shales with interbeds of limestone make up the next 500 feet. The upper portion consists mainly of interbedded sandstone and shales. These sedimentary strata are steeply inclined or vertical in attitude and vary considerably in strike.

Igneous rocks of quartz monzonite and granodiorite compositions intrude the Moenkopi Formation and form small stocks, dikes and sills in sedimentary strata. Ore bodies are found near igneous contacts forming contact metasomatic type deposits which tend to be somewhat tabular and lenticular. Limestone beds forming the main host rocks were metamorphosed and mineralized to a rock composed mainly of magnetite, garnet, diopside, epidote and chlorite. The proportion of magnetite to silicates varies widely, from about 90 percent magnetite and 10 percent silicates to 90 percent silicates and 10 percent magnetite. Minor constituents are primary sulfides of pyrite, chalcopyrite and bornite; secondary copper ores are azurite, malachite, copper pitch and chrysocolla. Copper ranges from a trace to two percent and was the principal metal extracted during mining operations. Scheelite is found with the magnetite in Old Hickory mine.

The magnetite and copper ore body of *Old Hickory mine* was known for many years before extraction of copper in 1906-07. In 1917-18 the mine was worked for iron ore to be used as a flux, and in 1941-43 18,000 tons of tungsten ore were removed. The property was developed by a 300-foot shaft and several working levels. Most of the ore above the 80-foot level was stoped out to the surface forming a glory hole. The main Old Hickory magnetite ore body forms a tabular block cut by a quartz monzonite dike. It measures about 450 feet long, 6 to 30 feet wide and roughly 300 feet deep. This property is estimated to contain at least 100,000 tons of magnetite ore.

The nearby *Montreal magnetite-copper property* was known prior to 1900. Copper production has been intermittent and small, and no known iron production is recorded. A magnetite ore body about 50 feet long and 12 feet wide at the surface of the mine was covered by waste rock from the Bawana open pit mine.

The *Bawana magnetite-copper mine* lies northeast of the Old Hickory mine about one-quarter of a mile. Geochemical and geophysical surveys outlined an anomalous area, and exploratory drilling disclosed an ore zone 500 feet in strike and 70 feet wide, with the ore body dipping steeply to the northeast. Ore minerals occurred as a replacement of a roof pendant of a limestone member of the Moenkopi Formation that lies adjacent to a mass of quartz monzonite. In 1962 stripping operations began, and a flotation plant with a daily capacity of 400 tons of ore was put in operation. The plant is two miles south of the Bawana open pit. The property was largely mined out by 1967, producing roughly 700,000 tons of ore. At present the iron ore concentrate is collected in a tailings pile adjacent to the plant. Ore processed in the flotation plant contains 20 to 25 percent iron, principally magnetite.

The *Maria magnetite-copper ore body* was discovered by geophysical surveying and lies about one-quarter mile west of the Bawana open pit. Stripping operations in 1967 exposed the top of the ore body that measures about 600 by 50 feet. The mineralogy and general geology is similar to the Bawana mine. It is estimated that the Maria ore body contains about 500,000 tons of magnetite-copper ore.

The total ore potential of Old Hickory, Bawana and Maria mines and their extensions probably ranges between 1.5 million and 2 million tons. The iron ore potential lies in the copper byproduct concentrate, consisting of high-grade magnetite which is wasted in mill tailings. Chemical analyses of these ores and the mill tailings concentrate are given in table 1.

Wah Wah Mountains Deposits

Blawn Mountain prospects are located on Blawn Mountain in the southern Wah Wah Mountains, 21 miles northwest of Lund. The crest of the mountain is an east-west trending ridge of white silicified rhyolite with a maximum elevation of 8,390 feet. Iron mineralization lies along this ridge in the S½ sec. 30, T. 29 S., R. 15 W. (figure 1). The largest iron outcropping is the Iron Queen mine. The property is held by assessment work by Mickey Robis of Milford and Murray, Utah.

Blawn Mountain consists of Paleozoic quartzite and dolomites that have been intruded by rhyolite and rhyolite porphyry (Miller, 1959) which lie mainly north of Blawn Ridge. The oldest sedimentary formation in the immediate area is Ordovician Eureka quartzite, a white fine-grained orthoquartzite, perhaps 150 feet thick. The south side of Blawn Mountain is bounded by dolomites that conformably overlie the Eureka quartzite. The oldest of these strata consists of 400 feet of alternating beds of black and medium to light gray dolomite which is correlated with Ordovician Fish Haven dolomite. These strata are overlain by about 1,200 feet of light to medium gray dolomite correlated with Silurian Laketown dolomite. Conformable above these strata are about 300 feet of dense and light-colored Devonian Sevy dolomite.

Hydrothermal activity has produced argillic and alunitic alteration and silicification (Whelan, 1965). The argillic alteration produced extensive kaolinite deposits of potential economic value. The kaolinite is massive, remarkably pure, and is tan and white; the tan color is caused mainly by surficial iron staining. Some dickite and montmorillonite are present. The alunite is tan and white and is distinguished from the kaolinite by its powdery character. At the Iron Queen mine alunite overlies kaolinite. The crest of Blawn Mountain consists of silicified rhyolite porphyry, white in color and forming a hard porcelain-like rock.

There are 10 small iron occurrences on Blawn Mountain occurring near the rhyolite intrusive and dolomite contact as small lenticular replacement pods in hydrothermally altered dolomite. Most of the exposures more or less align themselves in a west-northwest direction for 4,200 feet. The chief iron ore is hematite, containing varying amounts of magnetite, goethite and limonite. Much of the ore is dense with a dark brown to black color; occasionally masses contain voids partly filled with limonite and goethite. Some samples are iridescent and others are slightly magnetic. The ore lies adjacent to or surrounded by kaolinitic and alunitic alteration zones, and veinlets of kaolinite cut the ore. Small quantities of purple fluorite and manganese oxide ores are also present.

Iron Queen mine, the largest iron occurrence, lies midway along the iron ore alignment. Mineralization on this outcrop extends for 250 feet with a maximum width of 60 feet. The property has been developed by glory holes, an adit and drifts. Several hundred tons of iron ore were shipped from this mine to the San Francisco mining district to be used as a fluxing ore. A recent drift driven about 150 feet below the surface outcrops exposed a replacement body of ore seven feet thick.

Most of the other iron outcrops on Blawn Mountain have been prospected by shallow pits and trenches, with few or no shipments. Some of the iron outcrops and old workings were buried or destroyed by recent development work in search of kaolinite. The Blawn Mountain iron ore potential is probably less than 1,000 tons of gossan ore, principally associated with the Iron Queen mine. Chemical analyses are given for the Iron Queen mine in table 1.

Blawn Wash iron mine is on the north side of the wash near the head of the canyon on the southeast end of the Wah Wah Mountains, about one and one-half miles northeast of Blawn Mountain in sec. 20, T. 29 S., R. 15 W. (figure 1). The property is situated about 22 miles by road from Lund and 38 miles via Utah Highway 21 from Milford. It has been restaked several times.

The iron occurrence is associated with undifferentiated Ordovician Fish Haven and Silurian Laketown dolomites. The Fish Haven consists of 400 feet of light gray to black dolomite. The Laketown is estimated to be about 1,200 feet thick near the Staats mine, a light to medium gray, medium-bedded dolomite about three miles southwest of the property. One mile east of the mine in Dry Canyon, Ordovician-Silurian strata are exposed as an overthrust sheet resting tectonically on Mississippian strata (Miller, 1959).

Iron ore occurs along a high-angle fault in the overthrust sheet; the ore deposit consists of a fissure-filling and a bedded replacement deposit. The ore consists mainly of goethite and limonite gossan with some hematite and manganese oxides. The property was developed by a shaft about 50 feet deep, a drift, and a stope that has caved near the shaft, forming a glory hole about 30 feet in diameter and 35 feet deep. Iron mineralization is exposed as a carbonate replacement in the glory hole and measures 10 feet long and 5 feet wide. Small stockpiles of iron ore are found near the shaft. Several hundred tons of gossan ore were shipped during the late nineteenth century to the San Francisco district for fluxing. A 20-foot shaft was sunk 100 feet southeast of the iron mine shaft in search of uranium during the early 1950's. The ore appears to be largely depleted, with perhaps less than a 200-ton ore potential remaining. A chemical analysis of the ore is given in table 1.

Dry Canyon prospects lie near the mouth of Dry Canyon on the southeast end of Wah Wah Mountains. Dry Canyon lies midway between Willow and South Willow creeks, about two miles south by road from Willow Spring. The iron prospects lie on each side of the road between two prominent knolls in sec. 14, T. 29 S., R. 15 W. (figure 1), about 24 miles by road north of Lund and 35 miles via Utah Highway 21 from Milford. The prospects were staked as Mainline claims by Lamar Hodges of Beaver, but no assessment work has been done.

Iron mineralization is associated with Pennsylvanian Ely limestone. The Ely forms the easternmost sedimentary outcrops in Dry Canyon where several hundred feet are exposed in a window through a thrusted plate of Ordovician-Silurian strata (Miller, 1959). The base is not exposed. The limestone is folded into a north-plunging anticline which has been cut by the overriding thrust plate and is composed of light to medium gray limestone with dolomite and a few interbedded calcareous sandstones and shales. Locally it contains abundant lenses and nodules of brown-weathering chert.

Several small iron outcrops in a gossan-type deposit are scattered over an area several hundred feet in radius; the largest outcrop measures only 20 feet in diameter. Three shallow prospect holes reveal that the main minerals are goethite and limonite, with small amounts of hematite and occasional manganese stainings. The ore occurs as small fissure fillings and bedded replacements and is hard and spongy. No iron ore has been shipped from this property. The ore potential is small, with less than 100 tons of iron ore exposed. A chemical analysis of Dry Canyon ore is given in table 1.

Emma mine is located about 15 miles northwest of Lund in the low hills west of Blue Mountain in the southeast Wah Wah Mountains. It lies in the hills immediately east of the lower Blawn Wash drainage in sec. 7, T. 30 S., R. 14 W. (figure 1). The mine is about three miles north of Adams Well, which is near the junction of Milford and Lund roads. The original Emma property consisted of eight claims and was held by assessment work for many years by Flag Mining Company. The property was restaked in 1967 by W. S. Neal.

Iron mineralization occurs in undifferentiated Cambrian strata which form the higher ridges and knolls north and east of Adams Well. These strata are Middle and Upper Cambrian carbonate rocks, part of the Blue Mountain thrust plate (Miller, 1959), over Mesozoic strata. A small window of Jurassic Navajo sandstone is exposed near the Emma mine. Iron ore occurs along high-angle faults near the thrust fault and is a gossan-type deposit. The ore is found as fissure fillings and partial replacements in the carbonate rocks on both sides of a prominent limestone ridge. The chief iron mineral is hard and ocherous hematite. Goethite, limonite and manganese oxides are abundant locally.

Emma mine and adjacent prospects were developed by numerous pits, adits and shafts; the adits are now caved. Several hundred tons of fluxing ore came from selective mining operations. The largest development work was at the Emma shaft, where the ore assayed about $5.00 per ton in gold on the surface outcrops. A shaft 220 feet deep was sunk and drifts were made on the 50-, 100-, and 200-foot levels, totalling more than 1,000 feet of workings. A small vein of copper was found on the 100-foot level. The iron ore potential is extremely small, less than 100 tons useful as ocher. A chemical analysis of the Emma iron ore is given in table 1.

Iron Duke (Iron Glory, Ruby) prospects are about 13 miles northwest of Lund in the low hills west of Blue Mountain in the southeast Wah Wah Mountains. These prospects lie one mile east of Adams Well which is situated near the junction of Milford and Lund roads, near a small reservoir 500 feet from the Milford road. They lie in sec. 17, T. 30 S., R. 14 W. (figure 1). The property has had various ownerships. They were restaked in 1967 by Glen Lowder of Springville who called them the Lowder claims.

Iron mineralization is associated with undifferentiated Cambrian strata which form the high ridges and knolls east of Adams Well. These strata, Middle and Upper Cambrian carbonate rocks that are part of Blue Mountain thrust sheet, were thrust over Mesozoic sedimentary rocks. The Cambrian formations are cut by numerous high-angle and tear faults. Tertiary volcanic rocks lie east of the property. Mineralization took place along a high-angle fault that cuts Cambrian carbonate rocks, and considerable brecciation and gouge has developed. A gossan deposit has formed with some fissure filling and partial replacement taking place along the fault. The main iron minerals are limonite and goethite, with some manganese staining. The ore is hard, spongy and clinkery in appearance.

The property was developed by two shallow shafts, each about 12 feet deep and lying within 50 feet of each other. A few tons of iron ore are stockpiled at each working but none has been shipped. The ore potential is small, with less than 100 tons in this occurrence. Chemical analyses of these ores are given in table 1.

King Iron prospect lies 15 miles by road northwest of Lund in the southern hills of the Wah Wah Mountains, in sec. 33, T. 30 S., R. 15 W. (figure 1). The property is held by assessment work by Lamar Hodges of Beaver.

Iron mineralization is associated with Middle and Upper Cambrian carbonate rocks that have been thrust over Jurassic Navajo sandstone. These Cambrian strata form most of the ridges and knolls rising above Tertiary volcanics and Quaternary alluvium and have a local relief of about 1,200 feet. Near the King Iron property the Cambrian strata strike northeast and dip about 35° northwest. They outcrop for eight miles in a north-south direction and three miles in an east-west direction. In the center of these outcrops is a large window through the Blue Mountain thrust plate in which Navajo sandstone of the autochthon is exposed. The Cambrian section of rocks consists of about 150 feet of olive green shales and more than 1,700 feet of medium to dark gray limestone, dolomitic limestone and dolomite.

The Blue Mountain thrust plate of Cambrian strata is cut by numerous tear and high-angle faults. The King Iron prospect lies along such a faulted zone in medium gray limestone. The ore consists of a gossan-type deposit containing limonite and goethite with some hematite. The deposit is largely a fissure replacement body in limestone. One large outcrop of iron ore measures 40 feet long and up to 12 feet wide; the ore is hard and massive and weathers to dark brown and black. The property was developed by numerous bulldozer cuts and one core drill hole. Large blocks of iron float are scattered below the iron outcrop. This ore body has potential of about 1,000 tons. A chemical analysis of the ore is given in table 1.

Wah Wah Pass prospects occur in the central Wah Wah Mountains, where Utah Highway 21 crosses the range. The summit lies 32 miles northwest of Milford at 6,445 feet. Two iron occurrences were prospected west of the summit and north of the highway. Red claim lies one and one-half miles northwest of the summit in SE¼ sec. 19, T. 26 S., R. 15 W. (figure 1). West claim lies a little over one-half mile west in the same section. The properties are unclaimed.

Sedimentary rocks in the Wah Wah Pass area consist of gently east-dipping Cambrian strata. Iron mineralization is associated with Orr and Weeks formations. The Orr Formation is exposed throughout most of the pass area, and Weeks Formation is exposed only on the west side of the range. Older Cambrian strata underlie these formations along the west side of the pass and are exposed at Lime Point. The Weeks Formation consists of 600 feet of light to dark gray laminated limestone and dolomite. The Orr Formation is composed of 1,400 feet of medium to dark gray, thin- to medium-bedded limestone (Erickson, 1966).

Intrusive igneous rocks of diorite and quartz diorite composition cut the sedimentary strata and are exposed discontinuously for four miles through Wah Wah Pass. Although much of the area is covered by grus and pediment gravels, the intrusives appear to be three separate plugs or stocks with numerous sills and dikes of similar composition. The topographic low of the pass is the result of more rapid weathering of the igneous rock compared to Cambrian sedimentary strata at higher elevations. The intrusives vary in quartz content and type of ferromagnesium minerals present but otherwise appear to be closely related. Textures range from coarse-granular to porphyritic-aphanitic. Fresh surfaces are medium to dark gray, and weathered surfaces turn brownish.

Intrusive igneous rocks have produced an irregular contact metamorphic aureole surrounding the stocks. The aureole varies from 200 to 2,000 feet in width and produces marble and skarn minerals. Marble composes most of the zone of alteration and is generally light colored and coarse-grained in texture. Locally, dark brown or greenish brown skarn rocks occur adjacent to igneous contacts; the main skarn minerals are grossularite, chlorite, anorthite, diopside, idocrase, calcite and forsterite.

Iron mineralization occurs at several places on the north side of the diorite intrusions through Wah Wah Pass, usually along the outer edge of marble or in adjacent limestone. Hematite is the main iron mineral and produces reddish outcrops in limestone and marble. Most of the iron occurrences are limited to staining of carbonate rocks. Mineralization occurs along bedding planes, joints, small fissures and faults, and as small pipelike bodies. Outcrops are suggestive of gossans and most have been prospected by shallow pits or shafts.

The two largest iron occurrences are found along faults with gouge up to five feet wide. At Red claim hematite occurs as a fissure filling and replacement in a four-foot gouge zone along a north-trending fault. Hematite occurs as small hard chunks and clusters in gouge. Some ocherous hematite and small amounts of limonite, turgite, goethite and manganese oxides are found. Not all of the gouge zone is mineralized. The deposit is associated with cherty, medium to dark gray limestone belonging to the Orr Formation. This property was developed by a 10-foot prospect pit into the side of the hill, then by mining along the fault zone by means of a short adit. A second iron outcrop is developed by a three-foot pit 200 feet farther north. This outcrop shows little gouge, has more massive hematite, and manganese oxides are present. At least 25 tons of bright red ore are stockpiled at the two dumps.

The iron ore on West claim in sec. 19 is a fissure filling and replacement in a marbleized zone of the Weeks Formation. Iron occurs in a five-foot gouge zone along a north-trending fault. The adjacent rock is light to medium gray marblized limestone; hematite is the main iron mineral and consists of hard clinkery ore, in large chunks and blocks in gouge. Some ore is iridescent. Limonite, turgite and manganese oxides are present. The small amounts of hematite are soft and ocherous. The gouge is not all mineralized, showing streaks of light-colored rock. This deposit was developed by a shaft nearly 30 feet deep and by a short drift northward along the gouge zone. At least 30 tons of ore are stockpiled at the shaft. Some shipment of iron ore appears to have been made from this property. Fifty feet east is a shallow prospect pit containing clinkery and spongy hematite, goethite, limonite, turgite and pyrolusite. Two iron-stained outcrops occur in marble east of the shaft about 500 and 1,000 feet respectively. Each shows a reddish staining of carbonate rocks over an area about 100 feet in diameter.

The iron ore potential of Wah Wah Pass deposits is small, fewer than 500 tons of hematite ocher. Chemical analyses of these ores are given in table 1.

BOX ELDER COUNTY

Pilot Range Deposits

Copper Mountain mine, in the Lucin mining district at the north end of Pilot Range, lies along the summit of the range about eight miles southwest of Lucin and about eight miles east of Montello, Nevada. The claims lie in secs. 9, 10, 15 and 16, T. 6 N., R. 19 W. (figure 2). The ore deposits were discovered in 1868 and the mining district was organized in 1872. Between 1886 and 1894 copper properties were extensively worked. During this interval iron ore, high in silica and aluminum, was mined and shipped to Salt Lake Valley smelters.

The largest iron and copper development was the "Glory Hole" at the summit of Copper Moun-

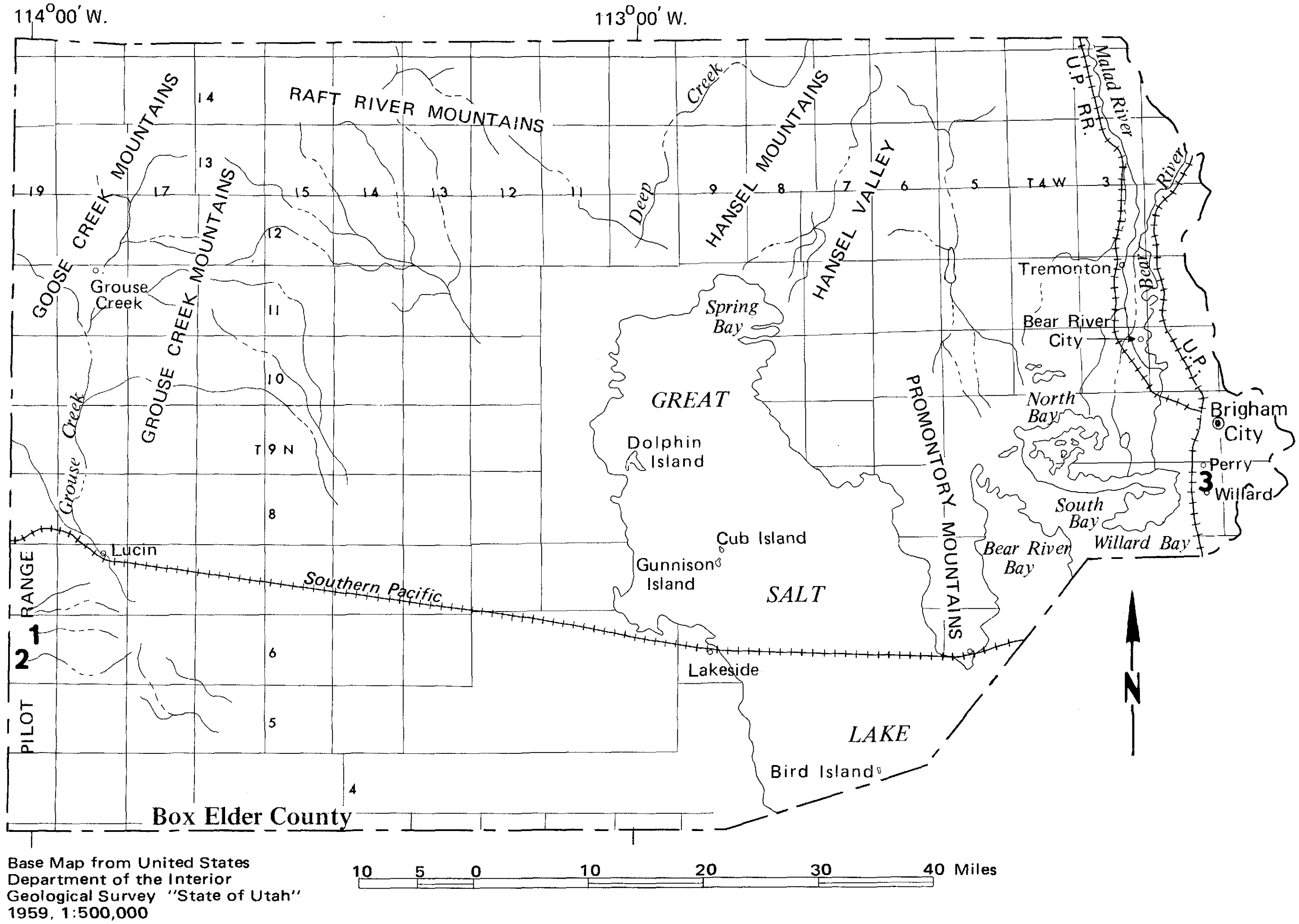


Figure 2. Box Elder County iron occurrences.

1. Copper Mountain mine, Pilot Range
2. Tecoma mine, Pilot Range
3. Wasatch Iron and Gold Mining Company prospects, Wasatch Mountains

tain. The original glory hole is now covered by waste from newer open pit operations. The last major mining operation was carried on in 1953, when about 9,000 tons of low-grade iron ore were mined from this glory hole area and shipped to Richland, Washington, for use by the Atomic Energy Commission. Copper Mountain mining property was purchased by the Uranium Petroleum Corporation (Upetco) in 1955.

Ore deposits at Copper Mountain mine are hydrothermal fissure fillings and replacement bodies along the Copper Mountain fault zone. Mineralization is genetically related to the Patterson Pass monzonite intrusive from which solutions have selectively replaced carbonate rocks and filled fissures. Sedimentary rocks that are mineralized are Ordovician Fish Haven dolomite, the Silurian Laketown Formation, and the lower member of the Devonian Guilmette Formation. Primary ores of copper, iron, silver, lead and zinc were formed and oxidized, forming oxidized and gossan ore bodies. Copper ore minerals are azurite, malachite, native copper, cuprite and chrysocolla. Iron ore minerals are goethite, limonite and hematite. Native silver, cerrusite, anglesite, and small amounts of primary galena have been reported. Copper and iron deposits were worked by open pits and extensive underground workings. Ore was removed to depths of 150 to 200 feet below the outcrops and consisted mainly of ocherous to hard, massive to spongy, reddish brown gossan. It often contains mixtures of white to reddish brown clay composed of halloysite, kaolinite and alunite. Copper content of the gossan varies greatly at different locations, from little or no copper to commercial quantities.

The principal structural control of the area is the Copper Mountain fault zone that trends northerly near the summit of the mountain. On the east side of the fault zone gossan contains only small quantities of copper, lead and silver. On the west side a high percentage of copper carbonates occurs with small amounts of iron oxides. These copper ore bodies are typically surrounded by masses of porous iron oxides.

Three main ore bodies are exposed at the Copper Mountain property within 2,000 feet; no connection among them was observed. The central and eastern ore bodies, forming continuous ore faces for 220 and 250 feet respectively, have been the most important producers, and of these two the central or "Glory Hole" gave the largest tonnage. The eastern ore body contains a low copper content in gossan and is truncated on the east by a vertical diabase dike. The western gossan ore body is smaller than the other two, but it has a similar type of ore.

More than 200,000 tons of measured and indicated ores containing 2.5 percent copper in gossans were determined on Copper Mountain property by Blue (1960). Reserves are estimated to be much larger. Many milling problems related to these ores make them unsuitable for either copper production or for steel making, but other uses such as natural pigments, atomic adsorption or other industrial uses could be developed in the future. Chemical analyses of these ores are summarized in table 1.

Tecoma mine lies on the northwest slope of the Pilot Range along the Utah-Nevada boundary line in the Lucin mining district. The mine lies approximately seven miles east of Montello, Nevada, in secs. 9 and 16, T. 6 N., R. 19 W. (figure 2). The property lies about one mile west of the Copper Mountain mine.

Metallic ore was discovered in the Lucin district in 1868. Between 1875 and 1890 more than 10,000 tons of high-grade oxidized lead ore were mined, largely from the Tecoma mine. Fourteen shipments of lead ore and approximately 2,000 tons of oxidized zinc ore went to American Smelting and Refining Company at Murray between 1914 and 1919. In 1920 Utah Zinc Company received 6,000 tons of zinc ore; no work of importance has been done at the Tecoma property since then. These ores were obtained mainly from gossan ore bodies.

The mines at Tecoma Hill are fissure fillings and replacement bodies in favorable carbonate beds. The original ores were mainly sulfides that were oxidized. Some primary galena, pyrite, chalcopyrite and sphalerite are present, but the sulfides are very limited in distribution. The ore is composed of substantial quantities of iron oxides as gossan which includes goethite, limonite and hematite. Commercial ore minerals in the past have been anglesite, cerrusite, wulfenite, smithsonite, hemimorphite, plumbojarosite, native gold and native silver. Alunite, halloysite and kaolinite clay minerals occur here.

The ore deposits are structurally controlled by east and northeast fractures in Paleozoic strata. Ore deposition is in Fish Haven and Laketown dolomites and the Guilmette Formation (Blue, 1960). The Ordovician Fish Haven is massive, gray to black calcareous dolomite, with chert nodules and stringers. This formation is typically a cliff former and measures about 375 feet thick. The Silurian Laketown dolomite is a light to medium gray dolomite and a calcareous dolomite. It is a conspicuous cliff-former and measures about 1,050 feet thick. The overlying Devonian Guilmette Formation is divisible into two members, the lower, a dark gray to black, thick-bedded limestone with dolomite stringers near the base and measuring more than 850 feet thick, and the upper, a fine-grained, massive, thick-bedded orthoquartzite 270 feet thick. These strata strike slightly west of north and dip about 30° to the east.

Patterson Pass monzonite stock outcrops over a considerable area on the east side of the Pilot Range. A few outcrops occur on the west side near the Tecoma Hill mines. An east-west dike cuts across the area. Underground exposures indicate that the dike thickens rapidly with depth. Other dikes have been intersected by underground workings.

The major structural feature at the Tecoma mine appears to be an east-west zone of brecciation paralleling the hanging wall side of the east-west trending monzonite dike. A few pronounced fractures paralleling the zone of brecciation show some mineralization as iron oxides but they are tight and of minor importance. A stronger series of northeast-striking fractures appears to have localized ore at various places along the dike. The main ore body of the Tecoma mine is approximately 50 feet wide and 600 feet long and lies adjacent to and parallels the dike (Young and Thurber, 1950). Almost complete replacement of carbonate has occurred in the upper 80 feet of the ore body. The principal minerals are iron oxides. Oxidation of the original sulfides resulted in a segregation of zinc and lead. The lead ore contains very little zinc and occurs as narrow pipes and bedded replacements extending irregularly through the main ore body. The enclosing gossan contains zinc carbonate with small quantities of lead. Most of the lead ore was mined out, and the gossan remaining consists of red, brown and yellow iron oxides containing varying amounts of smithsonite.

The Tecoma mine was worked through four adits, located at successively higher elevations. The three upper levels intersect the main ore body; most of the ore was taken from these workings. A 400-foot crosscut was driven from the surface to intersect a mineralized outcrop east of the main ore body. Several other adits and shallow shafts were dug, and most of the workings are open and accessible. The Tecoma mine has an estimated ore potential of 200,000 tons of gossan-type ore; much of it contains zinc. The ore would be most useful as a pigment in paint or related industries. Chemical analyses of the ores are given in table 1.

Wasatch Mountains Deposits

Wasatch Iron and Gold Mining Company property is located in the Willard mining district along the western front of the Wasatch Mountains, about three miles by jeep road northeast of Willard in the S½ sec. 13, T. 8 N., R. 2 W. (figure 2). Two main outcrops lie high above the valley floor midway between Willard Canyon and Facer Creek. The topography is steep and rugged. A jeep road extends east of U. S. Highway 91 about one mile north of Willard to the lower iron ore outcrops which lie at an elevation of about 5,500 feet. The second outcrop is approximately one-half mile farther east at a much higher elevation.

The original mining locations were made in 1870 and some shallow development work was done. Approximately 3,000 tons of iron fluxing ore were mined for use in local smelters, and 1,000 tons of ore were shipped to Ohio for use in steel mills. In about 1915, F. C. Fisher purchased the property and incorporated the Wasatch Iron and Gold Mining Company. The property is privately owned, and the major stock is controlled by Frank S. Mathis of Salt Lake City.

The geology of the Willard mining district is complex, consisting of Precambrian and Paleozoic strata that have been disturbed by folding and extensive overthrust and transverse faults. The Willard thrust is well exposed in the district. The Precambrian Mineral Fork Formation, consisting of quartzite, slate and tillite, is thrust over Cambrian Tintic quartzite, Ophir shale and undifferentiated Cambrian carbonate strata.

Iron mineralization lies in the overthrust Mineral Fork Formation and occurs as fissure fillings and replacements along southeast-trending faults associated with the Willard overthrust. The ore contains abundant brecciated fragments. The westernmost and principal ore body measures about 20 feet wide and can be traced continuously for 160 feet along the surface. The ore consists of blue-gray hematite, specularite, magnetite, limited reddish brown hematite and some malachite staining.

The other ore body, about one-half mile farther east and several hundred feet higher in elevation, measures 15 feet wide and is exposed for 50 feet along the strike. It contains abundant slickensides. The ore is composed of blue-gray hematite, specularite, some magnetite and malachite, and has a high quartz content. Iron float found between the upper and lower ore bodies apparently represents minor mineralization between the two ore bodies.

From the surface exposures and geophysical work done on the property, it is estimated that Wasatch Iron and Gold Mining Company has an ore potential of 50,000 and 100,000 tons. The deposits are composed of low-grade iron ore that is highly siliceous and contains large amounts of copper. Chemical analyses of these ores are given in table 1.

CACHE COUNTY

Bear River Range Deposits

Deadman Gulch (Red Bluff) prospects lie 35 miles northeast of Logan in the Bear River Range, in sec. 28, T. 14 N., R. 4 E., and are accessible from U. S. Highway 89 at the head of Logan Canyon (figure 3). The property is near the Cache-Rich County line, 1½ miles west of the highway. The property is held by Riley and LeMoille Harris of Hyde Park.

Iron mineralization occurs in the Cambrian Bloomington Formation, which consists of about 1,500 feet of gray, massive, thin-bedded limestone, some sandy argillaceous beds and a shale member at the base of the formation. Ore occurs in several small bedded replacements in limestone. Faulting does not appear to be a structural control for mineralization; if faulting has occurred the displacement is minor.

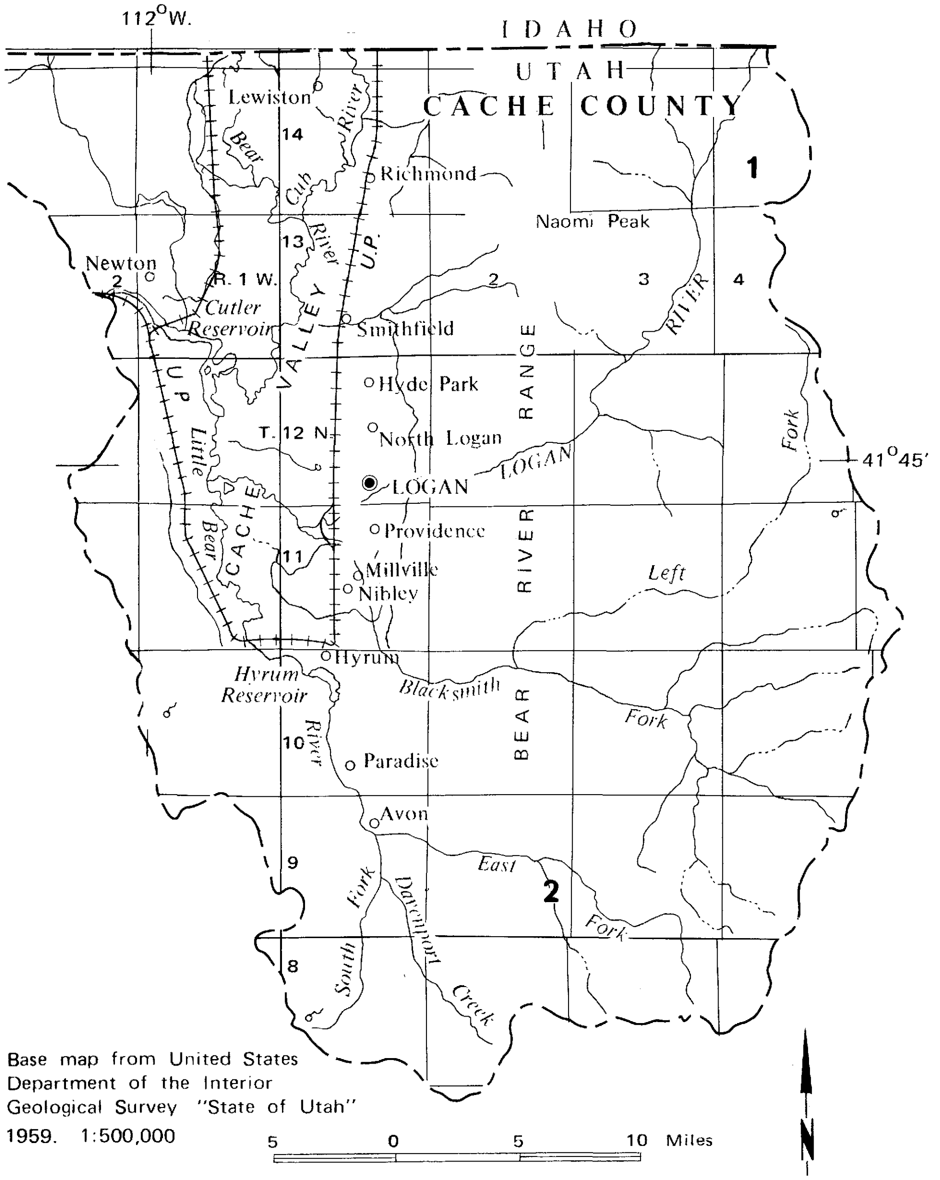


Figure 3. Cache County iron occurrences.

1. Deadman Gulch prospects, Bear River Range
2. Mineral Point mine, Bear River Range

Deadman Gulch prospects were developed by four bulldozer cuts in areas of reddish-stained limestone. One prospect hole exposed a small hematite replacement and another exposed limited magnetite replacement. The hematite is blue-black to reddish in color and is relatively hard; the magnetite is black, massive and high-grade ore. The iron ore potential is small for this property and has no commercial value. A chemical analysis is given for each type of ore in table 1.

Mineral Point mine is located on the east fork of the Little Bear River in the Bear River Range, about 13 miles east of Avon in NE¼ sec. 25, T. 9 N., R. 2 E. (figure 3). The deposit is accessible from Avon over a dirt road that follows the bottom of East Fork Canyon for about nine miles, then forms a series of switchbacks on the east side of the canyon to the deposit along the crest of Mineral Point ridge. The main underground workings at the 50-foot level are approximately 7,245 feet above sea level. The topography is relatively rugged, and the area is covered by a heavy growth of brush, aspen and mahogany; a few fir trees grow near the mine.

The Mineral Point iron deposit was discovered in 1875 by the Cranney family of Logan. In 1928, Supersteel Corporation of America purchased 32 unpatented claims from them. Charles P. Olsen made the last assessment filings on the property in 1964.

The deposit consists of hard, massive, steel-gray specular ore, well crystallized and composed of micaceous and foliated plates of hematite. Much of the ore is highly siliceous, with massive milky quartz and a few quartz crystals. A small quantity of red hematite ocher was found in the underground workings.

Strata in the immediate vicinity consists of Brigham quartzite and the Langston Formation, both Cambrian in age. Brigham quartzite is composed of purple, buff, gray and pink massive quartzite, with some conglomeratic beds, measuring about 2,000 feet thick. The Langston Formation, measuring 380 feet in this area, conformably overlies quartzite and consists of medium- to thick-bedded, crystalline, light gray dolomite which weathers to light tan, and some limestone and shale. The sedimentary rocks strike roughly northeast and dip 15° to 30° to the northwest.

Iron deposition occurs along the steeply dipping Mineral Point fault, which has brought the Langston Formation down to abut against the Brigham quartzite. Ore occurs mainly as a replacement body in dolomite of the downfaulted block. Near the footwall the ore is highly siliceous and consists mainly of fissure fillings in Brigham quartzite. The Mineral Point fault strikes northwest and dips about 75° to 80° southwest, with a minimum displacement of about 100 feet. Other faults are probably present, but they are of minor importance and cause small displacement near the mine.

The iron ore deposit is a hydrothermal replacement body along a fissure zone. Mineralizing solutions moved up along a fault zone, producing fissure fillings in quartzite. When dolomitic rocks of the Langston Formation were encountered, a wedge-shaped replacement body developed. Partial to complete replacement occurred in the dolomite, and pore space and fracture fillings took place in the quartzite. The ore replacing the dolomite is higher in iron content and is less siliceous than that found near the quartzite contact. Near the margins of the ore body the ore contains considerable unreplaced dolomite or quartzite fragments.

The iron deposit was originally explored by a 50-foot inclined shaft. The property was developed by extending the inclined shaft to 150 feet and connecting it by two adits or crosscuts. Since iron crops out near the crest of Mineral Point ridge, an adit was driven at the 150-foot level from the east side of the ridge for 375 feet. This level is cut entirely in Brigham quartzite in the footwall block. A second adit was driven at the 50-foot level from the west side of the ridge 525 feet. Short drifts to the north of this level helped to explore the deposit. The portal of this level is at 7,245 feet, 100 feet higher than the workings driven from the east side of the ridge. This 50-foot level is developed entirely in Langston Formation in the hanging wall block. The east adit and inclined shaft below the 50-foot level are inaccessible because of caved ground.

In 1928, Columbia Steel Corporation of California drilled three diamond drill holes on the property from the surface. One hole 80 feet deep was drilled in the footwall of the ore body. Siliceous iron ore was found in this hole to 57 feet. Two holes, 170 and 180 feet deep, were drilled west of the outcropping iron deposit. Both holes were collared in Langston Formation but entered the underlying Brigham quartzite at approximately 150 and 160 feet respectively. No iron ore was encountered in either of these holes.

In cross section the Mineral Point ore body is wedge-shaped and formed along the Mineral Point fault. At the surface the iron deposit measures up to 55 feet wide and can be traced for about 150 feet along its strike. With depth the width of the ore body decreases to about 40 feet in the workings of the 50-foot level. The ore body apparently then thins rapidly below this level since the base of the Langston Formation is reached about 100 feet below the surface outcroppings. The ore is then confined to small fissure fillings along the steeply dipping fault in Brigham quartzite. A slightly mineralized zone was encountered at the intersection of the Mineral Point fault on the 150-foot level. Several magnetometer profiles were made across the property. A slight anomaly appeared directly above the main iron outcrops. The ore body was essentially nonmagnetic.

The Mineral Point deposit was discovered in 1875, and only small lots of iron ore were shipped from this property. Supersteel Corporation of America shipped 600 tons to Pittsburgh, Pa., for testing, but the ore proved unprofitable. From geologic studies and the development work on the proptery, it is estimated that the ore potential of the Mineral Point mine ranges from 50,000 to 100,000 tons. Chemical analyses of the ores are given in table 1.

DAGGETT COUNTY

Antelope Flat Deposits

Spring Creek prospects are located on the north side of Antelope Flat in secs. 14 and 15, T. 3 N., R. 22 E., S. L. B. M. (figure 4). The area is six airline miles north of Flaming Gorge dam, 13 miles by road from the dam site. No mining claims are known to be staked on the property.

Iron mineralization, exposed at Spring Creek (Minnies) Gap, consists of brown limonite in thin lenses and nodules, and cement in sandstone. The occurrence forms a prominent bed three to eight feet thick along the crest of a hogback. Small amounts of pyrolusite are present. The iron occurs in the Rock Springs member of the Cretaceous Mesa Verde Formation. At Spring Creek Gap this member is 350 feet thick and composed of massive fine-grained sandstone. The iron occurrence is traceable for several hundred feet; it is highly siliceous and varies widely in physical appearance and chemical character. Other mineralized zones are traceable along the strike of the Rock Springs member, but no commercial iron ore occurs in this formation.

A second occurrence of limonite and manganese at Spring Creek Gap is a bed of limonite sand up to four feet thick and an overlying bed of manganiferous sand up to one foot thick, outcropping in Quaternary sediments. These beds can be traced about 400 feet along the east side of Spring Creek Gap at road level. The beds are horizontal in attitude, and abut against the steeply inclined Rock Springs sandstone and the previously described mineralized zone in the sandstone. These two occurrences could be confused by a casual observer. Neither the Cretaceous Rock Springs occurrence nor the Quaternary sedimentary beds have commercial potential. Chemical analyses of these two occurrences are given in table 1.

Uinta Mountains Deposits

Birch Creek prospect, in the Uinta Mountains about 16 airline miles southwest of Manila and 31 miles by Utah Highway 43 and 165, lies on the east slope of Birch Creek about 700 feet above the road in sec. 10, T. 2 N., R. 17 E., S. L. B. M. near the Summit County boundary (figure 4). The slope is steep and heavily forested, and no road or trail has been established to the property.

The prospect occurs on the north flank of the Uinta Mountains in undifferentiated Mississippian limestone exposed in a mile-wide band from the western border of Daggett County east for 15 miles, where it is faulted out by the Uinta fault. The iron occurrence is a gossan consisting of highly siliceous

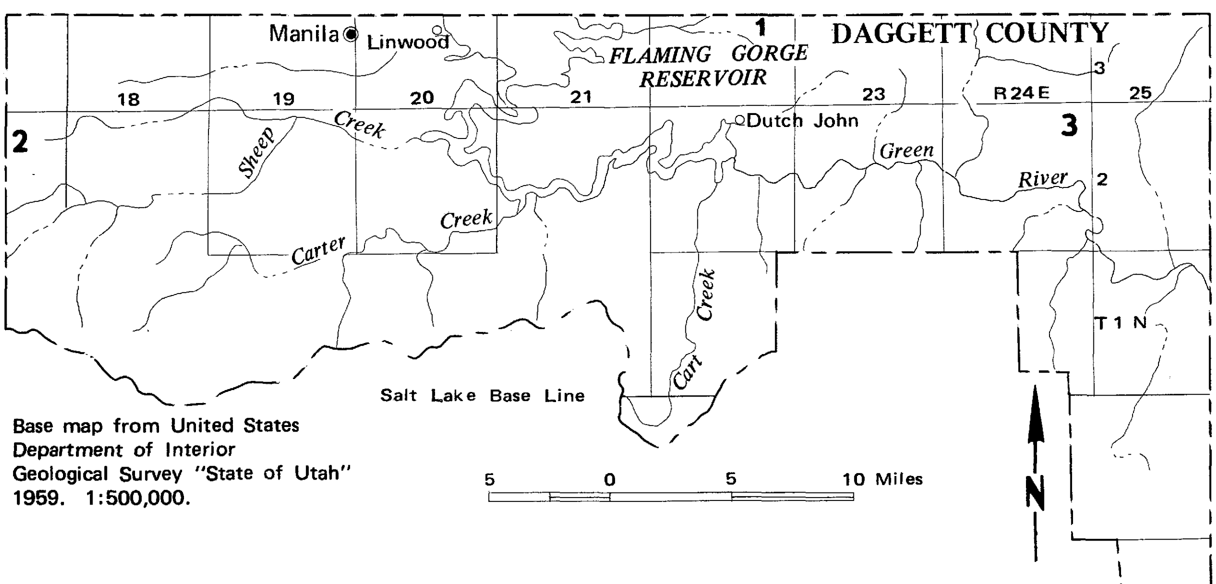


Figure 4. Daggett County iron occurrences.

1. Spring Creek prospects, Antelope Flat
2. Birch Creek prospects, Uinta Mountains
3. Red Creek-Willow Creek prospects, Uinta Mountains

limonite, goethite and hematite. These minerals have partially replaced brecciated limestone over an area about 10 feet wide and 30 feet long. The ore was bottomed at about 30 feet. Original development work was done by local ranchers in search of precious metals, none of which was found. The ore is low-grade and high in silica, and the ore potential of this prospect is extremely small. A chemical analysis is given in table 1.

Red Creek and *Willow Creek* are southward-draining tributaries to the Green River in the Uinta Mountains. These drainages lie about seven miles apart. Many small copper prospects, some with iron mineralization, occur in the canyons on the divides between Red Creek on the west and Willow Creek on the east. The area is bounded on the north by Clay Basin and on the south by Browns Park. The area lies in T. 2 and 3 N., R. 24 and 25 E., S. L. B. M. (figure 4).

Iron ore occurs as small fissure veins and disseminations associated with diorite and pegmatite dikes or along faults of varying magnitudes. It is commonly associated with quartz veins or is disseminated in quartzite and schist wall rock or in dike rock. Primary copper minerals are chalcopyrite and bornite; secondary minerals are chalcocite, malachite and azurite. Iron minerals are pyrite, limonite, goethite and hematite.

The prospects occur mainly in the Archeozoic Red Creek complex. This complex is composed of quartzite, mica schist, amphibolite, diorite, carbonates and pegmatites. Iron occurrences consist of limonite and goethite gossans or small veins of specularite or hard massive hematite. One vein of hematite measures one foot wide and can be traced for a few feet. Iron outcroppings are common, but they are so small that they were not sampled for analysis. The Red Creek-Willow Creek prospects have no commercial potential for iron ores.

DUCHESNE COUNTY

Uinta Mountains Deposits

Dry Gulch prospect lies in sec. 4, T. 2 N., R. 3 W., U. B. M. in the Uinta Mountains. The property is about one-half mile south of Heller Lake (figure 5), 43 miles northeast of Duchesne; it is accessible by the Altonah road to Dry Gulch. Glenn A. Hancock of Salt Lake City has four unpatented claims, the Linda claims, staked in the area.

The ore is a gossan deposit found in the basal section of the Pennsylvanian Morgan Formation, which is a light gray cherty limestone. Immediately below the gossan lies a black shale unit of the Mississippian series, a dark gray to black, highly organic and pyritiferous shale. The Morgan Formation is somewhat brecciated with some fault gouge. Iron mineralization occurs along the brecciated zone and has partially replaced limestone.

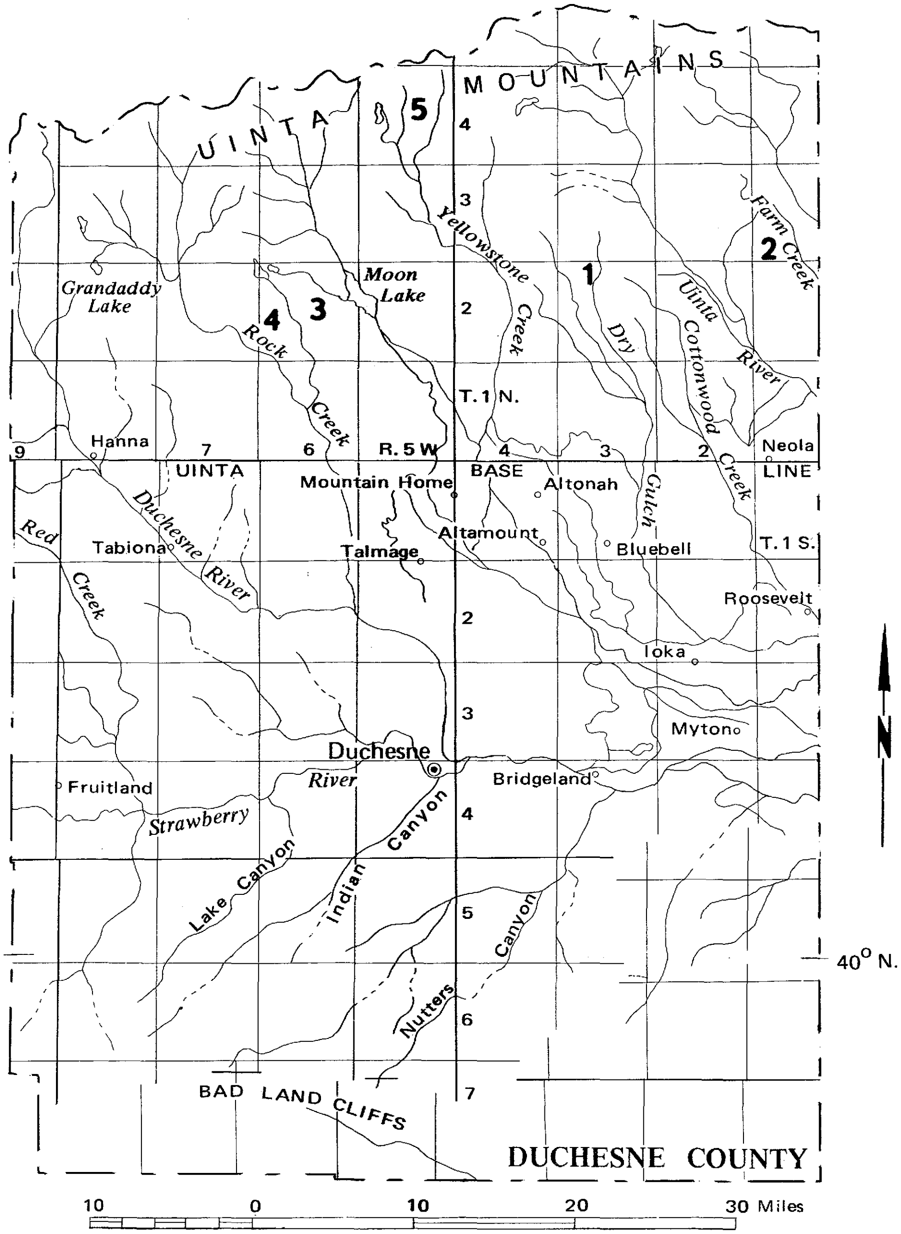
The deposit is a limonite and goethite gossan, cellular in nature and displaying iridescent color. Some manganese oxides and small amounts of hematite and pyrite can be found in the ore. The ore body, originally about 14 feet thick, has been disturbed by bulldozer cuts. The remaining gossan is less than four feet thick and can be traced for 100 feet. The ore potential of the Dry Gulch prospect is extremely small. Analyses of the ores are given in table 1.

Farm Creek prospects lie on the east side of Pole Mountain and the west side of Farm Creek in the Uinta Mountains, in sec. 33, T. 3 N., R. 1 W., U. B. M. (figure 5). The deposits lie 22 airline miles north of Roosevelt. It is 31 miles to the property by an oiled highway to Whiterocks, then north along Pole Mountain road. Six miles north of the Ashley National Forest boundary and the Elkhorn Guard Station is a logging road extending north for 1¼ miles. The nearest iron outcrop is about one-fourth mile farther north through forested land. Several prospects and two adits lie still farther north. The deposits have been staked under the names of Iron King, Iron Blossom, Black Laddle, Black Ruby, Black Slide, Lucky Strike and Red Bug claims. Utah Iron Corporation has staked 30 claims in this area.

Iron occurs along a faulted zone in Mississippian limestone which unconformably overlies the Precambrian Uinta Mountains group. The iron occurrences are generally near the base of exposed Mississippian rocks in brecciated zones, probably related to the South Flank fault zone of the Uinta Mountains. The hard, massive and spongy-textured ore deposits are limonite and goethite gossans. Mineralization consists of staining of limestone rocks, breccia fillings and partial replacements. Several prospect pits are cut into outcrops, and two short adits trend generally west into brecciated and iron-stained limestone. Several small iron outcrops are found in section 33 but all are small in size. Iron ore potential is probably less than 1,000 tons for all Farm Creek outcrops. A chemical analysis of a typical ore is given in table 1.

Moon Lake (Paint) mine lies approximately 40 miles south of Duchesne in the Uinta Mountains in sec. 15, T. 2 N., R. 6 W., U. B. M. (figure 5). It lies three miles west of Moon Lake at an elevation of about 10,000 feet and is accessible from Moon Lake road, one-quarter mile south of the lodge. The property consists of five claims held by assessment work by Ellis R. Maxfield of Midvale.

The deposit is composed of reddish hematite ocher which occurs in fault breccia and as pods or small lenses in Mississippian Madison limestone (Crittenden and Wallace, 1967). Small amounts of hard hematite and some limonite and malachite have been reported. A brecciated zone developed along the South Flank Uinta fault and was mineralized by fracture fillings and by partial replacements of limestone.



Base Map from United States Department of the Interior Geological Survey "State of Utah" 1959. 1:500,000

Figure 5. Duchesne County iron occurrences.

1. Dry Gulch prospect, Uinta Mountains
2. Farm Creek prospects, Uinta Mountains
3. Moon Lake or Paint mine, Uinta Mountains
4. Rock Creek prospect, Uinta Mountains
5. Tungsten Pass prospect, Uinta Mountains

Apparently renewed faulting crushed the ore into an earthy-ocherous product, but left some hard uncrushed hematite within lenses and pods of ore.

The area has long been prospected; there has been some mining of ore for use as ocher in the paint industry. During the summers of 1947 and 1948 the deposit was operated by two leasers. A small lot of 20 tons of hematite was sold to Bennett Paint Company of Salt Lake City. The steep rugged terrain makes mining operations difficult.

The mine was developed by two adits about 20 feet apart and reportedly 20 to 40 feet in length. Both adits are now completely caved. The Madison limestone is stained reddish near the workings, but outcrops of ore are poor because of talus, slump cover and inaccessiblity to the workings. Some iron float and the dump rock give a fair indication of the character of mineralization. Scanty hematite-bearing float in the vicinity of adits and limited production of ocherous hematite suggest a deposit too small for commercial exploitation. Chemical analyses of these ores are given in table 1.

Rock Creek prospect is 39 miles from Duchesne on the east side of Miners Gulch, a tributary of Rock Creek, and lies in the Uinta Mountains near the boundary line of secs. 18 and 19, T. 2 N., R. 6 W., U. B. M. (figure 5). The area is accessible from Utah Highway 35 from Duchesne and by Rock Creek road. The property was staked by Van C. Killian of Roosevelt. The property has been staked as the Hilltop, Red Ledge, Red Mare and Iron mine claims.

Rock Creek prospect is located along the South Flank Uinta fault. The ore consists principally of red hematite ocher, replacing limestone beds that were fractured and brecciated by faulting. The limestone belongs to undifferentiated Madison and Deseret formations, Mississippian in age.

The iron ore is chiefly hematite ocher occurring in pods and lenses in denser hematite. Some mineralization extends over an 8-foot zone and can be traced for 30 to 40 feet. Shallow shafts have been sunk in the best outcrops. Other outcrops show slight mineralization or staining of brecciated limestone. Ore potential of this property is small. A chemical analysis of this ore is given in table 1.

Tungsten Pass (Red Castle) prospect is located at Tungsten Pass in the high Uinta Mountains at about 11,000 feet, three airline miles southwest of Kings Peak in sec. 15, T. 4 N., R. 5 W., U. B. M. (figure 5). The area is accessible by road and several miles of trail from Yellowstone Creek, north of Mountain Home. The property was staked in 1954, but no assessment work has been completed since the original development work.

The iron outcrop is well exposed in a hillside cut. The ore is a specular hematite which occupies fractures and surrounds breccia fragments, and occurs in a 5-foot-wide fault zone which strikes north 60° east and dips 65° northwest, and in reddish brown quartzite of the Precambrian Uinta Mountain group. About three feet of mineralized rock contain 10 to 20 percent specular hematite and is traceable for 20 feet. Workings completely crosscut the deposit, exposing barren quartzite on both sides of the fault zone. Discontinuous specks of specularite are traceable for 120 feet along the fault zone. Bedrock exposures are excellent in the immediate area, and there is no likelihood that the occurrence extends beyond the above dimensions. The ore potential of this property is nil, and no samples were taken for chemical analyses.

GRAND COUNTY

Batchelor Basin prospects, about 15 miles east of Moab in Batchelor Basin on North Mountain of the La Sal Mountains, lie on the east side of Horse Mountain in unsurveyed secs. 11 and 14, T. 26 S., R. 24 E. (figure 6). The property is reached by 35 miles of road via Castle Valley and lies in the lower part of Batchelor Basin. The principal iron occurrences are on the Day and Petersen claims, composed of 30 unpatented lode claims. The property is held by assessment work by Lynn Day of Moab and Lloyd B. Petersen of Riverton, Utah.

The Day and Petersen claims have been restaked on land that was originally explored for gold and copper. Many old prospects and caved adits were left. Recent work was done by the present owners in search of iron ores. Small amounts of hematite, traces of malachite and some limonite are found on claim No. 3. Iron mineralization in Batchelor Basin is largely of the gossan type. Several other prospects and adits contain pyrite which has partially altered to hematite and limonite. Two shallow prospect pits contain small amounts of magnetite with occasional malachite staining.

The La Sal Mountains are composed of three distinct topographic masses, each of which is cut by a stock surrounded by a cluster of laccoliths radiating from the stock (Hunt, 1958). The earliest intrusions were diorite porphyry, followed by monzonite and later by syenite. Sedimentary rocks in the La Sal Mountains are late Paleozoic and Mesozoic in age. On North Mountain in the Batchelor Basin area, sedimentary rocks of undifferentiated Pennsylvanian and Permian strata have been intruded by diorite porphyry. The Day and Petersen mining claims are on or near the contact of sedimentary and igneous rocks. Mineralization is developed along zones of vertically sheeted joints in diorite and in fractured quartzose sandstone; similar mineralization occurs in Miners Basin on the west side of North Mountain. The iron ore potential on the Batchelor Basin property is small and of poor quality. Chemical analysis of the ore is given in table 1.

IRON COUNTY

Iron Springs District Deposits

Location and Geologic Setting

The Iron Springs mining district lies on the east edge of the Basin-and-Range province in southwest Utah, about 20 miles west of the Markagunt Plateau and the Hurricane fault scarp which form the west boundary of the Colorado Plateau. Ore bodies lie from 12 to 20 miles west of Cedar City in Iron County and occur in T. 35, 36, and 37 S., R. 12, 13, and 14 W. (figure 7). Iron Springs district is the largest iron ore-producing district in the western states. Several open pit iron mines are in operation in the district and are controlled by three major iron producing companies. Originally, the Iron Springs district included only Granite Mountain and Three Peaks deposits and the Pinto district included Iron Mountain operations. The Iron Springs district now includes the three iron-producing areas, covering a region about 4 miles wide and 21 miles long.

Three quartz monzonite porphyry intrusives are exposed at the surface and form the dominant topographic features of the district. These intrusives form the Iron Mountain, Granite Mountain and Three Peaks bodies. Exposed intrusions are oval in plan, three to five miles in diameter, and are aligned in a northeast direction. Jurassic, Cretaceous and Tertiary sedimentary rocks and Tertiary volcanic rocks flank the intrusive bodies. Concordance with intrusive rocks has been overemphasized. Margins of Iron Mountain and Granite Mountain intrusives are complexly folded and faulted.

Hematite and magnetite form contact metasomatic-hydrothermal replacements and breccia fillings in the Jurassic limestone. The principal ore deposits occur along borders of the quartz monzonite porphyry intrusives or in roof pendants of replaced limestone within the intrusives. Small fissure veins of magnetite occur in the quartz monzonite porphyry. Production from the Iron Springs district from 1923 through 1968 was more than 78 million long tons of ore, nearly all of which has been direct-shipping ore with a weighted average iron content of 52.7 percent.

Previous Work

The Iron Springs district received only passing attention by members of the early scientific expeditions of Powell (1875, 1878), Dutton (1880, 1882) and associates in their general surveys of the high plateaus and the Colorado River, and from the geologists of the Wheeler Survey–Gilbert (1875), Howell (1875) and Marvine (1875). Howell was the first of the early geologists to make anything like a specific description of the Iron Springs district and its iron deposits. Newberry (1880, 1881a, 1881b, 1882) regarded Iron Springs iron ores and intrusive rock to be metamorphosed sediments of probably Lower Silurian age. Putnam (1880) prepared the first map of the Iron Springs district, showing the location of mining claims and briefly describing some ore deposits. Blake (1886, 1893) made a brief note on the iron deposits and described the association of apatite with magnetite, and Hewett (1902) wrote a few notes on iron ores of southwest Utah. A general economic account of the district with special reference to the chemistry of the ores was made by Lerch (1904). Leith (1904, 1906) made a reconnaissance study of the Iron Springs district, tentatively regarding them as contact metamorphic in origin. Jennings (1904, 1905) believed the iron ores resulted from ore magmas which filled fissures in igneous rocks and formed sheets of ore in sedimentary rocks.

The first concerted geologic investigation of the Iron Springs district was made by Leith and Harder (1908). They mapped the area, described the sedimentary and igneous rocks, discussed some of the exposed ore deposits and proposed a contact metamorphic origin for the ores. Ores occurred along margins of laccoliths replacing overlying Carboniferous limestone, and formed fissure fillings in the intrusive bodies. The work of Leith and Harder was accepted with little question for several decades. Butler (1920) made a brief study of the district and expressed agreement with the work of Leith and Harder; however, he regarded the intrusive bodies as stocks rather than laccoliths. Rohlfing (1923) and MacVichie (1925, 1926) described some of the known ore bodies in the district based on outcrops and shallow development workings.

Brief reviews of the writings of Leith and Harder are given in textbooks by Lindgren (1933), Tarr (1938), Knopf (1933, 1942) and Emmons (1940), portraying a pyrometasomatic origin of Iron Springs deposits; they generally agree that the ores are associated with stocks. Wells (1937, 1938) regarded the intrusives to be plugs or stocks and suggested a pneumatolytic origin for the ores.

A detailed investigation of the Iron Springs district was started during World War II by J. H. Mackin of U. S. Geological Survey as a strategic mineral project. Plane table mapping of mineralized border zones of intrusions was accompanied by magnetometer surveys and diamond drilling by U. S. Bureau of Mines. Final reports covering magnetic studies and drilling were published by Young (1947), Allsman (1948) and Cook (1948, 1950). A preliminary geologic report on structural control of mineralization, with a map of the Three Peaks intrusion, was published by the Utah Geological and Mineralogical Survey (Mackin, 1947a). Mapping was subsequently extended throughout the district, and in 1951 a preliminary aeromagnetic map of the district was completed (Dempsey, 1951). In 1954 a geologic map of the Granite Mountain intrusion was published (Mackin, 1954). Lead-alpha age determinations of igneous rocks in the district are given by Jaffe (1959), and Bellum and Nugent (1963), and Granger (1963) briefly describe the general nature of ore deposits and mining operations in the district. In their textbook, Park and MacDiarmid (1964) review the literature of the Iron Springs district and describe the general geology and deuteric origin of the ore deposits as proposed by Mackin.

Lewis (1958) and Ratté (1963) made detailed investigations on rock alterations in the Iron Springs district. Slawson (1958) and Dahl (1959) performed detailed trace element studies on ores of the district, and a similar study was made on the Carmel Formation by Everett (1967). Magnetic beneficiation and concentration of iron ores in the district are treated by Erspamer (1964), Juvelin (1965), McArthur and Porath (1965), Juvelin and McArthur (1967) and O'Carroll (1967). Reports on a gravimeter survey (Cook and Hardman, 1967a, 1967b), an aeromagnetic survey (Blank and Mackin, 1967) and a preliminary report on the iron ore deposits (Mackin, 1968) of the Iron Springs district have recently been published. This writer gives a review of the studies of previous writers in addition to his own investigations and interpretations of the Iron Springs district. Detailed accounts of other investigations can be found in the cited literature. Plate 1 is a geologic map of the Iron Springs district.

Sedimentary Rocks

Jurassic and Cretaceous sedimentary rocks crop out in the Iron Springs district near the iron ore deposits. Jurassic marine limestone and siltstone are overlain by Jurassic and Cretaceous terrestrial clastic rocks. Tertiary sedimentary and layered ignimbrite volcanic rocks lie along the fringes of the district.

Carmel Formation is the oldest (Jurassic) stratigraphic unit exposed in the Iron Springs district, and is composed of the Homestake limestone and a basal

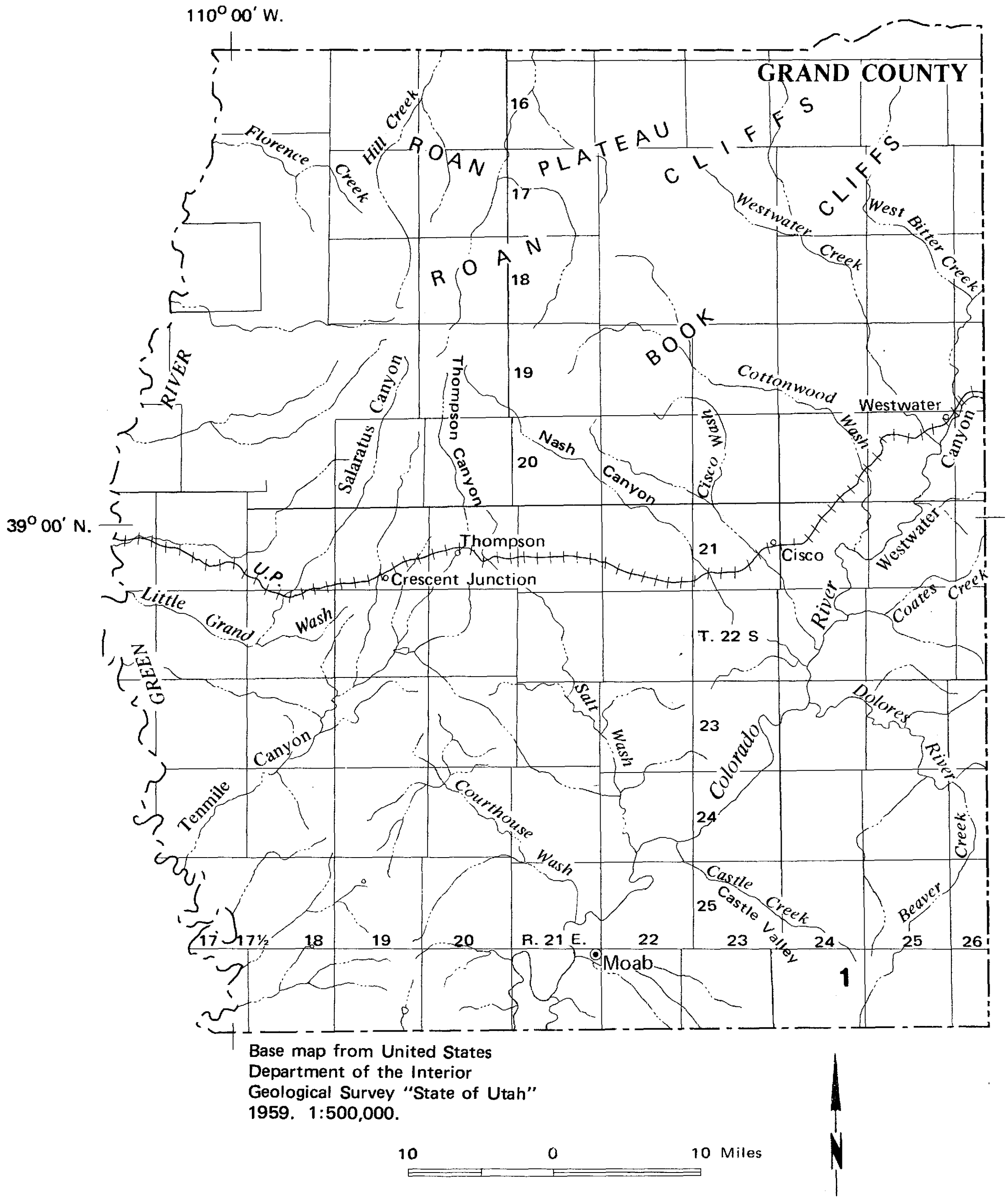


Figure 6. Grand County iron occurrences.

1. Batchelor Basin prospects, La Sal Mountains

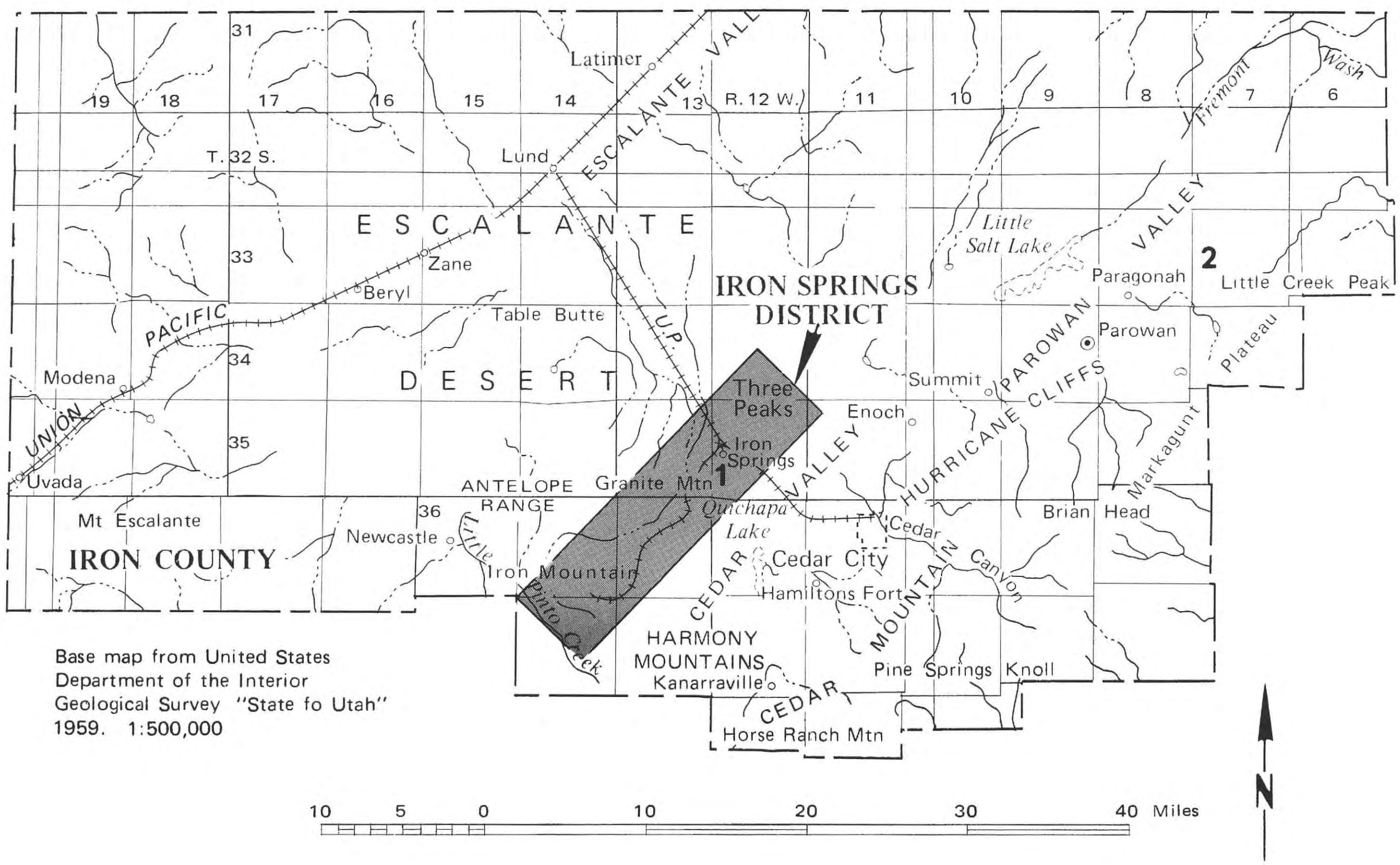


Figure 7. Iron County iron occurrences.

1. Iron Springs district, Iron Mountain-Granite Mountain-Three Peaks area
2. Iron Peak prospects, Markagunt Plateau

siltstone member. These strata form the innermost of several concentric belts of sedimentary and volcanic rocks around the igneous intrusions.

The basal siltstone is in contact with quartz monzonite porphyry intrusions, and is typically hard, fine-grained and generally thin-bedded, but may be massive. The color varies from light to dark greenish gray or grayish tan. Maroon banding and mottling are common, and rock coloration frequently is spotted or splotchy as a result of irregular alteration. A portion of the siltstone member is noticeably granular and is composed of small quartz grains. The basal siltstone varies in thickness to 100 feet, with an average thickness of approximately 50 feet. Variations in thickness are caused primarily by minor cross cutting by the intrusive contact.

Leith and Harder (1908) considered the basal siltstone to be altered limestone, a contact metamorphic phase of Homestake limestone. Mackin (1954), Lewis (1958) and Everett (1967) demonstrated that compositional differences between limestone and siltstone members are primarily stratigraphic. Contact metasomatic effects on the siltstone are limited to development of a fine-grained skarn rock. The siltstone is easily separable from Homestake limestone where the limestone is unaltered, but can be distinguished from silicified phases of limestone only petrographically. The basal siltstone is highly resistant to iron mineralization and commonly occurs as a barren layer between iron ore replacements in Homestake limestone and quartz monzonite porphyry. The Carmel Formation (Gregory, 1950) in the Colorado Plateau east of the district consists mainly of limestone underlain by tuffaceous siltstone, sandstone, limestone and gypsum, collectively called the Temple Cap member of the Carmel by Cook (1957). The Temple Cap member is underlain by Jurassic Navajo sandstone. In the Iron Springs district the basal siltstone is equivalent in part to the Temple Cap member in the Colorado Plateau.

The Homestake limestone member (Mackin, 1954) of the Carmel Formation consists of massive- to thick-bedded limestone from 210 to 300 feet in thickness, averaging approximately 250 feet. It consists chiefly of gray, blue-gray and black limestone, locally shaly or carbonaceous. Several beds contain a few Jurassic marine fossils which indicate it is equivalent to middle and upper portions of the Carmel Formation in the Colorado Plateau. Leith and Harder (1908) erroneously classified Homestake limestone as Carboniferous. The upper 5 to 20 feet of the Homestake limestone consist of light gray, thin-bedded, argillaceous and siliceous limestone which is composed locally of soft, gray-green, earthy limestone which is distinguished by its ripple marks and mudcracks, providing a good horizon marker. Also locally, a thin sedimentary breccia occurs at the top of the Homestake limestone member. This suggests that some parts of the limestone were exposed to weathering and erosion for a short time prior to Entrada deposition.

The Homestake limestone is the host rock for the iron ore replacements in the Iron Springs district. Ore normally replaces the lower half of the limestone member, but with increasing intensity of metallization the full thickness may be replaced. Where the entire Homestake limestone is replaced by iron ore, assay logs and drill holes indicate that the lower half contains high-grade ore ranging from 50 to 58 percent iron. The ore in the upper half of the formation averages 40 to 45 percent iron.

Entrada Sandstone. The Homestake limestone member of the Carmel Formation is overlain conformably by a clastic unit believed to be equivalent to Upper Jurassic Entrada sandstone of the Colorado Plateau (Gregory, 1950). Entrada sandstone in the Iron Springs district is quite unlike the red and white beds of friable, gypsiferous sandstone of the Colorado Plateau. In the Iron Springs district it consists of thinly stratified maroon and gray-green shales and siltstones and medium- to coarse-grained gray or gray-green sandstone. A basal unit composed of maroon and gray shale measures about 40 feet thick and often contains blebs of finely crystalline rose quartz and calcite which give the rock a pink and spotted appearance. An overlying sandstone about 20 feet thick contains deep maroon spots up to one-quarter inch in diameter; it is a distinctive horizon marker throughout the district. Upper Entrada sandstone consists of medium- to coarse-grained channel sandstone with interbeds of shale and siltstone. Layers of quartz sandstone usually occur as thin beds, and layers of arkosic sandstone are normally thick-bedded, both interlensing with variegated shale and siltstone. The upper 30 to 40 feet of Entrada sandstone often contain pink blebs of rose quartz and calcite similar to the basal unit.

Thickness of the Entrada varies to 250 feet in the district. Variations in thickness are created by erosion previous to deposition of the overlying Iron Springs Formation. Unaltered Entrada sandstone is readily recognizable in outcrop and in drill cores by its maroon color. Where Entrada sandstone has been altered by the intrusions, the formation has been modified to various shades of gray by emanations from intrusions.

Marshall Creek breccia. The local talus-fanglomerate Marshall Creek breccia, of Cretaceous age, occurs along the margins of the Iron Springs intrusions (Mackin, 1947b, 1954). It occurs at a disconformable contact between Entrada sandstone and the overlying Iron Springs Formation. It has no counterpart in the Colorado Plateau, and owes its existence to local post-Entrada deformation in the Iron Springs district. The Marshall Creek breccia lenses irregularly, varying in thickness to 100 feet within short distances along the strike. It consists largely of angular blocks of Homestake limestone up to five feet in diameter and smaller fragments of Entrada sandstone. The matrix commonly is maroon calcareous siltstone, which may or may not contain limestone fragments. Thin, irregular bands of jasper occur frequently in the matrix.

It appears that after Entrada deposition, several local horstlike blocks were uplifted, crackling the Homestake limestone in the uplifted blocks. Most of the Entrada sandstone and part of the crackled Homestake limestone were removed from uplifted horsts, forming a talus-fanglomerate, Marshall Creek breccia, over Entrada near the boundary faults. Iron Springs sediments were subsequently deposited over normal Homestake and Entrada sediments in parts of the district remote from uplifted blocks, on Marshall Creek breccia mantling the Entrada along the borders of uplifts, and directly on the crackled phase of Homestake limestone on the horst blocks.

Iron Springs Formation. The Entrada sandstone and Marshall Creek breccia are overlain unconformably by the Iron Springs Formation (Mackin, 1947b, 1954, 1968) which is probably of Late Cretaceous age. This formation is composed of lenticular beds of sandstone, siltstone, shale and conglomerate with local beds of limestone and coal. The beds are so irregularly distributed throughout the section that the formation is difficult to subdivide. The lower 400 feet of the formation are composed of a basal conglomerate made up mainly of quartzite pebbles, with some limestone pebbles, in a gray quartzitic matrix. This grades upward into variegated fresh-water limestone and sandstone with small conglomerate lenses. This in turn grades into interlensing coarse gray and brown limy sandstone and mostly limestone conglomerate.

The remaining 2,600 feet of the Iron Springs Formation consist of sandstone, siltstone and shale, with small lenses of limestone and conglomerate. Conglomerate and sandstone are dominantly brown in color; shales and siltstones are variegated, ranging from red through gray to green; the limestones vary from gray to reddish. A few thin lenses of coal are present. The Iron Springs Formation varies in thickness to more than 3,000 feet in the district, owing partly to relief of the surface during deposition, but chiefly to folding and subsequent erosion prior to deposition of overlying Tertiary rocks.

Claron Formation was first described by Leith and Harder (1908) in the Iron Springs district. The formation consists of Early Tertiary fluvial and lacustrine sediments ranging from 1,000 to 1,500 feet in thickness (Mackin, 1968). The Claron Formation is composed of conglomerate, red and gray sandstone and siltstone, and pink and white limestone. These strata rest unconformably on the Iron Springs Formation; in places the pre-Claron erosion surface truncates the Iron Springs Formation and the Entrada sandstone so that the Claron rests directly upon Homestake limestone.

The Claron Formation is correlated with the Eocene Wasatch Formation (Gregory, 1950) in the Markagunt Plateau at Cedar Breaks, 20 miles east of the district. The Claron consists of two principal members: the lower red Claron, made up chiefly of conglomerate, sandstone and fresh-water limestone, characterized by their red color; the upper gray Claron, composed chiefly of light gray sandstone and conglomerate with some interbedded layers of white limestone. The upper gray Claron member contains increasing amounts of tuffaceous materials toward the top. Recent age-dating (Armstrong, 1963) of the overlying Needles Range Formation indicates a mid-Oligocene age. This suggests that at least the upper gray Claron member which contains pyroclastic materials could possibly be Oligocene in age.

Igneous Rocks

Igneous rocks in the Iron Springs district are composed of three pre-intrusive volcanic sequences with a maximum aggregate thickness of 2,300 feet, three quartz monzonite porphyry intrusives with which the iron ore deposits are associated and two younger volcanic sequences with a maximum thickness of about 2,000 feet. The volcanic rocks are mainly ignimbrites rather than lava flows, and were probably formed by *nueés ardentes* which spread laterally as density currents. Maps of these sequences show that they form sheets substantially uniform in thickness. Mackin (1960) gave formal stratigraphic names to these volcanic sequences in southwest Utah and in the Iron Springs district. Correlation of volcanic stratigraphic units by distinctive lithologic features has been independently verified by quantitative study of phenocrysts in volcanic rocks (Williams, 1960). A brief summary of the igneous rocks occurring in and near the Iron Springs district is given below.

Needles Range Formation. The beginning of volcanism in the Iron Springs district is signaled by shards of glass near the base of the upper gray Claron Formation which becomes increasingly tuffaceous toward the top. The Needles Range Formation is the first major volcanic unit in the Iron Springs district. It overlies the Claron Formation and measures up to 1,000 feet in thickness. The type locality is on the east side of Needles Range in Beaver County and consists primarily of crystal-rich ignimbrites. The formation has two and at some sections three ignimbrite members. Colors are pink to dark red-brown, but range from black welded vitrophyre phases near the base to light gray near the top. The lower two members of the type locality are designated Wah Wah Springs tuff, 800 feet thick and showing a complete gradation upward from a black vitrophyre to light gray nonwelded ashy top, and the Minersville tuff, a dark gray to black devitrified tuff several hundred feet thick. Potassium-argon age dates (Armstrong, 1963) for the Needles Range Formation are 28 to 29 million years, placing it in the mid-Oligocene.

Isom Formation. At the type locality in the Iron Springs district, the Isom Formation rests on the Needles Range Formation, and in some places rests directly on the Claron Formation. Isom consists of three members with a total thickness of about 200 feet. The lower member consists of rather uniform tuffaceous ignimbrite materials and occurs only locally. The overlying Baldhills member is composed of black to dark brown latite porphyry and forms the bulk of Isom volcanic outcroppings. The uppermost member, Hole-in-the-Wall, consists of purplish gray latite porphyry about 40 feet thick. Baldhills and Hole-in-the-Wall members exhibit some ignimbrite features but have internal structures indicative of viscous lava flows. The Isom Formation is probably Middle Oligocene in age.

Quichapa Formation. The Iron Springs district is the type locality for the Quichapa Formation which consists of four ignimbrite members with a total thickness of nearly 1,100 feet. Leach Canyon tuff is the lowermost member and is about 500 feet thick. The rock is a gray to flesh-colored rhyolite tuff which encloses conspicuous lithic fragments of dark red felsite, pumice and broken pyrogenic minerals. A black, gray and pink vitrophyre to several tens of feet in thickness forms a basal unit; the upper 50 or more feet are an ashy top of distinctly bedded tuff. Leach Canyon tuff is characterized by dark lithic fragments up to 10 percent, pyrogenic minerals ranging from 15 to 25 percent and by a moderate degree of welding. The overlying Swett tuff member of the Quichapa Formation ranges from 30 to 45 feet in thickness and occurs only locally. It is composed of a thin basal vitrophyre and a massive lithoidal rock, both with a high degree of induration.

The overlying Bauers tuff member of the Quichapa Formation is about 200 feet thick and consists of three units. The basal unit is a black vitrophyre about 10 feet thick and is flecked toward the top with red spherulites. The main or middle unit measures more than 150 feet thick and consists of a strongly indurated red to deep red-brown rhyolite tuff. This unit possesses a prominent compaction foliation which is made apparent by parallel light gray lenticules. The upper 10 to 40 feet are composed of massive lithoidal rock containing no lenticules. Bauers tuff is characterized by a low content of pyrogenic minerals (10 to 15 percent), by a high degree of welding and by flattened white pumice fragments or lenticules. Harmony Hills tuff forms the uppermost member of the Quichapa Formation and measures up to 350 feet in thickness. The rock is tan to light red-brown latite tuff containing up to 45 percent pyrogenic minerals. The tuff shows no grain size stratification or sorting, indicative of its ignimbrite origin. Harmony Hills tuff is characterized by a low degree of welding, moderate induration and a high content of pyrogenic minerals.

The Quichapa Formation is the youngest of the pre-intrusion volcanic sequences. Leach Canyon tuff, the oldest ignimbrite member of the Quichapa Formation, has a lead-alpha date of 28 million years (Jaffe, 1959). This dates the Quichapa Formation as probably Middle to Upper Oligocene in age.

Quartz monzonite porphyry intrusions. Three bodies of quartz monzonite porphyry crop out in the Iron Springs district: Iron Mountain, Granite Mountain and Three Peaks. These intrusive bodies were emplaced at or near the end of the Quichapa episode of volcanism. They may be floored in part by Jurassic Navajo sandstone. The emplacement occurred along the base of the Jurassic Carmel Formation, arching the sedimentary and volcanic roof rocks and producing steep-sided topographic and structural features. Navajo sandstone, however, has not been seen in outcrop nor penetrated by drilling. Marginal contacts of the intrusions are concordant with the Carmel Formation or are ruptures in roof rocks formed during emplacement. The three intrusions are aligned along a northeast-trending Laramide anticlinal flexure which is locally overthrust. Each intrusion is oval in plan, three to five miles long, with its long axis trending parallel to the regional alignment. The intrusions have fine-grained chilled borders, and though they lack noteworthy assimilation effects along the margins, they definitely resulted from forceful injection of a viscous melt. Along the southeast side of Iron Mountain the intrusive contact is a breccia zone on a Laramide thrust.

Detailed studies of the Iron Springs district by Mackin (1947b, 1954, 1968), Lewis (1958) and Ratté (1963) show that the three intrusives possess a zonal arrangement of three phases of quartz monzonite porphyry. These phases are a peripheral shell, a zone of selvage joints, and an interior phase. These phases are well developed and easily discernable at the Three Peaks intrusion. At the Granite Mountain intrusion the major portion of the igneous rock is considered to be the zone of selvage joints. Some marginal portions and a few high peaks of Granite Mountain belong to the peripheral shell phase; only small exposures of interior quartz monzonite appear. At the Iron Mountain intrusion the peripheral shell phase apparently is well exposed and covers most of the outcrops; the interior phase and the zone of selvage joints are less distinctive and are found only where deeper erosion has cut the intrusion.

The peripheral shell phase developed along the sides and across the top of the intrusions as a chilled border zone. The thickness is probably variable but usually ranges from 100 to 200 feet. The surface outcrop patterns are related to the structure and the degree of erosion at each intrusion. Erosion has bared the Iron Mountain intrusion, exposing primarily the peripheral shell phase in most outcrops. Deeper erosion at the Granite Mountain and Three Peaks intrusions limits the peripheral shell phase to cappings of higher peaks and appearances along the margins of intrusions, except where faulting has brought sedimentary rocks in contact with the other two phases. The peripheral shell phase consists of fine-grained quartz monzonite porphyry which is resistant to weathering, forming bold outcrops and ledges. The rock is fresh and hard in outcrop, has a light to medium gray color and contains sparkling crystals of black hornblende and biotite. Phenocrysts of plagioclase crystals form from 30 to 40 percent of the porphyry, hornblende and augite from 4 to 8 percent, and biotite from 6 to 10 percent. The groundmass totals 38 to 58 percent of the rock and is made up mainly of quartz and quartz-potash feldspar intergrowths. Accessory and opaque minerals total from 2 to 4 percent of the rock.

The second zone of intrusions is an interior phase that consists of coarse-grained quartz monzonite porphyry. Chemical composition and mineralogy are substantially identical to the peripheral shell. The interior phase weathers easily to grus, because of alteration of mafic minerals. The rock has a rusty brown color with white splotches of relatively fresh plagioclase phenocrysts. Rocks of the interior phase, which is characterized by low, crumbly knobs or flat barren areas, seldom occur as outcrops. The outcrops have a coarse granular friable texture. In large outcroppings the porphyry forms rounded knobs with thin concentric exfoliation shells. The interior phase is well exposed at the Three Peaks intrusion, but only small outcrops are found at the Granite Mountain and Iron Mountain intrusions. Numerous xenolithic blocks believed to be Navajo sandstone are found in the interior phase of the Three Peaks intrusion. Both peripheral shell and interior zone are jointed along radial and concentric planes a few feet to a few tens of feet apart and show little or no alteration.

The third and intermediate zone in quartz monzonite porphyry intrusions in the Iron Springs district is the zone of selvage joints (figure 8). Rocks from this zone form an area of rugged topography. Selvage joints are composed of roughly parallel ribs of highly resistant porphyry. Quartz monzonite porphyry on each side of any individual joint is bleached and hardened, through a width across the rib ranging from a fraction of an inch to one foot or more. Differential weathering produces a ribbed topography since each selvage joint forms a resistant linear outcrop pattern which stands above the adjacent porphyry. Selvage joint ribs grade within one-half inch into crumbly, altered quartz monzonite characteristic of the interior phase. The rock is light gray to greenish gray, occasionally pink. Selvage joints are radial, concentric and oblique, with smooth planar surfaces; they are not always present between interior zone and peripheral shell. Those joints which are mineralized contain magnetite and accessory pyroxene, apatite, calcite and hematite. Selvage joints end abruptly as they merge with the interior phase of porphyry. The zone of selvage joints is well exposed at the Three Peaks intrusion, forming a belt from one-half to one mile wide and separating interior and peripheral shell phases. Most surface outcrops at Granite Mountain are composed of this zone of selvage joints, with some border exposures of peripheral shell zone. Iron Mountain apparently has very few exposures of the zone of selvage joints, because of the limited depth of erosion of the intrusion.

Rencher Formation is regarded as evidence of the first important volcanism that accompanied and followed the emplacement of igneous intrusions in the Iron Springs district. Intrusions produced dome mountains to several thousand feet high. Lowlands between the domes became sites of deposition of volcanic products and detrital materials supplied by erosion from the domes. The Rencher Formation (Cook, 1957) consists of ignimbrites and other volcanic rocks with a thickness to 1,000 feet in southwest Utah. The rocks are welded tuffs and tuff breccias of rhyodacite and quartz latite compositions. The formation apparently fills depressions between intrusive domes and lies on the surface of folded and eroded rocks. It rests directly on the Harmony Hills member of the Quichapa Formation in the Iron Springs district, on aprons of detritus bordering intrusive domes, and unconformably across truncated edges of eroded strata on the flanks of some domes. It is regarded as probably of Miocene age.

Page Ranch Formation overlies the Rencher Formation in the Iron Springs district. The type locality (Cook, 1957) lies on the southwest end of the Iron Springs district. The Page Ranch Formation is composed of two members (Mackin, 1960), and is nearly 1,000 feet thick. The lower member consists of crudely bedded fanglomerates, made up chiefly of subangular blocks of older volcanic rocks, and is designated the Ironton member. The upper part of the Page Ranch Formation is known as Kane Point tuff and is composed mainly of rhyodacite ignimbrites. This member is a vitric to crystal tuff, moderately welded; it contains a few lithic fragments and is gray-brown to purplish brown. Jaffe (1959) determined the age of Kane Point tuff as 19 million years, and therefore Miocene in age.

Surficial Deposits

Unconsolidated and poorly consolidated Pleistocene and Recent sediments occur as intermontaine basin fillings on both sides of the Iron Springs district. Pleistocene fanglomerates or high-level alluvial terraces are found 150 to 500 feet above valley floors and present drainage systems. Deposits are poorly sorted sediments, sand and gravel and a few include huge boulders. Fanglomerates are certainly stream-borne sediments, and must interfinger with certain valley floor deposits. These fanglomerate terraces represent accumulations in areas which are no longer sites of deposition because of more recent structural adjustments.

Gravity surveys on the east side of the Iron Springs district have recognized the Cedar Valley graben block (Cook and Hardman, 1967b) with an indicated depth to bedrock of about 4,000 feet. On the west side of the Iron Springs district, gravity surveys outline the Avon graben block with an alluvial depth of approximately 6,000 feet. The Cedar Valley and Avon grabens probably contain Middle to Upper Tertiary and certainly Pleistocene sediments. Surficial deposits of the valley floors consist of recent lacustrine sediments, sand dunes, stream bed deposits, alluvial fans and landslide debris.

Figure 8. Selvage joints in bold relief, Three Peaks intrusion.

Along the flanks of Iron Mountain, Granite Mountain and Three Peaks Mountains, a thin veneer of pediment gravels rests on the truncated surfaces of older rocks. These pediment surfaces blend into alluvial fan and bajada deposits, some of which contain from 3 to 20 percent iron. A mobile magnetic concentrator is being used to recover alluvial ores to depths of 60 feet; its operation may soon extend to depths of 100 feet or more.

Structural and Age Relationships

Concordant contacts. The primary structural relationship in the Iron Springs district is concordance of intrusive porphyry contacts with sedimentary bedding at the same stratigraphic horizon. Concordance of intrusive porphyry is with the basal siltstone member of the Jurassic Carmel Formation. This relationship is proven by detailed mapping of border zones of intrusions, by hundreds of drill holes to 1,000 feet down-dip from surface outcrops, and by many scattered drill holes up to several miles from the intrusive contact. About one-half of the exposed length of the intrusive contact is faulted, yet drilling on the down-thrown sides indicates that the contact remains concordant with the same stratigraphic horizon.

Pre-intrusive setting. The Jurassic Carmel Formation is the lowest stratigraphic unit exposed in the Iron Springs district. The formation consists of basal siltstone and Homestake limestone members and measures to 300 feet in thickness. A ripple-marked argillaceous limestone at the top of the Homestake limestone member grades upward within a foot into maroon and gray shale which in turn grades into shale and siltstone interlensing with arkosic sandstone. This unit varies to 220 feet in thickness in various parts of the district. It rests conformably on well-dated Homestake limestone with no erosional break and is regarded as equivalent in part to Jurassic Entrada sandstone of the nearby Colorado Plateau. After deposition of Entrada sandstone, local horstlike blocks were uplifted several hundred feet along the present alignment of Iron Springs intrusions. Most of the Entrada and some of the Homestake limestone were removed from the uplifted areas by erosion. Local talus-fanglomerate breccia, made up partly of angular fragments of Homestake limestone and lesser amounts of Entrada sandstone, was spread out over the Entrada near the boundary faults. This local unit was named Marshall Creek breccia by Mackin (1947b) from exposures in the southern part of Three Peaks area, and varies to 100 feet in thickness.

The Cretaceous Iron Springs Formation was deposited conformably on the normal Carmel-Entrada succession in parts of the district remote from the uplifted blocks. Lower members of the Iron Springs Formation were never deposited on the belt of Homestake hills because it stood at least 300 feet above the surrounding lowland at the beginning of Iron Springs time. As Iron Springs sedimentation continued, deposition took place unconformably over Marshall Creek breccia and Homestake limestone. Sedimentation continued until more than 3,000 feet of sandstone, conglomerate and shale accumulated in late Cretaceous time in the Iron Springs district.

In most of the district, the Tertiary Claron Formation rests on various members of the Iron Springs Formation with an angular unconformity of generally less than 30°. Regional relationships indicate that the Iron Springs Formation was only moderately warped and eroded before deposition of the Claron Formation. Locally, however, along the border of the three Iron Springs intrusions, the Iron Springs Formation shows an angular discordance up to 90°, indicating tight folding. The major structural element associated with this post-Iron Springs deformation is a Laramide anticline, overthrust toward the east and centered along the northeast structural alignment of Iron Springs district intrusives. The Tertiary Claron Formation rests on steeply dipping beds of the Cretaceous Iron Springs Formation on both flanks, and directly upon the Homestake limestone member of the Jurassic Carmel Formation. The full thickness of the Iron Springs Formation must have been removed by erosion along this anticlinal ridge previous to deposition of the Tertiary Claron Formation. No post-Claron disturbance is observed in the district until after the emplacement of mid-Tertiary intrusives.

Intrusive relationships. During late Oligocene or early Miocene, the Iron Springs district intrusions were formed by injection of magma along a zone of incompetent sedimentary rocks between Navajo sandstone and the Carmel Formation. The top of the Navajo sandstone is commonly the sole of bedding thrusts in southwest Utah (Miller, 1966) and southeast Nevada (Longwell, 1940). Tectonic gliding along incompetent Carmel members between the Homestake limestone member and Navajo sandstone has been suggested (Mackin, 1954). Field studies indicate this relationship for the Laramide Iron Springs district structure which trends about north 30° east through the district. The Iron Springs structure is a foreland anticline, overthrust to the east and rising abruptly above gently tilted Cretaceous Iron Springs strata on the southeast and northwest. Structural features that developed in sedimentary strata above the intrusive zone during post-Entrada and post-Iron Springs deformations controlled the manner and shape of roof-yielding when intrusions occurred.

Iron Mountain, Granite Mountain and Three Peaks intrusions are believed by the writer to be essentially stocklike. Originally, advancing magmas were injected through several feeders that served mainly to further distort pre-intrusive structures. Magma reached the incompetent zone in the lower Carmel Formation and was forcibly inserted into this zone in a sill-like fashion, with a mushrooming effect, and by lifting the roof rocks in a concordant manner. Intrusions made room for themselves mainly by doming and upfaulting the roof which consists of basal siltstone and Homestake limestone members of the Carmel Formation and from 3,000 to 6,000 feet of overlying sedimentary and volcanic rocks. Magmatic stoping, melting and assimilation must have taken place at depth, as evidenced by xenolithic blocks of Navajo sandstone in the interior zone of the Three Peaks intrusion, all of which enlarged the intrusive bodies to stocklike forms and dimensions.

The Three Peaks intrusion probably advanced from a stocklike body from the east, forming in part laccolithic lobes to the west and south. Emplacement of the Granite Mountain intrusion from the northwest formed either a thick sill-like body or a stocklike intrusion which mushroomed below the Carmel Formation, producing several bulges. The exposed Granite Mountain intrusion represents an eastern intrusive horst of a much larger intrusion. The Iron Mountain intrusion is essentially a stock. Intrusive deformation was intense as indicated by the overturning of the Carmel Formation around the southeast half of the border and an intrusive fault contact with the Iron Springs Formation on the west and northwest borders. The southeast contact is along an intrusive thrust (Mackin, 1968) which follows a breccia zone of an earlier Laramide thrust.

Size of intrusions. The Iron Mountain, Granite Mountain and Three Peaks intrusions are each oval in plan, three to five miles long, and are aligned for 18 miles along a northeast trend. Their total surface exposures are less than 14 square miles in extent. Aeromagnetic surveys by Dempsey (1951) and Blank and Mackin (1967) roughly delineate lateral subsurface extent of the three intrusions. Study of the Three Peaks intrusion shows that the northwest boundary is an intrusive fault and that the southwest and south margins form a series of monoclines and monoclinal flexures. The northern part of the intrusion is largely buried beneath pediment gravels but extends at least two miles north from the main surface outcroppings. The east margin terminates along a line believed to represent the trace of a fault.This fault postdates the intrusion and probably displaced it for several hundred feet. The subsurface margin of the intrusion is apparently about one mile farther east of the fault. Surface exposures of the Three Peaks intrusion cover an area of more than six square miles. The aeromagnetic survey of the area suggests that the subsurface size of the intrusion is at least 18 square miles, or three times as great as that exposed by erosion (figure 9).

The Granite Mountain intrusion is the easternmost and structurally the highest bulged part of a largely concealed intrusive body. The intrusion is many times larger than the surface outcrops and peaks from which it gets its name. Isomagnetic contours of the Granite Mountain intrusion show that porphyry extends beneath sedimentary and alluvial cover for about four miles southwest, and two or three miles west and northwest of Granite Mountain. The intrusion is a long slab several thousand feet thick whose upper surface shows several local bulges. The exposed Granite Mountain bulge is bounded on the southeast by the Cory-Armstrong fault and on the northwest by the Clive fault. Granite Mountain is regarded as an intrusive horst laid bare by erosion. The exposures of the Granite Mountain intrusion cover slightly more than two and one-half square miles. The aeromagnetic survey of the area suggests that the subsurface size of the intrusion is at least 24 square miles, or nine times greater than that exposed by erosion. The Granite Mountain and Three Peaks intrusions appear to be connected in the subsurface and are about the same age.

Margins of the aeromagnetic anomaly at the Iron Mountain intrusion correspond more closely to the porphyry outcrop margins than the other two intrusions and suggest a more limited subsurface expansion. A westward continuity of the south-dipping sedimentary rocks along the south margin of the Iron Mountain intrusion, weak incomplete magnetic anomalies and penetration of the intrusion by deep test drilling in the area, however, all suggest a westward expansion of the intrusion beneath alluvium and bedrock cover. The Iron Mountain intrusion is marked by severe intrusive deformation. Surface exposures on the intrusion cover an area of slightly more than five square miles. An aeromagnetic survey of the Iron Mountain area suggests a subsurface size of the intrusion of at least 11 square miles or more than twice as great as that exposed by erosion.

Shape of intrusions. The nature of igneous intrusions in the Iron Springs district has long been a controversial issue. Leith and Harder (1908) classified the intrusions as laccoliths. They based their conclusions on the more or less circular outline of the intrusions and the manner in which the sedimentary rocks encircle the intrusions. Butler (1920) regarded them as stocks since their laccolithic character had not been demonstrated. Wells (1938) referred to the igneous intrusions simply as plugs or stocks with no discussion. Granger (1963) considered the intrusions to be stocks. Ratté (1963) suggested that the intrusions began as laccoliths but later, as a result of wholesale foundering and assimilation of Navajo sandstone and subjacent rock, became stocklike. Mackin (1947b, 1954, 1968) regarded the intrusions as laccolithic blisters, and based his premise entirely on circumstantial evidence such as concordance of contact, limited contact metamorphism, flattish planar flow structures, radial pattern of primary tension joints, aeromagnetic data suggesting floored intrusions and the floored Pine Valley laccolith south of the Iron Springs district.

A gravity survey of the Iron Springs district (Cook and Hardman, 1967b) shows a continuous gravity high about 30 miles long extending over the Iron Springs district and including the Stoddard Mountain intrusion south of Iron Mountain. Gravity surveys, aeromagnetic and ground magnetometer data, geologic relationships and scattered exploratory drill hole data suggest that a large porphyry body of batholithic dimensions underlies the Iron Springs district. A common source of magma is indicated by the quartz monzonite composition of Stoddard Mountain, Iron Mountain, Granite Mountain and the Three Peaks intrusions. The gravity survey further shows a gravity ridge centered one to two miles west and northwest of the intrusions in the Iron Springs district. This offset suggests that the main body of porphyry is probably buried at a relatively shallow depth beneath the gravity ridge. The aeromagnetic survey supports this interpretation (figure 9).

The three Iron Springs igneous intrusions are structural domes several miles wide. They are attributed to the deformation that accompanied physical injection of quartz monzonite magma. The intrusions are regarded by this writer as being essentially stocklike in form and connected at depth by a large batholithic body. The obvious alignment of the exposed intrusions and their offset from the gravity ridge suggest that the intrusions were fed at depth along a zone of weakness such as a gliding plane that accompanied folding and thrusting along Laramide structures. Feeders, regarded as stocklike or perhaps even sill-like in the case of Granite Mountain, spread out along the zone of weakness between Navajo sandstone and Carmel Formation by mushrooming into zones of weakness.

The Iron Mountain intrusion is the most stocklike in form; it has contacts that are principally the result of intrusive faulting. The Three Peaks intrusion is also stocklike with an intrusive fault contact on the northwest side and a laccolithic nose shown best on the southwest side. A laccolithic nose on the southeast side of the intrusion is suggested by aeromagnetic and gravity data. Granite Mountain shows the fewest stocklike characteristics. Data from the aeromagnetic survey have been interpreted by Blank and Mackin (1967) to be a thick sill-like mass. A more or less centrally situated feeder stock, however, is visualized by the writer, mushrooming laterally below the Carmel Formation and producing several bulges at points of greatest weakness. The exposed Granite Mountain intrusion has been described by Blank and Mackin under the noncommittal term of intrusive horst.

The writer doubts the circumstantial evidence advanced by Mackin (1947b, 1954, 1968) that Iron Springs intrusions are all floored, and concludes that only a small portion of the intrusions can be floored by Navajo sandstone. The sandstone has never been encountered by the thousands of drill holes cut in the district nor by exploratory drill holes around the periphery of the district where all holes have bottomed in porphyry. Concordance of contacts has been overemphasized in the district since about half of the exposed length of intrusive contacts are faulted. Concordant roofs, on the other hand, are found among stocks as well as laccoliths. Limited contact metamorphism occurs wherever a magma lacks superheat and does not negate subjacent intrusive bodies. The planar flow structures and the radial pattern of primary tension joints could be produced by central stocks feeding sill-like or laccolithic lobes. Aeromagnetic surveys do not show the depth of a thick causative body and therefore cannot provide conclusive evidence that the intrusions are floored.

It appears to this writer that the three intrusive bodies might be better interpreted as an igneous complex of semiconcordant stocks rather than simply laccolithic blisters. The stocks in turn are underlain and were fed by a larger batholith. The above conclusions have been reached after evaluation of the following: gravity surveys of Cook and Hardman (1967b); aeromagnetic surveys by Dempsey (1951) and Blank and Mackin (1967); ground magnetometer data by Cook (1950) and by others; persistent bottoming of drill holes in quartz monzonite porphyry at the various iron properties, and similar bottoming by exploratory drilling throughout the district and in adjacent areas; the same quartz monzonite composition for all the intrusions; detailed geologic and geophysical investigations of the district by the writer, mining company geologists and others.

Age of intrusions. The Iron Springs district intrusives are post-Quichapa and pre-Rencher in age. A lead-alpha date of the Three Peaks intrusion is 22 million years (Jaffe, 1959). A potassium-argon date for the same intrusion is 24 million years, +4 or -2 million years (Armstrong, 1966). These dates suggest a late Oligocene or early Miocene age. From combined lithologic and structural evidence, Blank and Mackin (1967) considered the Iron Mountain intrusion to be the oldest of the three Iron Springs district intrusions.

Mineralogy and Mode of Occurrence

The most important iron ore minerals in the Iron Springs district are hematite and magnetite. These minerals are mixed in proportions that vary within a given area or deposit. Ores range from hard pure magnetite to soft friable varieties of hematite. Iron deposits have three primary modes of occurrence and one secondary origin. These are: replacement type bodies in limestone; breccia fillings and replacements along faults and pipelike structures; fissure vein fillings in porphyry; alluvial ores of secondary origin that will be discussed in a later section.

Mineralogy of ores. In addition to magnetite and hematite, some specular hematite and martite occur in a few ore deposits, and goethite, limonite and turgite can be found in relatively small amounts. Gangue minerals in the ores are numerous and varied and include calcite, phlogopite, apatite (fluorapatite), quartz and chalcedony, pyrite, marcasite, diopside, azurite, malachite, chrysocolla, chalcopyrite, bornite, galena, magnesite, gypsum, barite, epidote, garnet, vesuvianite, scapolite, tourmaline, chlorite, tremolite, actinolite and wollastonite. The minerals are listed in order of their relative abundance, the most abundant first. A more complete list of minerals found in the ores is found in the section Genesis of Ore Deposits.

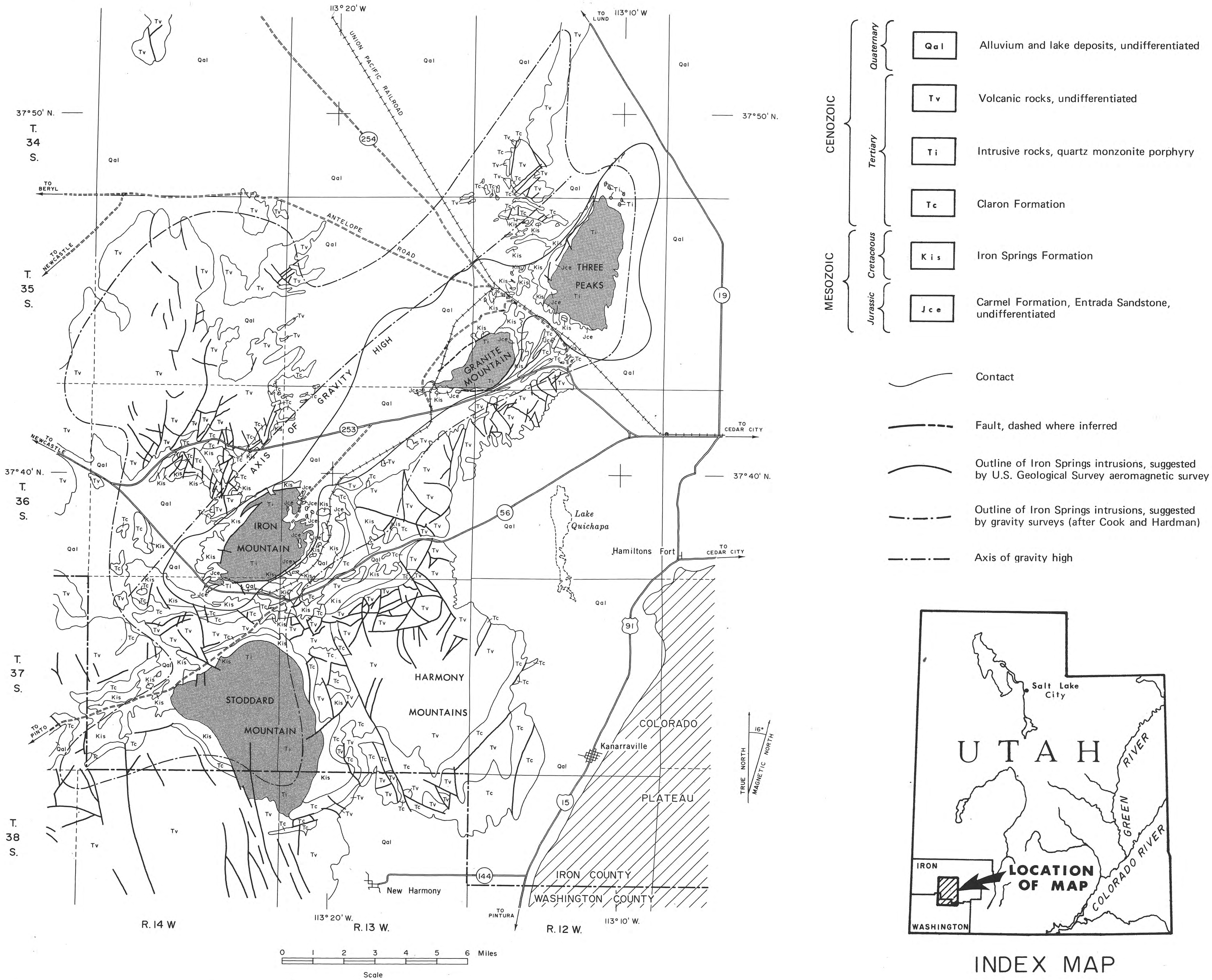


Figure 9. Size and shape of Iron Springs district intrusions from outcroppings and geophysical data.

Mineralogy of the various types of ore occurrences in the district is similar but relative abundance changes considerably. Replacement type ores in limestone are finely crystalline magnetite and hematite, the magnetite ranging from about 10 to 50 percent within each ore body. Disseminated in the ore in small amounts are fine-grained calcite, quartz and garnet. Pyrite, apatite and phlogopite often occur in small veins cutting the ore or as fillings in vugs. Large fissure veins and some open-space breccia fillings along faults contain coarsely crystalline magnetite octahedra. Long prismatic crystals of apatite are commonly intergrown with magnetite. Quartz, chalcedony, amethyst and pyrite occur in vugs and open spaces in veins and breccia fillings. Mineralization in small fissure veinlets and many of the breccia fillings along faults consist of fine- to coarse-grained intergrowths of magnetite and hematite. Magnetite may be present in small quantities or may be absent. Calcite and phlogopite are often the main gangue minerals. Diopside, apatite and dolomite may dominate small veins. Actinolite, tremolite, gypsum and dolomite may be present in noticeable quantities. Pipelike breccia fillings and replacement ore bodies differ from other occurrences mainly in that the ores are predominantly hard and coarsely crystalline magnetite, and in the case of the Blowout and Little Allie ore bodies, there is also an abundance of fibrous magnetite.

Replacement ore bodies. By far the most important ores in the Iron Springs district are replacement deposits in the Homestake limestone member of the Carmel Formation. Ore replaces the lower part of limestone first, but with increasing metallization the full thickness of about 250 feet may be replaced. Where the entire Homestake limestone is replaced by iron ore, the lower half is high-grade ore containing from 50 to 58 percent iron, and the upper half of the formation averages 40 to 45 percent iron.

The limestone replacement ore bodies are usually tabular and lenticular in form, occurring in offdipping limestone along the contact zone of intrusives; they measure a few feet to 1,000 feet or more along strike and down-dip. The footwall of the ore conforms with the stratigraphic base of the Homestake limestone member and is separated from porphyry by the basal siltstone member of the Carmel Formation. Iron ore replacements extend upward from the base of the Homestake limestone, ranging from a few feet thick to the full thickness of the limestone, in which case the hanging wall is the basal shale member of the Entrada sandstone. If replacement is less than complete in the Homestake, the ore edges against limestone where the contact is sharp or grades off within a few inches.

The Lindsay ore body on the east side of Granite Mountain is a good example of an offdipping homoclinal replacement ore body (figure 10). The Shortline ore body on the southwest side of Granite Mountain is of the replacement type in a premineral graben block. Another variation is the April Fool ore body on the west side of Three Peaks, a replaced xenolithic slab or roof pendant of limestone completely surrounded by porphyry. Some of the major replacement ore deposits in limestone at Iron Mountain are A and B, Burke, Blackhawk, McCahill, Pinto, Rex, Comstock and Mountain Lion ore bodies. At Granite Mountain are Desert Mount, Shortline, Pioche, Lindsay and Vermilion ore bodies; and at Three Peaks are April Fool and Irene ore bodies. Deposits range from less than 100,000 to more than 100 million tons of iron ores.

Breccia fillings and replacements. Brecciated zones in the Carmel Formation, Entrada sandstone, Iron Springs Formation and quartz monzonite porphyry contain iron ore mineralization as breccia fillings and breccia replacements (figure 11). Brecciated zones may occur within Homestake limestone replacement ore bodies, or they may occur above, along the margins, or below these ore bodies, or independently of these relationships. Breccia fillings and replacements of rubble occur in broken zones of the Entrada sandstone and the Iron Springs Formation above the non-deroofed Rex ore body at Iron Mountain. Diamond drilling of the Rex deposit disclosed extensively replaced breccia extending through the main limestone replacement body. A basal breccia involving the siltstone member of the Carmel Formation and the outer part of the porphyry is found in parts of the footwall beneath the Lindsay ore body at Granite Mountain.

Mineralized brecciated fault zones associated with replacement ore bodies are typified by Shortline, Clive-Constitution, Little Allie, Armstrong, Lindsay and others at Granite Mountain, and the A and B, Burke, Dear, Pinto, Comstock, Mountain Lion and others at Iron Mountain. The Blowout and Pot Metals ore bodies occur along the Calumet fault zone which is probably the mashed lower plate of the Laramide thrust in the district, and replaced this breccia. Basal siltstone and Homestake limestone members of the Carmel Formation lie in the overthrust block and are essentially unmineralized.

Some ore bodies in the Iron Springs district resemble breccia pipe structures and form crude cylindrical ore bodies. They lie on the periphery of intrusives along major faults or fault intersections. These breccia pipes occur mainly in the monzonite and may contain large angular to rounded blocks and fragments of porphyry or sedimentary rocks completely surrounded by ore. The principal ore mineral of the breccia pipes is magnetite. Examples of such breccia pipes are Blowout and Pot Metals ore bodies on the southeast side, the Dear claim in the Comstock area on the northeast side of Iron Mountain, and Armstrong and Little Allie ore bodies on the east side of Granite Mountain.

Drill hole cores from the Rex ore body on the west side of Iron Mountain and the Desert ore bodies

Figure 10. Replacement type ore body, Lindsay Pit, Granite Mountain. Quartz monzonite porphyry in rear, replacement ore body in lower center, unreplaced Homestake limestone on right.

Figure 11. Fillings and partial replacements in quartz monzonite porphyry breccia, Dear claim, Iron Mountain.

in secs. 2, 3, 4 and 9 which lie in the valley between Iron and Granite mountains show high brecciation. Tonnages of ore associated with breccia fillings and replacements are some of the largest in the district.

Fissure fillings. Most of the vein or fissure fillings, abundant in quartz monzonite porphyry intrusions, are too small to be of economic importance. Fissure veins occur in numerous selvage joints which cut intrusions and are of radial, concentric and oblique types. Radial joints are continuations of the joint system from the interior zone and strike normal to intrusive contacts and have vertical dips. Concentric joints strike parallel to igneous contacts and dip into intrusives, normal to contacts. Oblique joints are curved types that swing from radial to concentric patterns.

Thirty to 50 percent of the selvage joints contain some magnetite and accessory hematite, apatite, calcite, pyrite, pyroxene and other minerals. Comb structures and vugs with abundant magnetite octahedra indicate that fissures were filled rather than replaced. Encrustations of magnetite crystals in many veins suggest that joints were opened repeatedly during the time of metallization. Contacts between the veins and porphyry are sharp. Inclusions of quartz monzonite porphyry fragments in some fissure veins represent either pre-ore breccia or stoping of joint wall rock by iron ore emanations.

Fissure veins are unusually abundant in the porphyry intrusions. Thousands of the veins in the district are less than four inches in width, scores of them are several feet wide, and a few are more than ten feet in width. Most of the larger veins occur in radial joints, but some fill concentric and oblique joints. Radial fissure veins are typically wedge-shaped both in plan and cross section, with the thickest part toward the margins or borders of the intrusions. Some of the larger veins in the district are Great Western, Blackbird and Zelma veins at Three Peaks, and Chesapeake, Excelsior and Tip Top veins at Iron Mountain (figure 12). Potential tonnage in the individual fissure veins ranges to about 100,000 tons.

Ore Deposits

Iron Springs district is a belt about 21 miles long and four miles wide and has been the largest iron-producing district in the western states. Iron ore bodies are clustered around three semiconcordant stocks as replacement bodies in limestone, as breccia fillings and replacements along faults and pipelike structures, and as fissure veins in quartz monzonite porphyry.

The Homestake limestone member of the Carmel Formation is exposed most of the way along the south and east margins of the Iron Mountain intrusive. On the west and northwest the Iron Springs Formation is in fault contact with porphyry for about three and one-half miles. The northeast margin is bordered by alluvium. Blocks of Homestake limestone, Entrada sandstone and the Iron Springs Formation also form roof pendants, particularly on the northeast side of Iron Mountain. Most pendants are less than 1,000 feet in length, but the one on which the Comstock-Mountain Lion group of claims is located is about one mile long and 2,000 feet wide. The main replacement ore bodies occurring along the margins of the Iron Mountain intrusive are the Rex and Burke ore bodies on the west side, A and B, Blowout, Duncan, Calumet, Limecap, McCahill and Pinto ore bodies on the south and southwest sides, and Pot Metals, Yellow Jacket and Homestake mine deposits on the east side. Black Hawk ore body on the south end, and Comstock-Mountain Lion and Dear ore bodies on the northeast side of Iron Mountain are roof pendant replacements. Some of the larger fissure veins on Iron Mountain are the Tip Top, Chesapeake, Excelsior and Black Magnetic deposits. Black Hawk, Burke and Pinto ore bodies have been mined out. Mining operations are being conducted at the Comstock, Mountain Lion and Duncan ore bodies.

At the Granite Mountain intrusion, Entrada sandstone and Iron Springs Formation are in fault contact on the south, southeast and northwest sides of the intrusive, and the Homestake limestone forms an intrusive contact on the east and north sides. Desert alluvium abuts porphyry on the west and southwest sides. Desert Mound, an east-west trending hill, lies less than one mile southwest of Granite Mountain proper. It is formed by monzonite and alluvium on the north side; Homestake limestone, Entrada sandstone, and Iron Springs Formation form the ridge and slopes on the south side. The principal ore bodies surrounding Granite Mountain on the southeast and east sides are Little Allie, Armstrong and Lindsay ore bodies, and Little Mormon, Pioche, Vermilion and Twitchell deposits on the north and northeast sides. Two blind ore bodies along the Clive fault on the northwest side of Granite Mountain are the Clive-Constitution and Georgia deposits. Ore bodies of note at Desert Mound are Shortline and Desert Mound deposits, and non-outcropping Desert ore bodies to the southwest of Desert Mound, including Thompson, Section 2, Section 3, Section 4 and Section 9 deposits. Shortline and much of the Lindsay ore bodies are mined out. Mines in operation are in Lindsay, Armstrong, Pioche and Vermilion deposits at Granite Mountain, and Desert Mound ore body at Desert Mound.

Homestake limestone is in intrusive contact on the south and west margins of the porphyry of the Three Peaks intrusion. The north, east and southeast borders of the intrusive are covered by alluvium. No large replacement ore bodies have been discovered along the intrusive margins at Three Peaks. April Fool, Irene, McGarry and Smith deposits are relatively small roof pendant ore bodies, occurring as partial replacements of Homestake limestone blocks completely surrounded by porphyry. Many fissure veins of magnetite are found in Three Peaks por-

Figure 12. Excelsior fissure vein in quartz monzonite porphyry, Iron Mountain.

phyry, the largest of which are Great Western, Blackbird and Zelma fissure veins. Mines are in operation at Smith and Irene ore deposits at Three Peaks (figure 13).

A brief summary of some of the more important ore bodies discovered in Iron Springs district is given below. The deposits are listed alphabetically.

A and B ore body lies in sec. 2, T. 37 S., R. 14 W., on the southwest end of Iron Mountain near the idle crushing and screening plant at Iron Mountain station, immediately south of Black Hawk and west of Blowout properties. The ore body was discovered and outlined by magnetometer studies and explored by drilling operations of U. S. Steel Corporation. It is now being drilled by CF&I Steel Corporation. The top of the deposit lies beneath 300 to 400 feet of cap rock and alluvium along a major fault structure extending along the south side of Iron Mountain. It is a replacement ore body occurring largely in vertical and overturned Homestake limestone. The deposit is probably a westward continuation of the Blowout ore body but has been displaced by a north-trending fault. Near the surface the Homestake limestone dips northward and is mineralized only near the base of the formation, but at greater depth the limestone is vertical and overturned and is largely replaced by iron ores. The mineralization consists of a mixture of magnetite and hematite extending to a depth of more than 2,000 feet. This is the greatest depth that ore has been traced in the district by drilling operations. The property is owned jointly by the U. S. Steel and CF&I Steel corporations. The ore body has a potential of 30 million to 40 million tons. Underground mining would be required for the deeper ore.

April Fool ore body lies in NW¼ sec. 10, T. 35 S., R. 12 W., on the northwest side of Three Peaks. The property is covered by alluvium. It was discovered by a U. S. Bureau of Mines magnetometer investigation of the area in 1944-45 and is held by the Charlotte Mining Company. An anomalous area about 1,700 feet long was drilled. The ore body lies about 250 feet below the surface and averages about 113 feet thick. April Fool ore body is a replacement of Homestake limestone which occurs as a foundered slab or sliver of limestone completely surrounded by porphyry. The ore consists of soft granular material with ribs of hard ore. Blocks of unreplaced limestone are common. Magnetite is the main mineral but hematite is common in parts of the deposit. Ore potential of this deposit is probably between .5 million and 1 million tons. The stripping ratio for open-pitting this deposit would be high.

Armstrong ore body lies in NW¼ sec. 32, T. 35 S., R. 12 W., on the east side of Granite Mountain. The property is about one-third mile south of the Lindsay deposit. The ore body has wholly replaced a wedge of Homestake limestone. Monzonite lies west of the deposit, and the Iron Springs Formation is in fault contact to the east. The deposit is associated with the Cory-Armstrong fault, a major in-dipping thrust fault that dips west and brings quartz monzonite porphyry against steeply dipping beds of the Iron Springs Formation. The throw of this marginal thrust exceeds 1,300 feet.

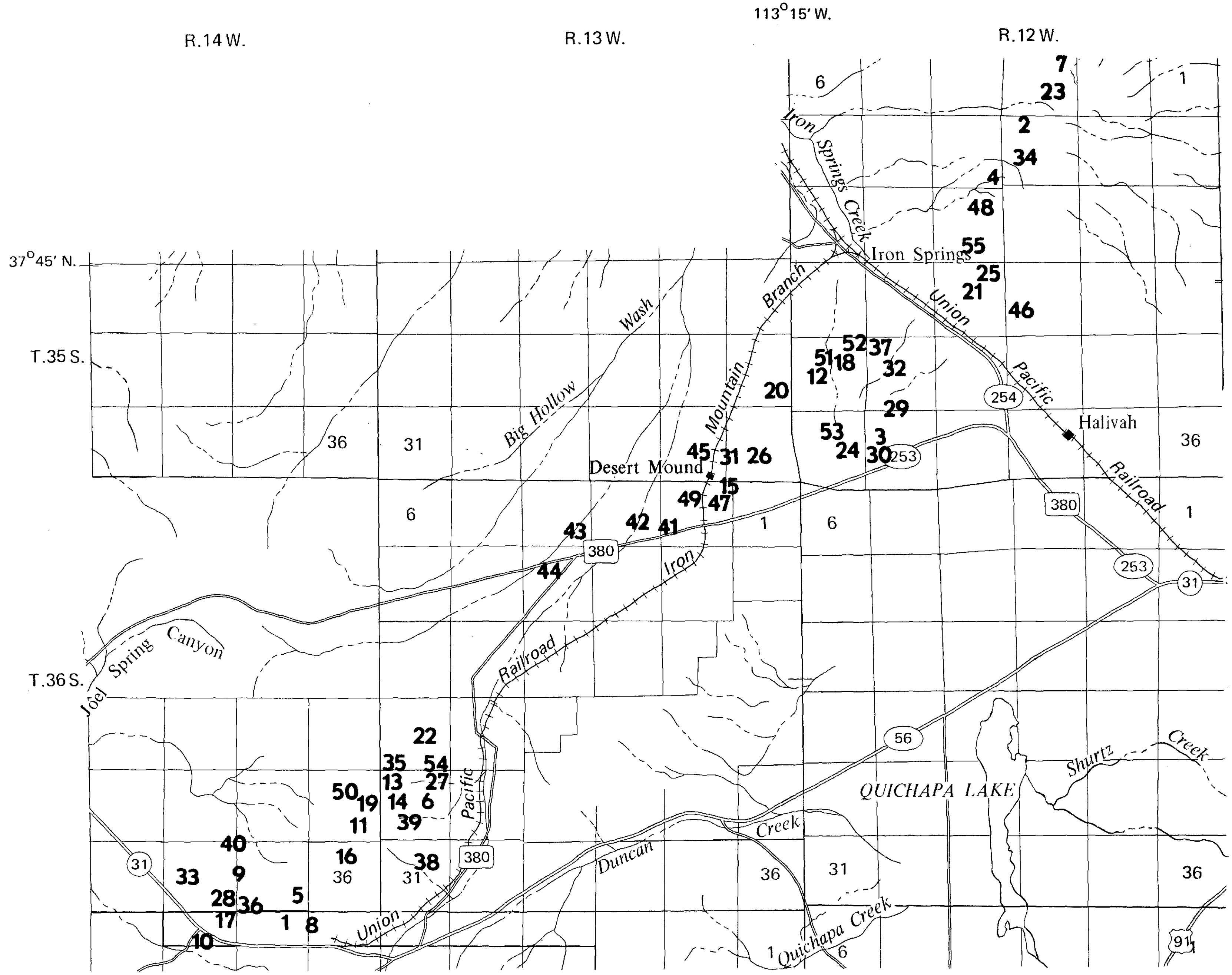
The Armstrong ore body was lens-shaped at the surface, extending about 1,000 feet along the contact zone and measuring about 270 feet at its widest surface outcrop. Below the surface, the ore narrows and extends downward along the fault zone to an undetermined depth. At about 350 feet the ore averages 40 feet thick and becomes a breccia filling and replacement along the Cory-Armstrong thrust fault which dips about 70° west.

Angular blocks of quartz monzonite are associated with fault breccia, indicating a late intrusive fault. The fault breccia is impregnated with magnetite and doubtless served as a conduit or feeder for the Armstrong ore body. Little Allie, Armstrong and Lindsay ore bodies form a more or less continuous ore zone with varying vertical and horizontal dimensions of ore bodies and perhaps separated by faults. Armstrong ore is somewhat harder, more massive, and higher in magnetite, silica and phosphorous content than other deposits on the east side of Granite Mountain. Mining by Utah Construction and Mining Company began on the Armstrong deposit about 1948. The property has an iron ore potential of at least 4 million to 5 million tons. The deeper ore would have to be recovered by underground mining methods.

Ashton ore body lies in SE½ sec. 9, T. 35 S., R. 12 W., on the west side of Three Peaks. This deposit is a fissure vein about 6 feet wide and 300 feet long in quartz monzonite porphyry and lies slightly more than one mile north of the Great Western fissure vein deposit. A 47-foot shaft appears to be the major development on this property which is held by Utah Construction and Mining Company. The property has a small ore potential, perhaps in the range of 50,000 to 100,000 tons.

Black Hawk ore body lies in SE¼ sec. 35, T. 36 S., R. 14 W., on the south end of Iron Mountain. The deposit is owned by U. S. Steel Corporation and has been depleted. Ore extraction began in 1936. A crushing, screening and loading plant to handle this and other ores was placed in operation at the Iron Mountain station a short distance southwest of Black Hawk pit.

The Black Hawk ore body was a large replacement deposit in a roof pendant of Homestake limestone. Near the surface the ore was extremely hard and dense, but with depth the ore changed to large masses of soft, granular ore containing magnetite and hematite. These ores had an average iron content greater than either the nearby Pinto or Burke deposits and contained a smaller amount of impurities. The property produced about 20 million tons of ore.



1 0 1 2 3 Miles

Base from General Highway Map,
Iron County, Utah No. 11

Figure 13. Iron Springs district iron occurrences, Iron County.

1. A and B ore body
2. April Fool ore body
3. Armstrong ore body
4. Ashton ore body
5. Black Hawk ore body
6. Black Magnetic ore body
7. Blackbird ore body
8. Blowout ore body
9. Burke ore body
10. Calumet ore body
11. Chesapeake ore body
12. Clive-Constitution ore body
13. Comstock ore body
14. Dear ore body
15. Desert Mound ore body
16. Duluth ore body
17. Duncan ore body
18. Eclipse ore body
19. Excelsior ore body
20. Georgia ore body
21. Great Western ore body
22. Homestake mine ore body
23. Irene ore body
24. Jeanette ore body
25. Jones ore body
26. King ore body
27. Last Chance ore body
28. Lime Cap ore body
29. Lindsay ore body
30. Little Allie ore body
31. Little Jim ore body
32. Little Mormon ore body
33. McCahill ore body
34. McGarry ore body
35. Mountain Lion ore body
36. Pinto ore body
37. Pioche ore body
38. Pot Metals ore body
39. Queen of the West ore body
40. Rex ore body
41. Section 2 ore body
42. Section 3 ore body
43. Section 4 ore body
44. Section 9 ore body
45. Shortline ore body
46. Smith ore body
47. State Section 2 ore body
48. State Section 16 ore body
49. Thompson ore body
50. Tip Top ore body
51. Twitchell ore body
52. Vermilion ore body
53. Wall Street ore body
54. Yellow Jacket ore body
55. Zelma ore body

N

Black Magnetic ore body lies in NE¼ sec. 30, T. 36 S., R. 13 W., on the northeast side of Iron Mountain. The deposit is a small fissure vein deposit in quartz monzonite porphyry, with an ore potential of about 50,000 to 70,000 tons. The ore outcrops near the crushing, screening and loading facility for CF&I Steel Corporation, owners of the property. Magnetite is the chief ore mineral.

Blackbird ore body occurs near the north end of Three Peaks in NE¼ sec. 3, T. 35 S., R. 12 W. This ore body is a fissure vein deposit in quartz monzonite porphyry, and consists principally of magnetite. The fissure vein is lenslike in form and apparently dips about 80° east; at the surface the vein has a strike length of 740 feet and a maximum width of about 30 feet. Abundant apatite in the ore gives it a high phosphorous content. The property is owned by Utah Construction and Mining Company. Ore potential of this fissure vein is perhaps in the range of 50,000 to 100,000 tons.

Blowout ore body lies at the south end of Iron Mountain, immediately east of the railroad loading station. The property is in NW¼ sec. 1, and the NE¼ sec. 2, T. 37 S., R. 14 W. The Blowout deposit originally formed a prominent outcrop. The property is owned by CF&I Steel Corporation and was mined under contract by Utah Construction and Mining Company. Mining operations have been virtually continuous since 1947 and produced 7,168,047 tons of ore through 1968 when production stopped. Tonnage potential is approximately 10 million tons. Ore from the Blowout deposit consists of hard massive magnetite with an average iron content near 60 percent. Original surface outcrops measured about 850 feet long and 400 feet wide. Drilling operations show that the ore body extends to a depth of at least 800 feet.

The Blowout ore body is located along the Calumet fault zone, traversing the south side of Iron Mountain. Downslope and south from the ore body, overturned Homestake limestone is essentially unreplaced and is part of the upper plate of the Laramide Iron Springs Gap thrust. Between the Homestake limestone belt and porphyry and extending for about two miles between Blowout and Pot Metals ore bodies is the Calumet fault zone. Breccia several hundred feet wide in this zone contains fragments of Homestake, Entrada and Iron Springs lithology, which is probably the mashed lower plate of the Laramide thrust. The Blowout ore body is a breccia pipe replacement along this faulted structure and lies mostly in quartz monzonite porphyry.

The Blowout breccia pipe is an excellent example of a previous channelway that provided a deep plumbing system for iron-rich hydrothermal solutions. The core was high in quartz which occurs mainly in vugs. White and drusy quartz was present, and amethyst quartz was common near the surface. The ore also contained galena, chalcopyrite, bornite and pyrite, with the pyrite content increasing with depth. The ore body contained an unusual variety of fibrous magnetite that occurred at every level. The Blowout ore deposit is a good example of an ore body showing a hydrothermal origin.

Burke ore body was located on the southwest side of Iron Mountain, mainly in SW¼ sec. 35, and SE¼ sec. 34, T. 36 S., R. 14 W. Ore originally was exposed continuously over a north-south strike for about 1,600 feet with a maximum surface width of exposure of 350 feet. The deposit was a typical contact metasomatic replacement of Homestake limestone. It was an ore body of average size whose form was tabular and homoclinal, dipping toward the west. Drilling operations by the U. S. Steel Corporation and the U. S. Bureau of Mines showed that the deposit was composed of two ore bodies at depth. The north section was known as Burke No. 2 and the south section as Burke No. 3. The Burke ore body has been mined out.

In the vicinity of the Burke ore deposit the Homestake limestone strikes north-south and dips 20° to 40° west. Quartz monzonite porphyry is in intrusive contact with Homestake limestone and lies immediately east of the iron deposit. A small porphyry cupola west of the Burke No. 3 ore body delimited its westward extension at depth. The Burke No. 2 ore body was considerably larger, and the ore extended to a depth of about 1,000 feet down-dip. The ore was variable in thickness but averaged about 150 feet and consisted principally of hard dense mixtures of magnetite and hematite. The property is owned by U. S. Steel Corporation. The Burke ore deposit produced about 16 million tons of ore and is now depleted.

Calumet ore body is located on the southwest side of Iron Mountain in N½ sec. 3, T. 37 S., R. 14 W. The deposit was discovered by an aerial magnetometer survey conducted by U. S. Steel Corporation. It lies 400 to 600 feet below the surface and measures about 400 feet long and 200 feet wide, and is a replacement type ore deposit that occurs in the lower portion of Homestake limestone. The limestone strikes north 70° west and dips 30° southwest. The property has an ore potential of nearly 2 million tons. The deposit is held by the Milner Corporation.

Chesapeake ore body is a fissure vein deposit in quartz monzonite porphyry on the east slope of Iron Mountain. The property lies in SE¼ sec. 25, T. 36 S., R. 14 W., and is held by CF&I Steel Corporation. The main vein can be traced for nearly 2,100 feet. Two veins are present for more than half the strike distance and have been cut by two northwest-trending faults. The veins vary from about 2 to 10 feet in width, with an average thickness of about 4 feet. No development work has been done on this property. The ore potential is perhaps between 100,000 and 200,000 tons.

Clive-Constitution ore body lies in NW¼ sec. 30, T. 35 S., R. 12 W., on the northwest side of Granite Mountain. The northeast-trending Clive fault brought the Iron Springs Formation in fault contact with quartz monzonite porphyry. The Iron Springs Formation strikes north 45° to 60° east and dips on the average about 15° northwest. Drill holes revealed mineralized breccia along the Clive fault and replacement ore in Homestake limestone. At least six drill holes passed through the full stratigraphic thickness of Homestake limestone, encountering about 55 feet of ore near the base between 738 and 793 feet below the surface. Drilling also suggests that ore extends up the thrust fault for about 600 feet toward the surface with an average thickness of about 33 feet. A magnetic anomaly extends for about 1,200 feet along the strike. Ore cut by the drill holes ranges from fairly soft mixtures of magnetite and hematite to somewhat harder ore, largely magnetite. If ore extends 200 feet down-dip replacing limestone beds, the ore potential is at least 1 million tons. The property is owned by James D. Murphy and Mildred R. Quinn and leased by Utah Construction and Mining Company.

Comstock ore body lies in NW¼ sec. 30, T. 36 S., R. 13 W., on the northeast side of Iron Mountain (figure 14). The property is owned by CF&I Steel Corporation. The Comstock ore body is a huge roof pendant replacement deposit in Homestake limestone and is associated with the largest roof pendant in the Iron Springs district. The roof pendant measures about one mile long and about 2,000 feet wide. It is cut by several faults of small to large displacements, producing a juxtaposition of sedimentary blocks. Brecciation of porphyry and sedimentary rocks is important in localization of the iron mineralization.

This deposit underlies Comstock, Copper Fraction, Dear, Sunbeam, Strip, Emma and the Mountain Lion group of claims, and is known to be one large continuous ore body. This deposit is one of the largest known ore reserves in the Iron Springs district, with an ore potential of approximately 50 million to 60 million tons. Production began in 1956. Current mining operations are conducted under contract by Utah Construction and Mining Company. Much of the future iron ore production of CF&I Steel Corporation will come from the Comstock ore body. A total of 4,161,041 long tons of ore has been mined from the Comstock deposit through 1968.

Dear ore body joins Copper Fraction and Comstock lode claims on the south and lies in W½ sec. 30, T. 36 S., R. 13 W., on the northeast side of Iron Mountain. The deposit is a small replacement body mainly in Homestake limestone, at the south end of the huge Comstock ore body. Iron ore replaces limestone, forming commercial ore, and occurs in brecciated porphyry (figure 11). Huge brecciated masses of quartz monzonite porphyry are mineralized by fracture fillings and partial replacements of porphyry. Many brecciated blocks several feet in diameter are exposed in the Dear ore pit. Several porphyry blocks are subrounded by forceful movements and by partial iron ore replacements. Brecciation has been of major importance in the localization of the Dear and Comstock ore bodies. U. S. Steel Corporation is owner of the property which has an ore potential of 1 million tons or more.

Desert Mound ore body occurs in NW¼ sec. 1 and NE¼ sec. 2, T. 36 S., R. 13 W., at Desert Mount, a low hilly area about one mile southwest of Granite Mountain (figure 15). The Homestake limestone, Entrada sandstone, and Iron Springs Formation strike east-west and dip 20° to 30° south along Desert Mound ridge. These sedimentary rocks form the south slope and top of the ridge, and the underlying quartz monzonite porphyry forms the north slope. The ridge has been cut by north-trending faults. This cross-faulting and shearing are regarded as premineralization.

The Desert Mound ore body is a typical homoclinal, off-dipping metasomatic replacement type ore body in Homestake limestone. The deposit dips 20° to 25° south, and the thickness of the overburden increases in that direction. The deposit is about 1,400 feet long, ranges from 50 to 250 feet thick and extends down-dip at least 1,000 feet. Ore is mainly hematite containing one-half to one percent pyrite in certain zones and has a relatively high phosphorous content. Some cinnabar, cuprite, tenorite and malachite were associated with the iron ore.

Mining started in surface outcrops in 1926 by the Milner Corporation on the Desert Mound and King No. 1 claims. Mining moved from the Desert Mound to the Contact claim in 1931. Mining continued on the Contact and King No. 1 claims at Desert Mound until 1936, when operations shifted to Iron Mountain. Mining was resumed on the Desert Mound ore body in 1949 by U. S. Steel Corporation and has been in more or less continuous operation since. The Desert Mound ore body is owned by CF&I Steel Corporation and Milner Corporation and mined by U. S. Steel. The ore body has produced 18 million tons of ore, and about 2 million tons remain to be mined.

Duluth ore body is located in N½ sec. 36, T. 36 S., R. 14 W., on the southeast side of Iron Mountain. The property contains five patented claims owned by U. S. Steel Corporation. Iron ore occurs mainly as fissure veins in quartz monzonite porphyry, and several small mineralized roof pendants of Homestake limestone outcrop. Limited exploratory work and no development work have been done. The deposit may possibly have an ore potential of 500,000 tons.

Duncan ore body lies in parts of SE¼ sec. 34, T. 36 S., R. 14 W. and NE¼ sec. 3, T. 37 S., R. 14 W., on the southwest side of Iron Mountain. The

Figure 14. Comstock ore body, Iron Mountain, owned by CF&I Steel Corporation.

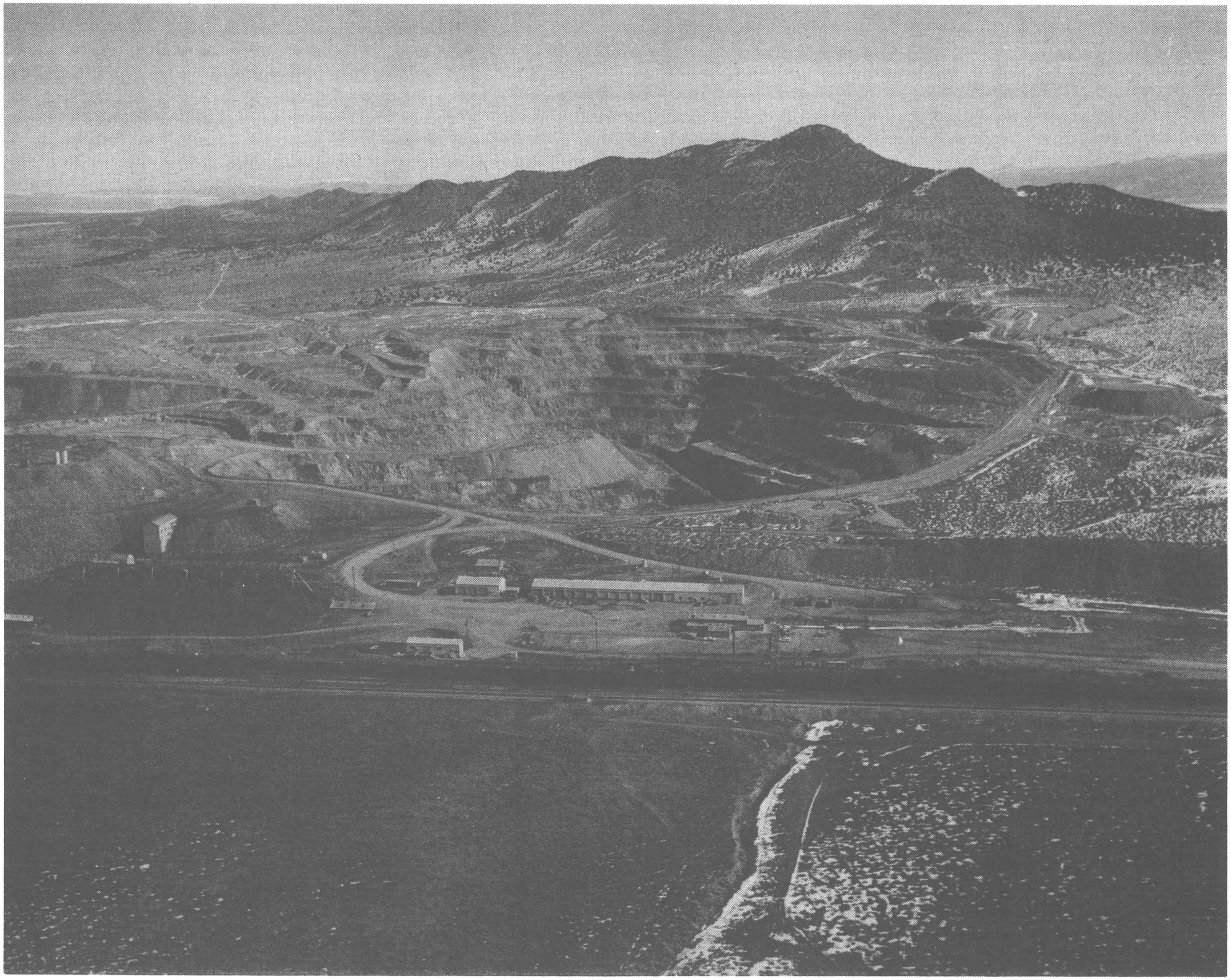


Figure 15. Desert Mound pit: operating facilities of U. S. Steel Corporation in foreground, and Granite Mountain in background.

property is owned by CF&I Steel Corporation. The ore body occurs as a massive replacement of Homestake limestone. The ores are medium soft to medium hard and have a high sulfur content. A fissure traverses the deposit and is bounded by pyrite mineralization. Pyrite gives the ore a sulfur content of 1 percent and higher in some areas.

The Duncan mining claims were acquired about 1900 by the Colorado Coal and Iron Company, later changed to Colorado Fuel and Iron Company, and now CF&I Steel Corporation. No mining activity was conducted on the property until 1942, when the corporation contracted with Utah Construction and Mining Company to strip and ship the ore. The deposit has been in continuous operation until recent years, and lately on an intermittent basis. The deposit has an ore potential of probably less than 5 million tons. A total of 2,301,249 long tons was mined from the Duncan ore body through 1968.

Eclipse ore body lies west of the Vermilion property in NE¼ sec. 30, T. 35 S., R. 12 W., on the north end of Granite Mountain. The deposit occurs in a step-faulted block of Homestake limestone as a small replacement body. Drilling operations exposed 14 feet of ore in one hole and 19 feet in another. A small magnetic anomaly extends for about 700 feet along strike. The west end of the anomaly swings southwest and conforms to the direction of the marginal Clive thrust fault. This ore body is owned by Utah Construction and Mining Company and has an ore potential of less than 500,000 tons.

Excelsior ore body is located on the Excelsior lode claim in E½ sec. 25, T. 36 S., R. 14 W., high on the east side of Iron Mountain. The ore body is a fissure vein about 1,000 feet long and from 2 to 20 feet wide (figure 12). It is cut by three northeast-trending faults which offset the fissure vein. The iron ore mineral is high-grade magnetite. The property is owned by CF&I Steel Corporation. No development work has been performed on the property. The deposit has an ore potential in the range of 200,000 tons.

Georgia ore body lies in SE¼ sec. 25, T. 35 S., R. 13 W., on the west side of Granite Mountain, and is associated with the northeast-trending Clive thrust fault. Drill holes and recent stripping operations show a replacement ore body in Homestake limestone occurring as a wedge along the Clive fault. Ore also occurs as breccia fillings and replacements along the fault zone. The ore body was covered by about 90 feet of alluvium which recently was stripped preparatory to mining operations. The Georgia ore deposit is owned by Milner Corporation and is leased by Utah Construction and Mining Company. The property has an ore potential of about 500,000 to 1 million tons. Mining operations started during the latter half of 1969.

Great Western ore body lies near the south end of Three Peaks in NE¼ sec. 21, T. 35 S., R. 12 W., a fissure vein in the selvage joint zone of quartz monzonite porphyry. The original fissure had an average strike of north 65° east with a dip of 75° northwest, a surface strike length of about 750 feet and a maximum width of 25 feet. The vein is the largest known in the Three Peaks area. The ore is composed of hard and dense magnetite with small amounts of hematite and limonite. The ore contains quartz, apatite and calcite. The average iron content is greater than 60 percent. Production from this property from 1937 to 1957 totaled about 80,000 tons. Utah Construction and Mining Company owns the property. The potential of the remaining ore in the fissure vein is probably between 50,000 and 100,000 tons.

Homestake mine ore body occurs in S½ and NE¼ sec. 19, T. 36 S., R. 13 W., on the northeast side of Iron Mountain. Original development work was done in the early 1900's. A 200-foot vertical east shaft encountered ore at 200 feet, and a 100-foot inclined west shaft penetrated more than 50 feet of ore. A crosscut at the 50-foot level of this shaft shows an ore body about 60 feet thick. In recent years drilling by the owner, U. S. Steel Corporation, has delineated the ore body in detail.

The Homestake mine ore body is a metasomatic replacement deposit in Homestake limestone. Near the mine the Homestake limestone, Entrada sandstone and Iron Springs Formation strike about north 40° west and dip 70° to 80° east. The ore body dips steeply east parallel with the bedding. A magnetic anomaly can be traced for about 1,100 feet along strike giving the highest values at the north end of the anomaly. The ore is covered with alluvium; there is very little outcropping on this deposit. The ore contains as much as 1 percent copper. Ore potential of this deposit is more than 5 million tons.

Irene ore body lies in SE¼ sec. 3, T. 35 S., R. 12 W., on the northwest side of Three Peaks, and is a replacement type deposit in a small roof pendant of Homestake limestone. It is steeply dipping, surrounded by quartz monzonite porphyry and is only partly replaced. The strike length of the deposit at the surface was about 300 feet and the maximum width was about 50 feet. The property is owned by Jones Brothers Company and leased by Utah Construction and Mining Company. The property produced about 1 million tons of high-grade ore, low in silica, sulfur and phosphorus. The ore potential may approach 2 million tons.

Jeannette ore body is located in SE¼ sec. 31, T. 35 S., R. 12 W., on the southeast side of Granite Mountain. The deposit is a fissure vein in quartz monzonite porphyry. The main vein, which averages about five feet in width, can be traced for more than 300 feet. It strikes to the northeast and is associated with smaller veins with a similar attitude. The ore potential is only a few thousand tons.

Jones ore body lies in NE¼ sec. 21, T. 35 S., R. 12 W., on the south end of Three Peaks, a short distance east of the Great Western fissure vein. The Jones ore body is a fissure vein in quartz monzonite porphyry. The strike length is about 300 feet and the average width is approximately three feet. The ore potential is perhaps only a few thousand tons of magnetite ore.

King ore body lies a short distance northeast of Desert Mound ore body in SW¼ sec. 36, T. 35 S., R. 13 W., on the southwest side of Granite Mountain. A magnetic anomaly outlined by the U. S. Bureau of Mines prompted cutting of seven exploratory churn drill holes. Brecciated and mineralized porphyry rock was encountered in six holes; the seventh was cut in barren Homestake limestone. The average iron content was 28.2 percent. The King claims are owned by the Milner Corporation. The ore body is considered noncommercial, with an ore potential possibly of 100,000 tons of low-grade ore.

Last Chance ore body is located in NE¼ sec. 30, T. 36 S., R. 13 W., on the east side of Iron Mountain, a small outcropping replacement type ore body a short distance east of the Comstock ore body. The property is owned by CF&I Steel Corporation. The deposit appears to have a potential of about 1 million tons. Utah Construction and Mining Company plans to strip and mine this ore body.

Lime Cap ore body lies in SE¼ sec. 34, T. 36 S., R. 14 W., on the west side of Iron Mountain, between the Burke and McCahill ore bodies. The ore deposit is a small off-dipping replacement in the lower part of the Homestake limestone. It is similar to the nearby Duncan ore body and has a moderately high sulfur content. The property is owned by U. S. Steel Corporation, Milner Corporation and A. E. Moreton. The ore potential is probably between 2 million and 3 million tons.

Lindsay ore body is located in SW¼ sec. 29, and NW¼ sec. 32, T. 35 S., R. 12 W., on the east side of Granite Mountain (figure 16). The Lindsay deposit originally outcropped along its strike for about 1,300 feet; its widest surface exposure was about 300 feet. The deposit extended an additional 700 feet southward beneath bedrock and alluvium. This ore body is an example of a homoclinal, contact metasomatic deposit which typifies the Iron Springs district. The deposit dips toward the east. Quartz monzonite porphyry and the basal siltstone member of the Carmel Formation are west of the deposit; the upper unreplaced limestone beds of the Homestake limestone member of the Carmel Formation lie to the east. The formation strikes approximately north-south and dips about 45° east. The dip of the ore body is somewhat steeper, 55° to 60° east. At the northeast end of the Lindsay pit the ore is nearly vertical. The deposit originally measured up to 200 feet thick and extended down-dip for at least 1,100 feet. The deposit was essentially a tabular pod with little or no lensing. At depth, however, the deposit apparently merges into a breccia pipe deposit, suggesting that the Lindsay deposit has been fed from depth and not from the adjacent porphyry as has been suggested by Mackin (1954).

The Lindsay deposit is underlain along part of the footwall by a basal breccia, composed of the basal siltstone member of the Carmel Formation and the outer margin of the porphyry which is strongly brecciated and mineralized. The upper contact of the ore and unreplaced limestone is sharp. The ore is often lean and poor near the quartz monzonite porphyry contact. The property is owned jointly by U. S. Steel Corporation and Utah Construction and Mining Company. Mining begun in 1945 by Utah Construction and Mining Company produced about 16 million long tons of ore through 1968. There are perhaps 4 million tons of ore that can yet be mined economically by open pitting.

Little Allie ore body lies in SW¼ sec. 32, T. 35 S., R. 12 W., on the east side of Granite Mountain. The ore body is located on the Cory-Armstrong in-dipping thrust fault which has a throw of about 1,300 feet. The Iron Springs Formation is in fault contact with quartz monzonite porphyry. The deposit was pipelike in form and situated mostly in the quartz monzonite porphyry, and was associated with a strongly brecciated zone which likely served as a feeder pipe for iron-bearing hydrothermal solutions. Breccia fillings and replacements extended northward from the main ore body along the Cory-Armstrong fault. Ores consisted of massive and fibrous magnetite and intimate intergrowths of magnetite and quartz, and vugs of quartz and amethyst were common. The property, owned and operated by Utah Construction and Mining Company, has produced more than 3 million long tons of ore.

Little Jim ore body is situated in SE¼ sec. 35, T. 35 S., R. 13 W., in the Desert Mound area on the southwest end of Granite Mountain. A magnetic anomaly was disclosed by the U. S. Bureau of Mines investigation during 1944-45. The deposit appears to be similar to the King ore body, consisting of mineralized and brecciated porphyry. The property is owned by Milner Corporation and leased by U. S. Steel Corporation. The ore potential is small and contains only low-grade ore.

Little Mormon ore body lies in W½ sec. 29, T. 35 S., R. 12 W., immediately south of Pioche ore body on the north side of Granite Mountain. This contact metasomatic replacement is associated with four small faults that displace the contact zone. The ore body is located where the largest fault crosses the contact. The deposit has a surface outcrop 375 feet long and an apparent width of 110 feet. Homestake limestone strikes northerly and dips 30° to 35° east. The ore body replaces about 50 feet of the lower part of the limestone and also dips toward the east. The property is owned by the U. S. Steel Corporation and has an estimated ore potential of about 1 million tons. The deposit is leased to the Utah Construction and Mining Company.

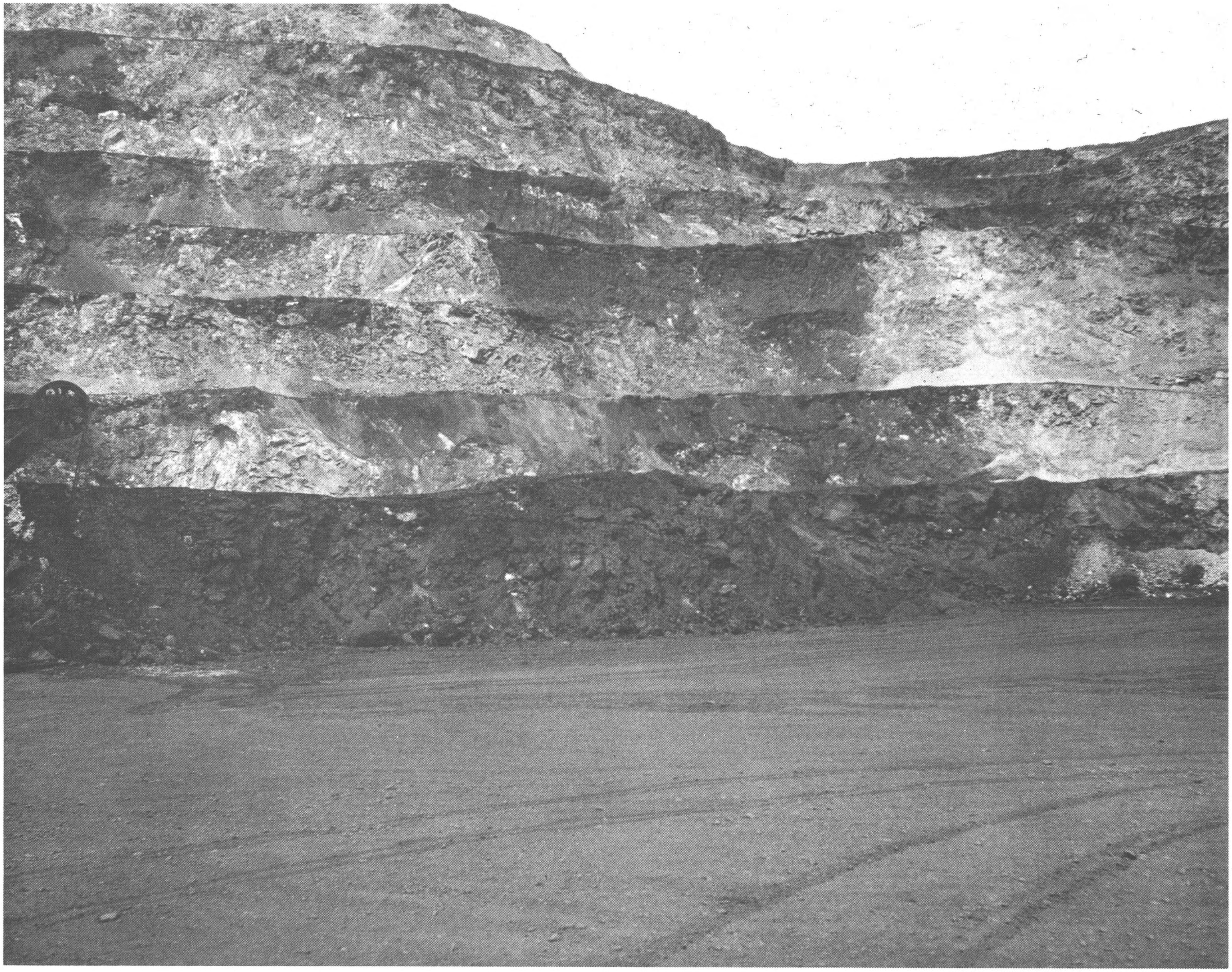


Figure 16. Lindsay ore body, Granite Mountain, showing 30-foot safety berms at 75-foot intervals along brecciated porphyry footwall, and replacement ore body in lower half of photo.

McCahill ore body lies in W½ sec. 34, T. 36 S., R. 14 W., on the southwest end of Iron Mountain, west of the Lime Cap and Burke ore deposits. The ore body was disclosed by an aerial magnetometer survey conducted by the U. S. Steel Corporation. The McCahill ore body does not outcrop and lies 500 to 800 feet beneath the surface, a tabular replacement ore body that dips to the west. Ore is traceable for about 1,200 feet down-dip; in places the full thickness of the Homestake limestone is replaced. The ore body apparently is cut by a fault which thins the ore body, a mixture of hematite and magnetite, fairly high in sulfur from the presence of pyrite. The deposit is owned by the Duluth and Utah Iron Mining Company and A. E. Moreton. The ore potential of this property approaches 30 million tons.

McGarry ore body lies in W½ sec. 10, T. 35 S., R. 12 W., on the west side of Three Peaks. The deposit is either a small roof pendant replacement of infolded Homestake limestone or a down-faulted slice of limestone completely surrounded by porphyry. Basal Homestake limestone is present. Ore is exposed at the surface in an area 380 feet long with a maximum width of 60 feet. The property is owned by the Utah Construction and Mining Company. The ore potential is small, probably less than 500,000 tons, averaging about 54 percent iron and 0.3 percent phosphorus.

Mountain Lion ore body lies in SW¼ sec. 19, and NW¼ sec. 30, T. 36 S., R. 13 W., on the northeast side of Iron Mountain (figure 17). This is a metasomatic replacement type of deposit, associated with the largest roof pendant of the Homestake limestone in Iron Springs district. It is a northward extension of the huge Comstock ore body. Surface exposures of the deposit are more than 2,000 feet in length. It is bounded and cut by faults of varying magnitudes and often shows brecciation. The property is owned by U. S. Steel Corporation. A total of 3,281,332 long tons of ore have been mined by CF&I Steel Corporation from the Mountain Lion deposit on an ore exchange agreement. U. S. Steel started mining in this pit in 1970. The ore body has been outlined by drilling operations. The Comstock, Mountain Lion and nearby claims constitute an ore potential approximating 50 million to 60 million tons, of which the Mountain Lion ore body would constitute approximately one-fourth.

Pinto ore body occurred in SW¼ sec. 35, T. 36 S., R. 14 W., and extended into NW¼ sec. 2, T. 37 S., R. 14 W., on the southwest side of Iron Mountain. Claims covering the deposit were located early in the history of the district, but no large-scale mining was done until 1942. The ore body was depleted in 1957 by U. S. Steel, owners of the property.

Pinto ores were formed by metasomatic replacement of the Homestake limestone. The deposit was a moderate sized, off-dipping, homoclinal ore, surrounded on three sides by quartz monzonite porphyry. The property lies between the Burke and Black Hawk ore bodies bounded by a fault at the south end of the deposit. The iron ore minerals were hematite and magnetite mixtures, and small pockets and veinlets of galena occurred in the ore. Only a thin mantle of overburden covered the main ore body. The property produced more than 10 million long tons of good quality ore.

Pioche ore body lies in NW¼ sec. 29, and NE¼ sec. 30, T. 35 S., R. 12 W., at the north end of Granite Mountain. The Pioche and Vermilion deposits are often regarded as one deposit because of their proximity, but the writer prefers to treat them separately since they are separated by a northeast-trending fault with a 300-foot breccia zone. Ores from the Pioche and Vermilion deposits provided ore for the initial blast furnace at Ironton, Utah, owned by the Columbia Steel Corporation of California. This operation which began in 1923 was the first commercially profitable iron ore venture in the Iron Springs district with significant yield. Mining continued until July 1926, then was idle until 1959, when U. S. Steel began stripping operations.

The Pioche ore body is a metasomatic replacement deposit in the Homestake limestone. This formation changes strike from northwest at the Lindsay ore body to east-west as the monoclinal structure extends northwest from the Lindsay Pit around the north end of Granite Mountain. At the Pioche deposit the Homestake limestone strikes essentially east-west and dips 30° to 45° north. The ore body is somewhat crescent-shaped and can be traced on the surface for more than 1,200 feet along strike. The deposit dips northward and was displaced by step-faulting. The ore body is of moderate size with potential of about 4 million tons.

Pot Metals ore body lies in NE¼ sec. 31, T. 36 S., R. 13 W., on the east side of Iron Mountain, along the brecciated Calumet fault zone. The structural setting of this deposit is similar to that of the Blowout ore body. Downslope and east from the main brecciated zone, the Homestake limestone has a nearly vertical dip, with several small replacement pods of ore. The deposit consists of several replacement pods and fissure veins in the breccia zone and porphyry. The ore is high in silica. The property, owned by CF&I Steel Corporation, has an ore potential of less than 1 million tons.

Queen of the West ore body lies in SW¼ sec. 30, T. 36 S., R. 13 W., on the east side of Iron Mountain. The ore body is a small roof pendant replacement type deposit in Homestake limestone and is completely surrounded by quartz monzonite porphyry. The ore outcrop originally measured about 600 feet along the strike and is 200 feet wide. Replacement of the roof pendant was not complete. The property is owned by CF&I Steel Corporation,

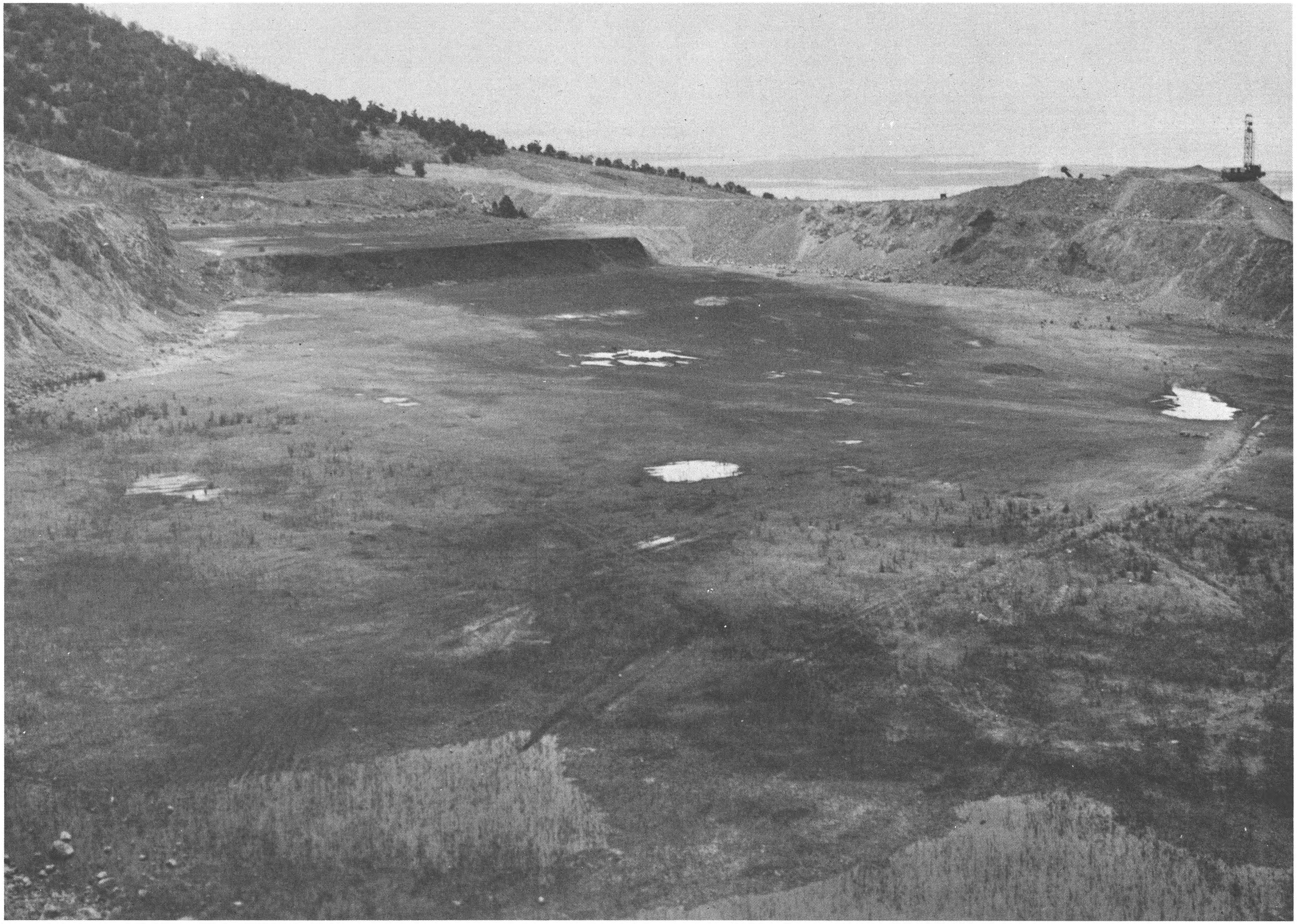


Figure 17. Mountain Lion ore body, Iron Mountain, exposed for 2,000 feet, owned by U. S. Steel Corporation.

which started mining the ore body in 1956; the deposit was depleted in 1967. The property produced about 500,000 tons of ore.

Rex ore body is situated in SW¼ sec. 26, SE¼ sec. 27, NE¼ sec. 34, and NW¼ sec. 35, all in T. 36 S., R. 14 W., on the west side of Iron Mountain. A small topographic high known as Milner Hill is exposed on the Rex property. It is part of the Iron Springs Formation and strikes north-south and dips about 20° west. The formation is in fault contact with the Iron Mountain intrusion. Surface expressions of the Rex deposit are limited to a small mineralized outcrop of Iron Springs Formation and a few large scattered boulders of iron ore.

A strong pear-shaped magnetic anomaly, about 3,000 feet in diameter, was disclosed over the Rex ore body during U. S. Bureau of Mines investigation of the district in 1944-45. This deposit produced the strongest and most extensive anomaly observed from magnetic surveys of the bureau. Drilling operations disclosed this deposit to be the largest replacement and breccia filling ore occurrence in the Iron Springs district.

The Rex ore body is situated on the non-deroofed westward extension of the Iron Mountain intrusion. Extensive brecciation is associated with Homestake limestone, overlying Entrada sandstone and the Iron Springs Formation. The main Rex ore body is a metasomatic hydrothermal replacement of Homestake limestone, but mineralization is also strong in overlying brecciated formations. Significant breccia filling as veinlets occurs in the Entrada sandstone and the Iron Springs Formation where they overlie the main Rex ore body. Iron mineralization was encountered in the lower Iron Springs Formation at a depth of about 500 feet, continuing through the Entrada sandstone and into typical replacement ore in underlying Homestake limestone. A mineralized zone more than 750 feet thick occurs at this deposit. The property is owned by U. S. Steel Corporation. The estimated ore potential of this ore body exceeds 100 million tons of ore.

Section 2 ore body lies in SW¼ sec. 2 and SE¼ sec. 3, T. 36 S., R. 13 W., southwest of Desert Mound. The deposit is non-outcropping and was discovered by aerial magnetic surveys by the U. S. Steel Corporation. The deposit, a nearly complete replacement body of the Homestake limestone member, thins in each direction. The property was extensively drilled by U. S. Steel, lessee of the property. The deposit is owned by the Milner Corporation and the Iron County Land Company. The top of the ore body lies from 900 to 1,300 feet below the desert surface. The Section 2 ore deposit has an estimated iron ore potential of more than 10 million tons.

Section 3 ore body lies in SE¼ sec. 3, T. 36 S., R. 13 W., southwest of Desert Mound and Granite Mountain. Section 3 ore deposit is a small replacement type occurrence in Homestake limestone. The top of the ore lies 600 to 800 feet below the surface and was discovered by aerial magnetic surveys by U. S. Steel Corporation. The property was drilled by U. S. Steel which leased the property from the Milner Corporation. The ore potential of this deposit is about 2 million tons.

Section 4 ore body is situated in SE¼ sec. 4, T. 36 S., R. 13 W., southwest of Desert Mound and Granite Mountain. This small deposit lies 900 feet below the surface and was discovered by aerial magnetic surveys by U. S. Steel; the deposit is a metasomatic replacement of Homestake limestone. The property, owned by the Lone Pine Company, has an estimated ore potential of about 1 million tons.

Section 9 ore body is located in N½ sec. 9, T. 36 S., R. 13 W., southwest of Desert Mound and Granite Mountain. This deposit lies 700 to 900 feet below the surface and was discovered by aerial magnetic surveys by U. S. Steel. An extensive drilling program was conducted during 1958-61. The deposit, a metasomatic replacement of Homestake limestone, was cut by five or six north-trending faults of varying magnitudes. The deposit shows considerable brecciation and may be separated in two ore bodies. Section 9 West ore body has an ore potential of about 15 million tons, and Section 9 East ore body has a potential of about 20 million tons. The property is owned by the Lone Pine Company and others.

Shortline ore body is situated in S½ sec. 35, T. 35 S., R. 13 W., near Desert Mound, at the southwest end of Granite Mountain. The deposit was originally concealed by more than 100 feet of alluvium and was discovered by a ground magnetometer survey. Initial drilling was conducted in 1930. A total of 23 churn drill holes were made during this period, mainly on the east half of the deposit. The U. S. Bureau of Mines completed six diamond drill holes on the deposit in 1942-45. Additional drilling was conducted by U. S. Steel and production begun in November 1949. The deposit is now depleted.

The Shortline ore body was a metasomatic replacement of Homestake limestone. The limestone occurred as a graben block or wedge of Homestake limestone that was infaulted into the intrusive porphyry and bounded by pre-mineral east-trending faults. The deposit had a maximum east-west length of about 1,800 feet and an average width of 300 feet. In some sections ore replaced the full thickness of Homestake limestone, from 150 to 300 feet. At depth along the south margin the ore became localized along a brecciated zone and extended to an undetermined depth. The ore was mainly hematite, a soft fine granular mixture with sporadic ribs of hard dense ore. The deposit averaged about 49 percent iron and 0.12 percent phosphorus. The property is owned by U. S. Steel and the Milner Corporation.

The Shortline deposit produced about 6 million long tons of ore. The pit is largely refilled by waste rock from the Desert Mound ore body.

Smith ore body lies on the south end of Three Peaks in SW¼ sec. 22 and SE¼ sec. 21, T. 35 S., R. 12 W. The ore deposit is a metasomatic replacement of Homestake limestone which occurs as a roof pendant in quartz monzonite porphyry. The ore is associated with a recumbent fold north of the Homestake limestone, is bounded on both sides by the basal siltstone member of the Carmel Formation, and has completely replaced up to 200 feet of limestone. Strike length of the east deposit was approximately 600 feet. This deposit produced about 1 million long tons of high-grade magnetite ore. The length of the west ore deposit is somewhat greater; it has an ore potential of about 2 million tons. The ore is good grade magnetite with some hematite and has been mined intermittently for several years. The property is owned by the Utah Construction and Mining Company.

State Section 2 ore body occurs on Utah state land in NE¼ sec. 2, T. 36 S., R. 13 W., at Desert Mound southeast of Granite Mountain. The deposit lies about 500 feet below the surface. A magnetic anomaly was mapped over the deposit by the U. S. Bureau of Mines in a geophysical survey in 1944-45. The property was leased from the state by U. S. Steel, which drilled the property. A small replacement type ore deposit was disclosed in Homestake limestone, about 500 feet below the surface, averaging approximately 40 percent iron, and has an ore potential between 1 million and 2 million tons.

State Section 16 ore body occurs on Utah state land in SW¼ sec. 16, T. 35 S., R. 12 W., on the southwest side of Three Peaks. A magnetic anomaly mapped by the U. S. Bureau of Mines in 1944-45 prompted exploration by diamond drilling. One hole, drilled by the Bureau in 1951, additional holes in 1962 and 1963, and subsequent holes drilled by the Utah Construction and Mining Company, reveal a metasomatic replacement type ore body in Homestake limestone. The limestone formation and ore body dip about 60° south. Ore lies 800 to 1,000 feet below the surface and is principally magnetite. The ore potential of this deposit probably is approximately 1 million tons.

Thompson ore body lies in NW¼ sec. 2, T. 36 S., R. 13 W., at Desert Mound on the southwest end of Granite Mountain. This deposit is not exposed at the surface but lies beneath a low hill of Entrada sandstone and Iron Springs Formation. It was discovered by the U. S. Bureau of Mines during its geophysical surveys of the district in 1944-45. Exposed sedimentary rocks strike east-west and dip about 20° south. Surface mineralization consists of martite crystals disseminated in bedrock and small fissure fillings of magnetite and hematite along joints and fractures. The deposit is a tabular pod, somewhat elliptical in shape, which dips southwest. The ore lies from less than 200 to more than 300 feet below the surface, is about 600 feet long and 300 feet wide, and ranges from 85 to 235 feet in thickness. The property is owned by Matthew Leonard and Orval Clark. The ore potential is about 1 million tons.

Tip Top ore body lies near the center of sec. 25, T. 36 S., R. 14 W., near the top of Iron Mountain. The deposit is a fissure vein in quartz monzonite porphyry and is about 800 feet long and 2 to 30 feet wide. The vein is located on the Tip Top patented lode claim and is owned by the Utah Construction and Mining Company. The property has an ore potential of 100,000 to 200,000 tons.

Twitchell ore body in NW¼ sec. 30, T. 35 S., R. 12 W., lies between the Clive-Constitution and Eclipse ore bodies on the northwest side of Granite Mountain. The ore body is non-outcropping and occurs along the Clive fault which brought the Iron Springs Formation in fault contact with quartz monzonite porphyry. The fault has vertical to high-angle reverse dips and shows considerable brecciation. Iron ore occurs as breccia fillings and minor replacements of the Iron Springs Formation and has marked silicification. The ore potential is probably between .5 and 1 million tons; the ore would require benefication.

Vermilion ore body lies in NE¼ sec. 30, T. 35 S., R. 12 W., at the north end of Granite Mountain. The deposit lies immediately west of the Pioche ore body, where a northeast-trending fault with a 300-foot breccia zone separates the two deposits. The Vermilion ore body strikes east-west for about 600 feet and dips gently north. It is a metasomatic replacement of Homestake limestone and averages about 50 feet in thickness. The Homestake limestone crops out on the south side of the deposit and dips about 30° north. Overburden increases rapidly toward the north. Homestake limestone is exposed throughout the Vermilion pit, but a few hundred feet west it is faulted down by the Clive marginal thrust fault, bringing the Iron Springs Formation in fault contact with porphyry. The Vermilion ore body is much smaller in length, thickness and depth than the nearby Pioche ore body; it is owned by U. S. Steel and leased to the Utah Construction and Mining Company. The ore potential of this deposit is about 2 million tons.

Wall Street ore body is located in NW¼ sec. 31, T. 35 S., R. 12 W., on the east side of Granite Mountain. The deposit is a fissure vein in quartz monzonite porphyry; the vein length is about 500 feet. The property is held by the Utah Construction and Mining Company. The ore potential is small, probably ranging between 50,000 and 100,000 tons.

Yellow Jacket ore body is located in SE¼ sec. 19 and NE¼ sec. 30, T. 36 S., R. 13 W., on the northeast side of Iron Mountain. The deposit lies immediately south of the Homestake mine ore body and is a contact metasomatic replacement in Homestake limestone. Replacement was not complete as shown by the presence of chlorite, epidote and other silicates in the ore. Limestone strikes northwest and dips from 70° to 80° northeast. Original outcrops of ore were about 375 feet along strike, and the ore body dips steeply parallel with Homestake limestone beds. The property is owned by U. S. Steel and leased by the Utah Construction and Mining Company. The ore body has been stripped in preparation for mining. Since the ore is high in silicates and sulfur it will be treated at the Iron Springs beneficiation plant. The ore potential of this deposit is at least 1 million tons.

Zelma ore body lies in SW¼ sec. 15 and SE¼ sec. 16, T. 35 S., R. 12 W., at the south end of Three Peaks, a short distance northwest of the Great Western ore body. The Zelma deposit is a fissure vein in quartz monzonite porphyry with a strike length of about 800 feet and a maximum width of 10 feet. The property, owned by the Utah Construction and Mining Company, has an ore potential of about 50,000 to 100,000 tons.

Magnetic Concentration

Magnetic concentration of iron ores was introduced in the Iron Springs district by the Utah Construction and Mining Company. They began direct shipping of iron ores from the Iron Springs district in 1944. As their reserves of direct-shipping ore diminished and as the need for higher-grade furnace feed at the Geneva Works increased, beneficiation facilities were added to meet the specifications of the steel mills. Such a plant was installed at Iron Springs where it began operations in April 1961 (Erspamer, 1964). Grinding, scrubbing and wet magnetic separation facilities were capable of handling 2,500 tons per day of minus 1¼-inch ore.

Three years later a revised contract called for a higher-grade product, and the Utah Construction and Mining Company expanded their Iron Springs plant to handle 4,000 tons per day of minus 1¼-inch ore (figure 18). Nearly all run-of-mine ore is processed at the plant by crushing, grinding, screening and open hearth cobbing, wet beneficiation of blast furnace ore by scrubbing and wet magnetic separation and stockpiling, blending and loading of concentrates for shipment. In 1967 the Utah Construction and Mining Company mined 398,152 tons of ore in the district, of which 19,247 tons were direct-shipping ores. The remaining 355,014 tons, with an average iron content of 42.7 percent, were shipped to the beneficiation plant. During the same year this company shipped 248,205 long tons of concentrates from mined ore with an average iron content of 58 percent to the Geneva works.

Alluvial Iron Ores

The principal iron ore deposits in the Iron Springs district occur as irregular bodies of magnetite and hematite which replace mainly the Homestake limestone member of the Jurassic Carmel Formation, and lie near contacts of Tertiary quartz monzonite intrusives. The ore bodies are major replacements in limestone, breccia fillings and replacements along faults and pipelike structures and as minor fissure fillings in intrusive rocks. Alluvial iron ores are concentrated from weathered products of intrusive rock and iron ore deposits. As weathering progressed, magnetite-hematite debris moved downslope and concentrated in alluvium on pediment and bajada slopes. The fact that alluvial deposits contained significant quantities of magnetic ore was known long before any serious considerations were given to ore recovery.

An innovation in the Iron Springs district was the installation of a mobile magnetic iron ore concentrator by the Utah Construction and Mining Company (Juvelin, 1965, 1967). This is a dry magnetic separation plant, self-propelled, and designed to treat low-grade alluvial deposits. A high-speed drum separation method, developed by Sala-Masinfabrik in Sweden, made treatment of low-grade ores feasible. In 1958 a laboratory model was purchased and installed in the company's research laboratory at Palo Alto, California.

A year later, trenches were dug in alluvium in the district with a backhoe and the debris sampled. A Caldwell bucket drill was used to determine the depth of alluvium and to obtain samples. Laboratory and pilot plant test results justified a more detailed investigation. A prototype of an Indiana General high-speed drum was used for additional tests on alluvial ores. In 1962 a full scale model was set up at the Iron Springs pilot plant and large scale tests were run. During this time a mobile plant was conceived and designing began. The final design and construction contract was awarded Bodinson Manufacturing Company of San Francisco in 1963. The mobile magnetic iron ore concentrator went into operation in 1964 (Juvelin and McArthur, 1967) on the McCahill-Thompson property on the northeast side of Iron Mountain.

Absence of titanium in the ore, relatively high magnetite concentration, and large quantities of debris between 28 mesh and 24 inches allow an especially favorable operation. The alluvial deposits average about 10 percent iron and range from 3 to 20 percent (McArthur and Porath, 1965). Three percent iron is roughly the inherent iron analysis of the intrusive rock. A cutoff as low as 6 percent iron is used in alluvial concentration. A typical structure of the crude alluvium follows:

Structure of Crude Alluvium

Size	Percent
+8"	2
-8"+4"	12
-4"+3/4"	15
-3/4"+1/4"	11
-1/4"+100 mesh	35
-100 mesh	25

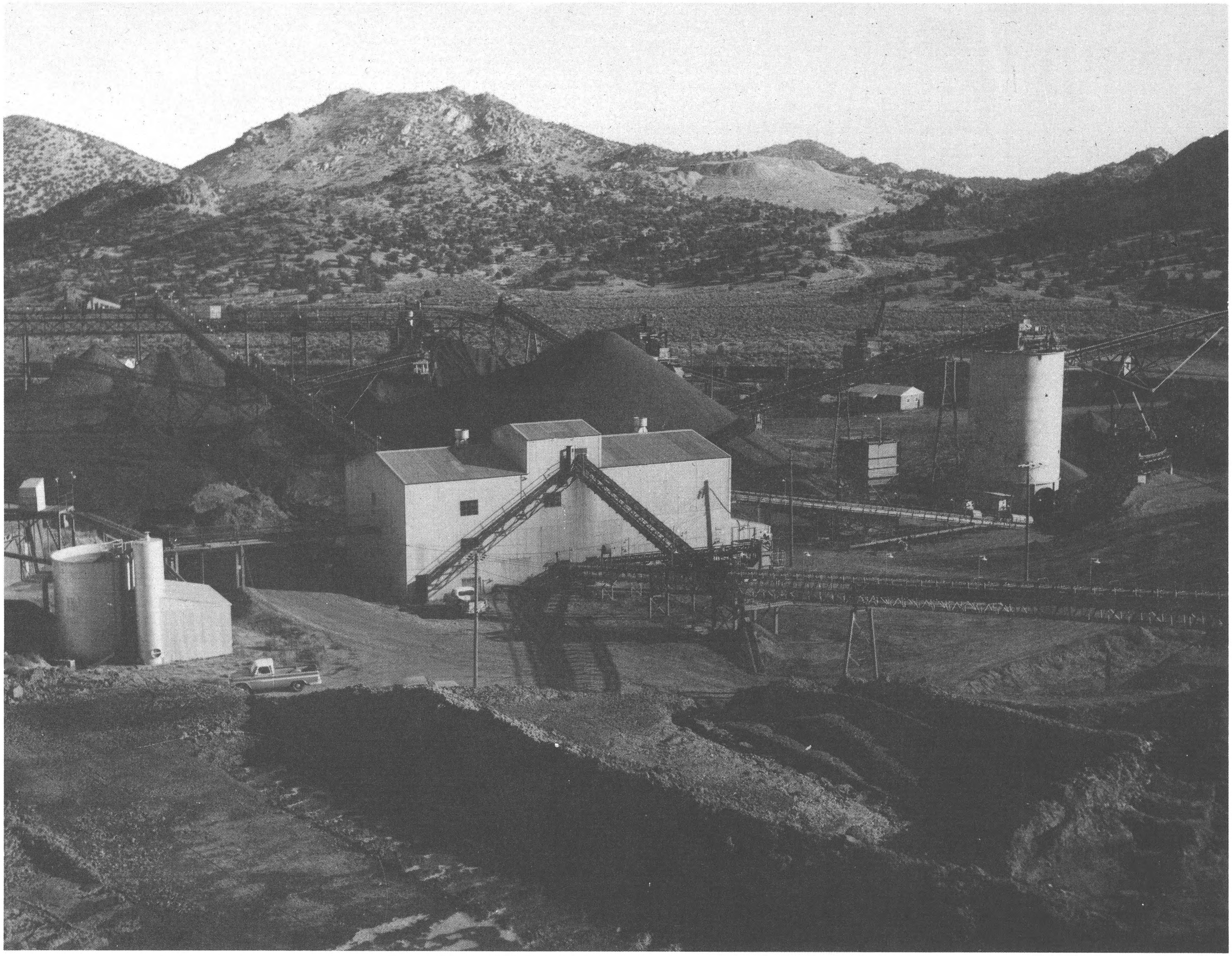


Figure 18. Iron Springs iron ore beneficiation plant, owned by Utah Construction and Mining Company.

Mining depths to 100 feet or more are contemplated.

The process used in recovering iron ore from crude alluvium is essentially a size separation followed by magnetic separation of size fractions (see figure 19). Oversize is eventually used as open hearth ore, the undersize in blast furnaces.

In 1967 Utah Construction and Mining Company produced 300,578 long tons of dry crude field concentrate with an average grade of 53.5 percent iron content. They shipped 227,711 long tons of alluvial concentrates with a minimum 60 percent iron content from the Iron Springs beneficiation plant.

Production and Chemical Analyses

Iron ore production from the Iron Springs district by Mormon pioneers was meager and sporadic, with only a few thousand tons of ore being processed. The first major development of metallic iron production from iron ores was achieved in 1924 by Columbia Steel Corporation of California at the Ironton Plant at Provo, where a blast furnace with a rated capacity of 500 tons of pig iron daily or 200,000 tons annually was erected. The greatest ore production from the district prior to United States entry into World War II was 354,795 long tons in 1938. After the Geneva Works was completed, ore production rose to 1,931,795 long tons in 1945. From 1944 to 1961 iron ore production averaged 3.25 million long tons annually. Under the stimulus of the Korean War, ore production from the Iron Springs district rose to 4,836,596 long tons in 1953.

Since August 1962 the Geneva Works has been receiving 1.5 million gross tons annually of agglomerated taconite pellets from U. S. Steel Corporation's mine at Atlantic City, Wyoming. Production of ore from the Iron Springs district has been greatly reduced since the use of taconite ore. From 1962 to 1968, ore production from the Iron Springs district has averaged 2.02 million long tons. Production during 1968 was 1,763,511 long tons.

Three major iron mining companies produce ores from open pit operations in the Iron Springs district: U. S. Steel, Utah Construction and Mining Company and CF&I Steel Corporation. The largest pit in the district has a diameter of about 2,500 feet. Pit depths extend to 500 feet. Three active open pits are operated in 1970 by U. S. Steel, the Desert Mound, Pioche and Mountain Lion pits; Utah Construction and Mining Company has five operations: the Armstrong, Lindsay, Irene and Smith pits and the alluvial iron ore deposits. CF&I Steel Corporation has two active pits, the Duncan and Comstock deposits.

The main production from the Iron Springs district is direct-shipping ore. Generally the grade of direct-shipping ore ranges from 45 to 68 percent iron with an average iron content between 50 and 55 percent. This ore only requires crushing and screening prior to shipping. Ores with iron content from 20 to 45 percent are upgraded by Utah Construction and Mining Company's beneficiation plant at Iron Springs. This low-grade ore is being stockpiled by other companies for future processing. Open hearth and blast furnace ores are shipped from the district. Open hearth ore must be coarse, dense, high-grade and low in impurities, from minus 7 inches to plus 2½ inches in diameter. The finer and lower-grade ores are used for blast furnace ore, all minus 2½ inches in diameter. U. S. Steel's specifications for iron ores vary somewhat, but the following examples are general guidelines which iron producers are required to meet.

Iron ore specifications of U. S. Steel Corporation (percent).

	Open Hearth Furnaces	Blast Furnaces
Fe	58.0 minimum	50.0 minimum
SiO_2	7.0 maximum	10.0 maximum
S	0.05 "	0.10 "
P	0.40 "	0.25 "
Cu	0.04 "	0.04 "
Ni	0.04 "	0.04 "
Pb	0.01 "	0.01 "
Zn	0.01 "	0.01 "
As	0.01 "	0.01 "

Since 1962, about 70 percent of the iron ore produced in the district was shipped to the Geneva Works at Provo, and most of the balance went to the Minnequa Works, Pueblo, Colorado. From 1923 through 1968, the Iron Springs district has produced nearly 78 million long tons of iron ore with a weighted average grade of 52.7 percent iron content. Table 2 shows the annual iron ore production from the district from 1923 through 1968 with weighted average grades of iron content for each year.

Ore Reserves

Leith and Harder (1908) estimated the iron reserves of the Iron Springs district to be 40 million tons, based on surface exposures and depths of ore exposed by pits, drill holes and erosional surfaces. The district had produced but a few thousand tons of ore when investigated by Leith and Harder. The largest single deposit estimate based on exposures was 15 million tons. They indicated that their tonnage estimate was too small rather than too large, since depths used in calculations were those actually observed, and nowhere were the bottoms of any ore deposits exposed to view.

Wells (1938) made a limited study of the Iron Springs and Bull Valley districts. He indicated that individual replacement ore bodies of 10 million tons of ore were known, and estimated that the total tonnage in Iron Springs and Bull Valley districts was probably about 100 million tons.

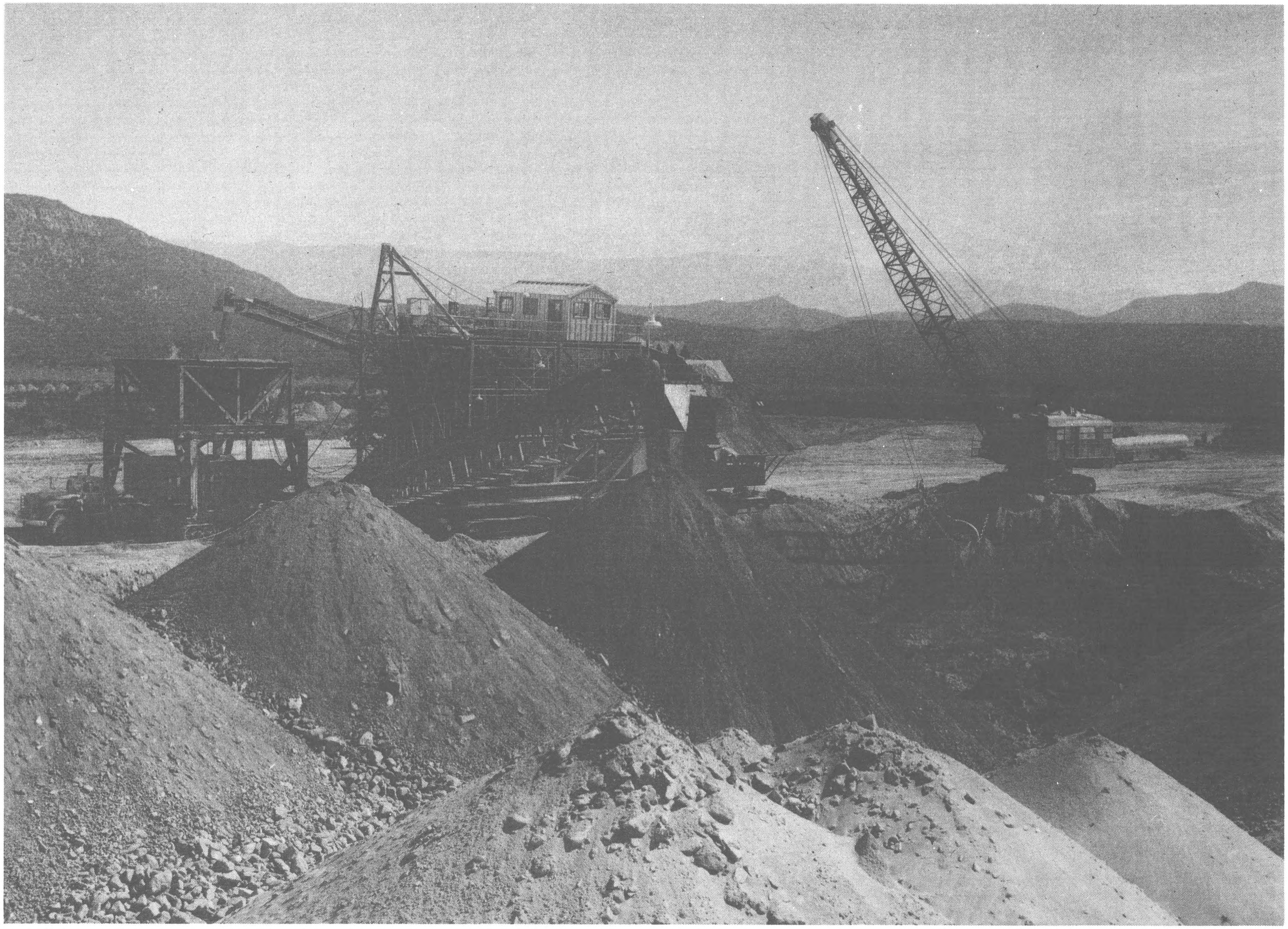


Figure 19. Alluvial iron ore concentrator, northeast end of Iron Mountain, owned by Utah Construction and Mining Company.

Table 2. Iron ore production, 1923-1968, and weighted average analyses of iron ores from Iron Springs district, Iron County.

Year	Long Tons	Iron Percent Weighted Average	Year	Long Tons	Iron Percent Weighted Average	Year	Long Tons	Iron Percent Weighted Average
1923	57,753	–	1939	262,087	53.1	1955	3,806,367	53.4
1924	164,154	–	1940	326,500	54.9	1956	4,126,811	52.6
1925	270,029	53.0	1941	355,006	54.4	1957	4,245,038	52.1
1926	275,567	54.1	1942	321,034	53.5	1958	3,563,760	49.6
1927	222,879	52.0	1943	922,959	53.7	1959	2,762,155	50.1
1928	320,655	52.6	1944	1,542,284	52.6	1960	3,369,084	50.7
1929	320,960	51.7	1945	1,931,749	52.8	1961	3,832,550	51.2
1930	277,774	52.0	1946	1,317,176	53.6	1962	2,629,758	51.7
1931	183,668	53.0	1947	2,823,853	53.3	1963	1,880,683	52.8
1932	136,874	52.6	1948	3,233,413	53.9	1964	2,082,180	52.9
1933	95,129	52.2	1949	2,712,390	55.9	1965	2,138,674	53.4
1934	161,009	52.3	1950	3,159,926	54.4	1966	1,956,101	52.7
1935	161,010	52.3	1951	3,902,594	55.1	1967	1,708,044	53.2
1936	153,923	54.7	1952	4,059,956	53.95	1968	1,763,511	53.4
1937	190,908	54.5	1953	4,836,596	54.1			
1938	354,795	54.1	1954	2,918,926	53.1	Total	77,838,251	52.7

Allsman (1948) of the U. S. Bureau of Mines estimated that 100 million long tons could conservatively be classified as measured, and indicated reserves with a grade of 45 to 50 percent iron content. This estimate was based on results from drilling, geology and geophysics. An additional 250 million long tons were inferred from geological and geophysical evidence supported by very limited drilling.

Mackin (1968) considered the reserve estimates by Allsman to be optimistic. This writer on the other hand is impressed by the many large ore bodies delineated by magnetic surveys and by several large ore deposits whose tonnage has been determined by exploratory and development drilling operations. The Rex ore body exceeds 100 million tons of ore, and the Comstock-Mountain Lion deposit has at least 60 million tons. In addition to the 78 million long tons of iron ore mined from the district through 1968, the ore potential of the district exceeds 300 million tons. This estimate is based on ore occurrences in areas where the horizontal and vertical outlines of ore bodies are fairly well established by magnetic surveys and where detailed drilling has been done. Several areas in the district still are unexplored in detail but have been outlined in a broad way by aeromagnetic and gravity surveys. Some of these areas promise new deposits, especially since the geophysical data suggest the intrusive bodies are stocks rather than laccoliths in form. The writer estimates the ore potential of the Iron Springs district could easily exceed 500 million tons.

Genesis of Ore Deposits

The genesis of iron ores in the Iron Springs district has long been a controversial issue. The first two concepts of origin were derived from casual studies and are only of historical interest. Proposed origins are metamorphosed sediments, ore magma, contact metamorphic, pyrometasomatic, pneumatolytic, deuteric alteration and contact metasomatic-hydrothermal. The writer proposes the latter origin for the development of iron ore deposits in the district.

Metamorphosed sediments origin. The first hypothesis of origin of Iron Springs ores was proposed by Newberry (1880, 1881a, 1881b, 1882). He suggested the iron ores were metamorphosed sediments of probable Lower Silurian age. He considered the ores to be interstratified with layers of granite, and based his conclusion on examination of the Blair placer, now known as the Great Western fissure vein in the Three Peaks area.

Ore magma origin. Jennings (1904, 1905) also studied the fissure veins in the Three Peaks area. He thought the iron deposits to be ore magmas resulting from differentiation of a basaltic magma at depth, and that ore magmas were forced to the surface in the form of dikes into diorite porphyry. He further suggested that when the quantity of material was more than sufficient to fill the fractures it overflowed in the form of sheets, and when the fractures extended into the overlying sedimentary rocks they were filled with ore.

Contact metamorphic origin. After study, Leith (1904, 1906) and Leith and Harder (1908) concluded that the ores were contact metamorphic in origin. They suggested that the ores were closely related in origin to intrusions of large masses of andesite taken to be laccoliths. The first effect of the intrusions was contact metamorphism of the limestone in the form of fusion of limestone, introduction of silica and the formation of anhydrous silicates. Ore-bearing solutions followed shortly after contact metamorphism of limestone and after the outer part of the intrusives had crystallized. They suggested that iron was carried in the form of ferrous chloride. The resulting ore deposits constitute fissure veins in the intrusive, fissure and replacement deposits along the contact zone in limestone, and breccia cement in Cretaceous strata. The source of iron-bearing solutions for the various types of deposits was the same, and they considered the mineralizing solutions to come from still hot magmas of the intrusive interiors. Butler (1920) made a limited study of the Iron Springs district and agreed with the conclusions of Leith and Harder concerning the origin of the ores, except that he regarded the intrusives as stocks.

Pyrometasomatic origin. Lindgren (1925, 1933) called the Iron Springs district ores pyrometasomatic deposits associated with stocks. He defined the term as those deposits formed by metasomatic changes in rocks, principally in limestone, at or near intrusive contacts, at high temperatures, and under the influence of magmatic emanations. In his classification, however, he included numerous deposits remote from intrusive contacts. Tarr (1938), Knopf (1933, 1942) and Emmons (1940) agreed generally that Iron Springs ores are associated with stocks and classified them as pyrometasomatic or contact metamorphic deposits. Both terms, however, have become obsolete for ores associated with intrusive contacts.

Pneumatolytic origin. Wells (1938) ascribed the origin of the iron ores in the district to high temperature pneumatolytic action. Although he did not use the term, his description typified this process. He stated that during intrusion of monzonite porphyry stocks, the hoods and overlying rocks were fractured, causing sudden release of pressure and liberating water vapor and iron chloride gases from the stocks which were still hot. These gases escaped to the surface along tension fractures without appreciably heating the country rocks, and deposited magnetite and hematite in fissures and replaced contiguous fractured limestone.

Deuteric alteration origin. Mackin (1947b, 1954, 1968) hypothesized a deuteric alteration origin for Iron Springs deposits. He delineated three zones in the intrusive bodies which he regarded as laccoliths. The first zone, a peripheral shell 100 to 200 feet thick, is composed of fine-grained quartz monzonite porphyry containing fresh biotite and hornblende phenocrysts. An interior zone is composed of coarse-grained porphyry in which biotite and hornblende underwent deuteric alteration. A third zone, of selvage joints, separates the interior from the peripheral shell. Rock on each side of individual selvage joints is bleached through a narrow zone to six inches thick on each side of the joint, but ranging in thickness from less than one inch to several feet. Biotite and hornblende are completely altered in this zone. Mackin and Ingerson (1960) proposed a deuteric release of iron and associated substances from the bleached selvage zone to form the iron ores of the district. They considered the iron to be "sweated out" of the selvage joint rock by diffusion and deposited as fissures in porphyry and as replacements in limestone.

Mackin (1968) published the chemical composition of intrusive rock from the peripheral shell, interior rock, and selvage joint rock (table 3). Iron content in the peripheral rock is 3.64 percent, 3.26 percent in the interior rock, and 2.18 percent in bleached selvage joint rock. The deuterically altered zone contains about the same amount of iron as the fresh peripheral zone, but bleached selvage rock contains somewhat less total iron. Mackin therefore proposed that bleached selvage rock is the source of iron-forming fluids, and that the mechanism of transfer of iron to replacement bodies was by diffusion.

Table 3. Chemical composition (by percent) of intrusive rock types in the Iron Springs district, Utah (Mackin, 1968).

	Peripheral Shell[1]	Interior Rock[2]	Selvage Joint Rock[3]
SiO_2	60.67	62.47	63.96
Al_2O_3	17.13	16.74	16.98
Fe_2O_3	2.22	3.04	1.08
FeO	2.28	1.52	1.31
Fe	3.64	3.26	2.18
MgO	2.53	2.19	1.16
CaO	4.57	3.95	3.91
Na_2O	3.19	3.25	4.05
K_2O	3.39	2.83	3.34
H_2O	1.02	1.71	0.69
TiO_2	0.78	0.76	0.79
P	0.09	0.09	0.07
S	0.06	0.01	0.01
F (ppm)	419	282	69

[1] Average of 15 analyses.
[2] Average of 10 analyses.
[3] Average of 8 analyses.

Mackin was forced into a deuteric origin for iron since he eliminated a deep source of iron-rich emanations by his conclusion that Iron Springs district intrusions were shallow laccoliths. This writer questions the quantitative adequacy of this hypothesis since the selvage rock zone usually measures only a few inches thick on either side of any individual selvage joint. A deuteric theory of origin for the huge replacement ore bodies in the Iron Springs district appears to be entirely inadequate. Recent information further indicates that even if the intrusive bodies were floored, they are still sufficiently thick to produce ample residual iron-rich emanations to form Iron Springs ore deposits without requiring a deuteric release of iron from biotite and hornblende along thin bands of selvage joint rocks.

Contact metasomatic-hydrothermal origin. This writer proposes a contact metasomatic-hydrothermal origin for Iron Springs iron ore deposits. The term connotes ore occurrences near intrusive contacts with an assemblage of high-temperature minerals and the introduction of constituents from the intrusive into country rocks and fissures in chilled intrusive margins. The writer gives a brief review of his interpretation of the structural setting, magmatic activity, deuteric and metasomatic alterations, and hydrothermal deposition of ores in the Iron Springs district.

The stage for Tertiary intrusive activity and metallization of iron ores was set by post-Entrada and post-Iron Springs deformations. Deep penetrating faults of post-Entrada age prepared the ground and provided the loci for intrusive masses. Yielding of roof rocks was controlled largely by structural features produced during Laramide or post-Iron Springs deformation. An incompetent horizon between massive Navajo sandstone and the overlying basal siltstone member of the Carmel Formation served as a zone of tectonic Laramide gliding. Emplacement of quartz monzonite porphyry in the district was accomplished first along deep penetrating post-Entrada faults, and was accompanied and followed by stoping, assimilation and even cauldron subsidence of pre-Carmel strata. Intrusive masses later entered the incompetent horizon below the basal siltstone member, in part in a mushrooming manner, and raised the roof rocks in a concordant manner. Intrusive forces were so intense that sharp folding, overturning and thrust faulting occurred on several flanks of the advancing magmas. About one-half of the boundary contacts have high-angle and thrust faults. Concordance of the roof rocks on the one hand has led many geologists to conclude that the intrusions are laccolithic in form. Emplacement of magma on the other hand must have been accompanied by considerable stoping, assimilation and cauldron subsidence of pre-Carmel strata, as well as by bodily uplifting of roof rocks. The facts that deep diamond drilling on the flanks of intrusions has nowhere cut through porphyry, and that aeromagnetic and gravity anomalies indicate great depth and breadth to the intrusions, have led the writer to conclude that the igneous intrusions are discordant in depth and are essentially stocks in form.

Intrusive action at Iron Mountain, Granite Mountain and the Three Peaks areas are all related in time and space, but not all magmatic action came to rest simultaneously. Also depth of emplacement was different for the three intrusions. Groundmass texture of peripheral shell rock from the Three Peaks intrusion is consistently coarser than that of Granite Mountain and Iron Mountain porphyrys, hence must have formed at greater depths. Since the zone of emplacement is at the same stratigraphic horizon, a regional dip toward the northeast is assumed during the magmatic stage. As initial forces of the intrusion ebbed, intrusive bodies entered a magmatic stage of crystallization. A chilled border zone or peripheral shell formed along the outer margins of each intrusion, with widths from 100 to 200 feet thick. Since emplacement at Three Peaks was at a greater depth than either Granite Mountain or Iron Mountain, a much thinner peripheral shell was developed.

Two main stages are visualized for magmatic emanations, alterations and ore deposition at Iron Springs district: a late magmatic stage in which occurred deuteric alteration of porphyry, metasomatism of contact rocks and formation of magnetite-apatite fissure veins and a hydrothermal stage during which large limestone replacement ore bodies and breccia filling and replacement ore bodies were formed. The late magmatic stage started shortly after the peripheral shell had formed, and crystallization was nearing completion in the upper magmatic chambers. Subsequently, surges of magma opened tension joints that extended into the largely consolidated interior phase rocks. Early magmatic emanations were likely gaseous in nature, but liquid emanations probably dominated.

Rocks in the interior zones of intrusions are extensively deuterically altered. Biotite is partly or completely converted into an aggregate of orthoclase, albite, magnetite, chlorite and apatite, and hornblende into chlorite, biotite, magnetite and epidote. Pyroxene varies from fresh to altered masses of uralite, biotite, epidote and chlorite. Plagioclase and orthoclase are only slightly altered along small fractures to clay and sericite, and quartz is unaltered. Minerals in the peripheral shell rock are only slightly altered. Plagioclase and orthoclase show slight alterations to clay and sericite. Biotite and hornblende form phenocrysts that are usually fresh; quartz is not altered. In the bleached selvage joint rock, biotite and hornblende are completely deuterically altered. Pyroxene ranges from fresh to considerably altered grains. Plagioclase and orthoclase are moderately altered so that clay imparts a cloudy appearance to grains in thin section. Quartz appears to be fresh.

Escaping solutions from the cooling intrusions introduced silica and soda into the bleached porphyry adjacent the selvage joint, and at the same time leached iron, fluorine and phosphorus from the porphyry (table 3). When the proper temperature, pressure and concentration were attained, magnetite, apatite and chalcedony were deposited in open joints, giving rise to fissure veins. Iron is believed to have come also from residual fluids during this late magmatic stage of crystallization, contributing to the formation of fissure veins. Renewed openings produced encrusted fissure veins.

Ratté (1963) showed that large amounts of SiO_2, Al_2O_3, MgO, Na_2O, Fe, P and F were introduced into sedimentary rocks of the contact zone, producing fine-grained skarn rocks. Contact metasomatic minerals that developed in altered basal siltstone of the Carmel Formation are actinolite, diopside, hedenbergite, phlogopite, scapolite, tremolite, vesuvianite and wollastonite. The skarn minerals are fine-grained and are recognized from thin sections of the rocks. Mackin (1954, 1968) called the altered basal siltstone a hornfels, emphasizing contact metamorphism and isochemical changes only. This writer prefers the term fine-grained skarn rock for altered basal siltstone and altered Homestake limestone, emphasizing the introduction of constituents. Igneous emanations produced progressive metasomatic alteration of Homestake limestone. This can be observed by tracing unaltered limestone through altered zones into large replacement ore bodies. The first effect of this metasomatic action was bleaching of limestone, then enlarging grain size by recrystallization of calcite, followed by the development of some phlogopite and vesuvianite. Continued metasomatism converted the limestone into a fine-grained skarn rock composed of apatite, calcite, diopside, epidote, garnet, phlogopite, quartz, vesuvianite and wollastonite. The main skarn mineral is fine-grained andradite garnet. Altered siltstone and limestone are difficult to distinguish; however, the siltstone contains detrital quartz and feldspar, and the limestone typically contains andradite garnet.

As the intrusive forces subsided, previously formed tension joints were closed or filled with magnetite, and brought to a close the late magmatic stage. Subsidence of magmatic forces resulted in development of brecciated subsidence structures in porphyry and adjacent country rocks. Many similar brecciated zones were developed during the structural history of the district, including post-Entrada faults, post-Iron Springs or Laramide thrusts, intrusive structures, and finally subsidence structures. Some subsidence structures coincide with earlier brecciated zones, and others are cut or connected. These structural elements are expressed as brecciated fault zones and breccia pipes which formed pervious channelways and provided deep plumbing systems for iron-rich emanations. The main hydrothermal stage of mineralization followed subsidence, during which time the major replacement deposits, breccia filling and replacement ore bodies were formed.

Ore-bearing solutions entering the Homestake limestone preferentially replaced first calcite, then silicate skarn minerals, and formed replacement ores of magnetite and hematite. A metasomatic origin of the ore bodies is indicated by the lack of overall differences in stratigraphic thickness between limestone and equivalent replacement ore bodies, and is clearly demonstrated by detailed mapping and by numerous diamond drill holes. Bedding and other pre-ore structures can be traced in places from limestone into ore with no break in continuity.

The main replacement ore bodies are the result of hydrothermal emanations, rising principally along faulted and brecciated zones that not only formed important channelways but also formed important loci for replacement deposits. The Shortline deposit is located along a graben block. A basal breccia, strongly mineralized, is exposed in the footwall at the Lindsay pit. The Clive-Constitution, A and B, and other ore bodies are located along intrusive faults. The Blowout and Pot Metals deposits replaced brecciated portions of the lower plate of a Laramide thrust. The A and B, Armstrong, Blowout, Desert Mound and Burke ore bodies occur along or near cross-faults. Breccia pipe structures occur at Blowout, Dear, Armstrong, Little Allie and other ore bodies. These and other deposits are indicative of the importance of brecciation not only serving as channelways, but also important in the localization of ore bodies. Breccia pipes in particular appear to have been feeder pipes for hydrothermal solutions. The Blowout, Little Allie and Armstrong ore bodies occur along the contact zone but mostly in porphyry, and are composed mainly of magnetite, representing deep-seated plumbing for hydrothermal emanations. The cores of these breccia pipes are high in quartz as amethyst, galena, chalcopyrite, bornite and pyrite. The pyrite content increases with depth.

A contact metasomatic-hydrothermal origin of the Iron Springs ore deposits is further indicated by detailed studies of ore mineralogy. Minerals associated with the ore deposits of the district are actinolite, albite, amethyst, andradite, ankerite, apatite, aragonite, azurite, barite, bornite, calcite, chalcedony, chalcopyrite, chlorapatite, chlorite, chloropal, chrysocolla, cinnabar, native copper, cuprite, diopside, dolomite, dufrenite, epidote, fluorapatite, galena, garnet, goethite, gypsum, hedenbergite, hematite, isoclasite, lepidocrocite, limonite, lodestone, maghemite, magnesite, magnetite, malachite, marcasite, martite, melanterite, metastrengite, memetite, pyrite, quartz, phlogopite, rhodochrosite, rockbridgeite, scapolite, scolecite, selenite, siderite, specularite, sphene, spinel, tenorite, tourmaline, tremolite, turgite, vesuvianite and wollastonite. This list includes important contact metasomatic, hypogene and secondary minerals. Those that are particularily indicative of hypogene or hydrothermal mineralization are apatite, barite, bornite, chalcopyrite, cinnabar, dolomite, galena, hematite, lodestone, magnetite, marcasite, pyrite, quartz, rhodochrosite, specularite and tourmaline. The presence of bornite, chalcopyrite, galena and pyrite embedded in massive magnetite, pockets of cinnabar and other sulfides in iron ore, and intimate association of finely disseminated pyrite with the ore are conclusive evidence of a hydrothermal origin for the iron deposits. Pyrite increases slightly with depth of mining, and some ore has such a high content of pyrite that it is removed to lean ore dumps.

In summary, the writer proposes a contact metasomatic-hydrothermal origin for the main iron ore deposits in the Iron Springs district. The deposits are concentrated along the roof and margins of semiconcordant stocks in the form of replacement bodies in limestone roof rocks, breccia fillings and replacements along faults and pipelike structures along intrusive margins, and fissure fillings in quartz monzonite porphyry. The iron is thought to have been derived principally from residual fluids resulting from magmatic crystallization of the porphyrys. These magmatic emanations were released in part during the late magmatic stage but principally during the hydrothermal stage of mineralization. The main channelways for emanations are mostly along faults and brecciated zones, in part along selvage joints. Some iron apparently was leached from the porphyry wall rocks by ascending hydrothermal solutions, but it was a minor source of mineralization.

Markagunt Plateau Deposits

Iron Peak prospects lie about four airline miles and six miles by road northeast of Paragonah, on the north side of Little Creek, one-half mile east of the Dixie National Forest boundary line. The property is situated east of the Hurricane fault on the west side of Markagunt Plateau, in secs. 19 and 30, T. 33 S., R. 7 W. (figure 7). The elevation of Iron Peak is near 8,500 feet, with a local relief of about 1,000 feet, with steep slopes and rugged topography. The area is accessible on Little Creek road one-half mile north of Paragonah. The property has been restaked several times, most recently by W. L. and V. H. Rasmussen of Veyo. No assessment work has been done since 1964.

Iron Peak is composed of Tertiary volcanic rocks that overlie the Claron or Wasatch Formation which consists of about 1,400 feet of nonmarine sedimentary strata. They are composed of red basal conglomerate and sandstone up to 150 feet thick, an intermediate sequence of pink limestone and calcareous shales up to 900 feet thick and a top series of white limestones up to 350 feet thick. These strata essentially lie flat or dip gently east.

A sequence of Tertiary volcanic rocks, primarily of ignimbrite origin, overlies the Claron or Wasatch Formation. Iron Peak may be a volcanic neck or plug from which such extrusions took place. The igneous rocks are mostly latite and andesite in composition; the main rock-forming minerals are andesine plagioclase, basaltic hornblende, biotite and augite. Zeolites are found adjacent to zones of iron mineralization.

Hematite and magnetite occur as small vein and replacement bodies in volcanic rocks. The hematite is probably an oxidation product of magnetite. Scattered fragments of ore from small veins can be found on each side of Iron Peak. Three principal iron deposits were found. One, on the southwest slope of the mountain, was developed by a 25-foot shaft, now caved, that bottomed in ore. From the bottom of the shaft a crosscut ran in ore northwest for 14 feet. Low outcrops of iron ore extend northwest and southeast from the shaft and dip from 70° northeast to vertical. About 25 feet southeast of the shaft, an open cut was run toward the shaft, cutting 10 feet of ore. About 225 feet southeast of the shaft, an open cut and an adit ran north, cutting about 13 feet of ore. Other test pits and trenches in the vicinity show narrow seams of ore six inches to two feet thick.

A second occurrence, near the summit of Iron Peak, is an ore body 65 feet long and from 10 to 20 feet wide which has been exposed by shallow trenches. The strike of the ore body is north 36° east. A third ore body lies on the north slope of Iron Peak, forming a low outcrop for a few feet at the surface. A bulldozer cut exposed a 12-foot-wide deposit of magnetite. Surface exposures, limited development work and magnetometer survey work indicate that the Iron Peak property has an ore potential of less than 5,000 tons. Chemical analyses of the ore are given in table 1.

JUAB COUNTY

Canyon Range Deposits

Little Oak Creek (Iron Crown) prospects lie on the east side of Canyon Range, eight airline miles north-northwest of Scipio, about one-half mile south of Little Oak Creek in sec. 10, T. 17 S., R. 3 W. (figure 20). The property was staked by A. L. Alldredge of Delta and M. J. Alldredge of Oak City. It lies near the base of Canyon Range along the eastern mountain front which has been outlined by Basin and Range block faulting. The deposits occur in undifferentiated rocks belonging to Ordovician and Silurian systems and are composed mainly of Laketown and Fish Haven dolomites.

Ore mineralization consists of two main outcrops separated by about 600 feet, occurring as bedding replacements in dolomitic limestone. The southern outcrop is composed of clinkery limonite gossan exposed by workings along the surface for 30 feet. Debris now covers much of the workings. Limonite and goethite occur as a shallow replacement about two feet thick which dips into the hillside. This ore was smelted at one time by early settlers of Scipio. Several tons of ore are stockpiled here.

The northern outcrop lies about 100 feet higher in elevation. It was developed by a 30-foot adit and short foxhole workings. The ore is mainly hematite ocher with some hard hematite and spongy limonite and goethite. This mineralization is a bedding replacement ranging from a fraction of an inch to two feet in thickness. No ore shipments are known to have been made from this prospect. Chemical analyses of these ores are given in table 1.

Drum Mountains Deposits

Iron Blossom mine is situated in the Drum Mountains, 39 miles northwest of Delta and 2 miles north of the ghost town of Joy. The property occurs in sec. 15, T. 14 S., R. 11 W. (figure 20), and is held by assessment work by George Van of Delta. The Drum Mountains are formed by a westward-tilted structural unit, composed of as much as 9,000 feet of quartzite and 3,000 feet of carbonate rocks of Cambrian age. These strata strike north and dip west and are cut by numerous east- and northeast-trending faults with displacements of a few feet to a few thousand feet. Bodies of manganese carbonate ore were formed by replacement of two dolomite beds near the base of the carbonate series along intersections with faults. These ores have been oxidized to pyrolusite, wad and psilomelane. More than 72,000 tons of manganese ore were shipped from the Drum Mountains.

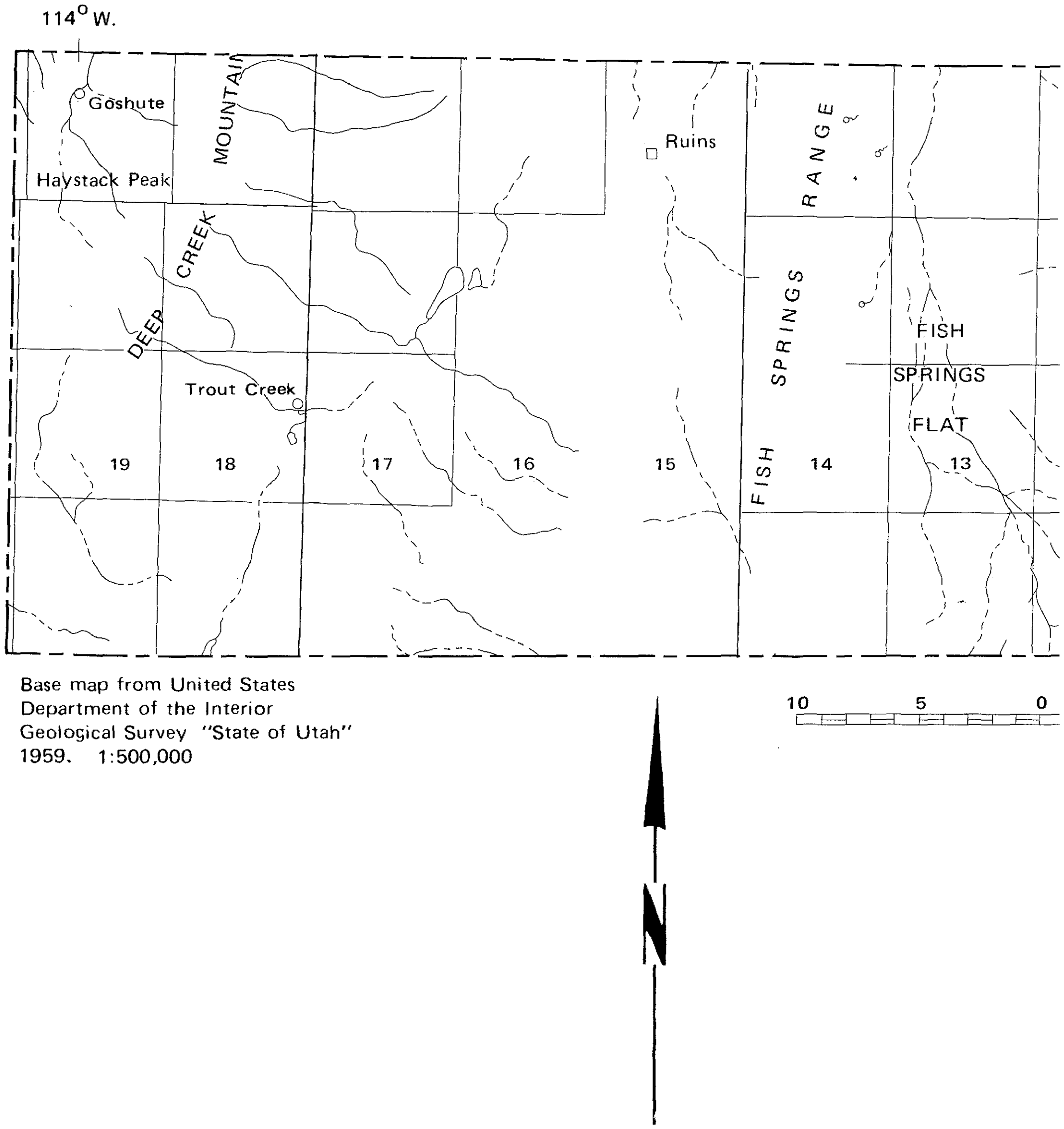
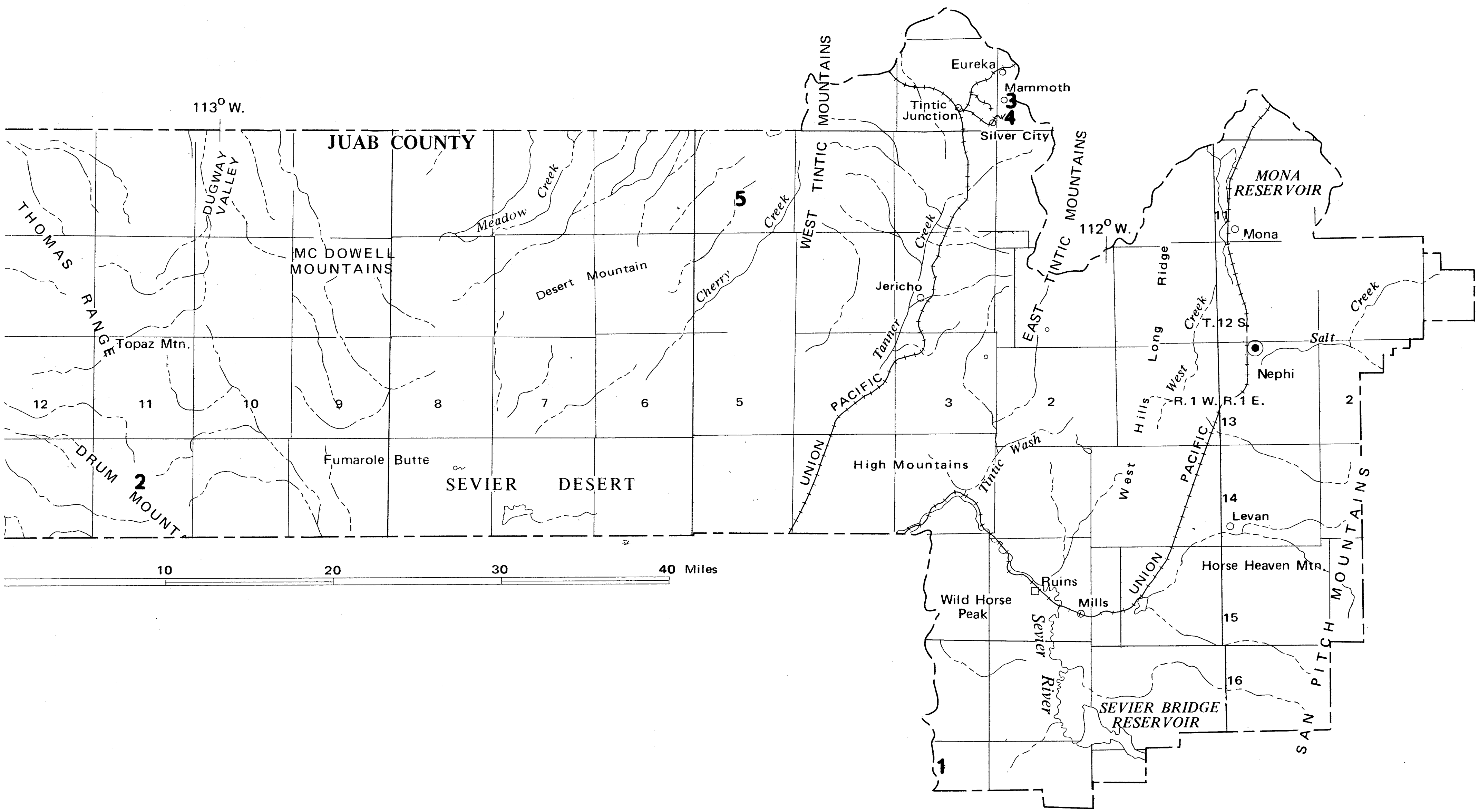


Figure 20. Juab County iron occurrences.

1. Little Oak Creek prospects, Canyon Range
2. Iron Blossom mine, Drum Mountains
3. Black Jack Iron mine, East Tintic Mountains
4. Dragon mine, East Tintic Mountains
5. Lockheed mine, Sheeprock Mountains


JUAB COUNTY
113° W.
112° W.
THOMAS RANGE
DUGWAY VALLEY
MC DOWELL MOUNTAINS
Meadow Creek
Desert Mountain
Cherry Creek
WEST TINTIC MOUNTAINS
EAST TINTIC MOUNTAINS
Eureka
Mammoth
Tintic Junction
Silver City
Tanner Creek
Jericho
MONA RESERVOIR
Mona
Long Ridge
West Creek
Hills
T. 12 S.
R. 1 W.
R. 1 E.
Salt Creek
Nephi
Topaz Mtn.
DRUM MOUNT.
Fumarole Butte
SEVIER DESERT
UNION PACIFIC
High Mountains
Tintic Wash
West Hills
Levan
Horse Heaven Mtn.
Ruins
Mills
Wild Horse Peak
Sevier River
SEVIER BRIDGE RESERVOIR
SAN PITCH MOUNTAINS
1
2
3
4
5
12
11
10
9
8
7
6
5
3
2
2
13
14
15
16
10
20
30
40 Miles

Local iron mineralization also occurs along faults in the Cambrian carbonate rocks. The Iron Blossom property represents the largest of these deposits. The ore is a gossan resulting from oxidation of an iron sulfide ore body and lies along a northeast-trending fault of undetermined displacement in Notch Peak limestone of Upper Cambrian age. Similar smaller gossans occur along other faults in the Cambrian carbonate strata. Iron minerals at the Iron Blossom mine are goethite and limonite, varying from massive to spongy, to ocherous varieties. Development work consists of an open pit and a short adit; about 50 tons of ore are stockpiled. The property has an ore potential of a few hundred tons. A chemical analysis of the ore is given in table 1.

East Tintic Mountains Deposits

Black Jack iron mine lies about one-half mile east of Mammoth in the Tintic district in the East Tintic Mountains, SW¼ sec. 30, T. 10 S., R. 2 W., immediately north of Diamond Pass (figure 20). The property is accessible by a short mountain road on the southeast side of Mammoth.

Black Jack mine is located along and near a monzonite dike that cuts Upper Cambrian Ajax limestone. The formation measures more than 500 feet thick and is composed of light to dark gray dolomite, chert and thin beds of limestone near the top. Silver City monzonite stock lies a few hundred feet south of the mine. Iron mineralization occurs along the north end of an altered north-trending dike extending from the nearby monzonite stock.

The Ajax limestone has been metamorphosed and shows various types of alteration. Below the deposit and south toward the contact with the Silver City stock, the formation contains enstatite, spinel, garnet and magnetite, and is criss-crossed with veinlets of white calcite. Near the iron deposit, both pyritic and argillic replacement took place in limestone. Pyrite ore was oxidized, forming a small gossan deposit. Iron ore is surrounded by halloysite clay which has extensively replaced Ajax limestone. Some exposures at the top of the iron outcrops are brecciated and consist of silicified limestone fragments in an iron-stained matrix.

The iron deposit is composed mainly of goethite and limonite with some hematite, and the ore is mainly hard, compact and spongy. The deposit was developed by an open cut, a shaft and crosscut, and an adit. The open cut lies along the east wall of the monzonite dike, which was altered to halloysite, and the adit from the road west of the dike lies 100 feet below the open cut, penetrating the ore. The Black Jack shaft at the 200-foot level failed to encounter iron ore, showing that the deposit pinches out. Mineralization that can be traced about 125 feet along the surface measures to 30 feet in width.

A small prospect about 450 feet up the slope east of the Black Jack deposit is composed of a small body of yellow and red low-grade iron ore, friable to soft earthy in texture. Some manganese oxides are also present. The ore potential of the Black Jack mine is estimated to be less than 5,000 tons. About 200 tons of fluxing ores were shipped from this property. Chemical analyses of Black Jack ores are given in table 1.

Dragon mine, in the Tintic district in the East Tintic Mountains, lies about 1½ miles east of Silver City in sec. 31, T. 10 S., R. 2 W. (figure 20). The original Dragon mine was operated before the turn of the century for fluxing ores by the Dragon Consolidated Mining Company. The ore was used in smelting siliceous ores from the Colorado-Humbug ore vein. Since 1949 the property has been under option from the International Smelting and Refining Company and mined for halloysite by Filtrol Corporation. More than a million tons of halloysite have been produced; it is used as a catalyst in refining crude oil.

The Dragon mine is situated near the northeast side of the Silver City monzonite stock at a point where the Dragon fissure extends south from limestones into the stock. Sedimentary rocks exposed at the Dragon mine are Upper Cambrian Ajax limestone and the lower part of the Ordovician Opohonga limestone. Close to the intrusive, the limestones are partially metamorphosed, extensively recrystallized and forming silicates locally. Beds strike southeast and dip to the east about 20°. Along the Dragon fissure, extensive and complete alteration of limestone took place. Both pyritic and argillic replacement occurred, especially in the upper Ajax Formation. Mineralization resulted from hydrothermal solutions rising along northeast fissures and replacing limestone.

Pyrite ore bodies formed by the hydrothermal solutions were extensively oxidized to form gossan iron ore deposits consisting of goethite and limonite with some hematite, turgite and manganese oxides, and ranging from massive and compact varieties to spongy and botryoidal masses. The largest deposits were irregular ore shoots whose largest dimensions were parallel to the Dragon fissure. Ore shoots and veins were nearly vertical and surrounded by halloysite. Boundaries of the ore bodies were marked by minute branching cracks of iron oxides penetrating the clay a short distance, and by small specks and spots of iron oxides in the halloysite.

Most of the iron production came from a large open pit measuring about 200 by 75 feet. Ore bottomed near the 300-foot level. A vertical shaft was sunk to a depth of 1,065 feet from which drifts and drill holes were extended to explore iron ore occurrences. On the 400-foot level a small iron body was encountered which appears to be a flat mass ending a short distance below that level. The Dragon mine produced 322,000 tons of iron ore which contained small amounts of silver and gold. The deposit was largely depleted by the early part of this century. Similar but smaller iron occurrences are found at Black Jack iron mine, Brooklyn shaft and Huntington tunnel. The present halloysite clay operations at the Dragon mine do not attempt to reclaim iron ore associated with the clay deposit. A chemical analysis of Dragon mine ore is given in table 1.

Sheeprock Mountains Deposits

Lockheed mine, in the West Tintic district in the Sheeprock Mountains, in sec. 28, T. 11 S., R. 5 W. (figure 20), is accessible from U. S. Highway 6, 16 miles south of Eureka. A dirt road extends west one mile to the Jerico railroad station on the Union Pacific railroad. The mine lies an additional 16 miles west of Jerico at the south end of the Sheeprock Mountains. The original mine workings were opened in 1913 and known as the Iron King mine. The property was renamed and is now held by D. H. Morrison of Salt Lake City.

Lockheed mine is in a contact metasomatic type deposit. Mineralization resulted from intrusion of West Tintic monzonite stock into the Ordovician Pogonip group which is composed of bleached and recrystallized limestone with small amounts of dolomite. The color of the limestone ranges from light gray to blue-gray, with yellowish streaks and partings of argillaceous material. The formation exceeds 1,000 feet in thickness near the mine. Ordovician strata have been steeply folded and overthrust by Precambrian strata. In the vicinity of the Lockheed mine, Pogonip limestone strikes northerly and dips from 70° to 80°. The stock intrudes Pogonip, forming an irregular contact which in places shows roof pendant relationships or follows the bedding in dikelike forms.

Iron ore is exposed along a north-trending limestone and monzonite contact. At the surface the deposit is approximately 200 feet long and from 10 to 20 feet wide, dipping steeply to the west. At the south end the ore body is V-shaped, with a 75-foot extension to the northeast. A tongue of monzonite cuts the deposit into two sections about half way along its strike. The ore is magnetite and specular hematite, with small amounts of pyrite which occurs as disseminated grains and small veinlets in the ore. The deposit contains some copper; malachite stains the surface outcrops, and chalcopyrite and covellite are associated with ores mined underground. Scheelite is erratically distributed in some tactite zones. Tiny amounts of sphalerite, silver and gold are present. A small shipment of ore containing gold, silver and copper, in addition to iron, was shipped from this property in 1913. In late 1942 a six-ton lot of magnetite and pyrite ore was shipped to Salt Lake City for testing. A 20-ton lot of scheelite ore was shipped in 1943. In 1946, 400 tons of magnetite ore were shipped to smelters in Tooele to be used as a flux.

The Lockheed property was developed by three vertical shafts, a few shallow prospect pits, and bulldozer cuts. Iron King shaft is 165 feet deep. Three short levels were driven from this shaft. On the 70-foot level a drift was made to the north in the hanging wall of the ore; a crosscut to the east penetrated 34 feet of ore. On the 97-foot level a short crosscut to the west and drifts to the north explore the deposit. There appear to be two separate masses of iron ore on this level; faults of small displacement apparently have shifted the ore body. On the 160-foot level a short crosscut to the west did not expose any iron ore. However, on the assumption that the dip of the ore body remains the same as shown on the 70-foot level and continues to this depth, the ore would be found farther to the west than the present face of the crosscut on the 160-foot level.

A magnetometer survey made on this property suggests a limited and shallow iron ore occurrence. From surface exposures, underground workings and geophysical data, it is estimated that fewer than 25,000 tons of magnetite and specular hematite ore occur on the Lockheed property. Chemical analyses of Lockheed iron ores are given in table 1.

MILLARD COUNTY

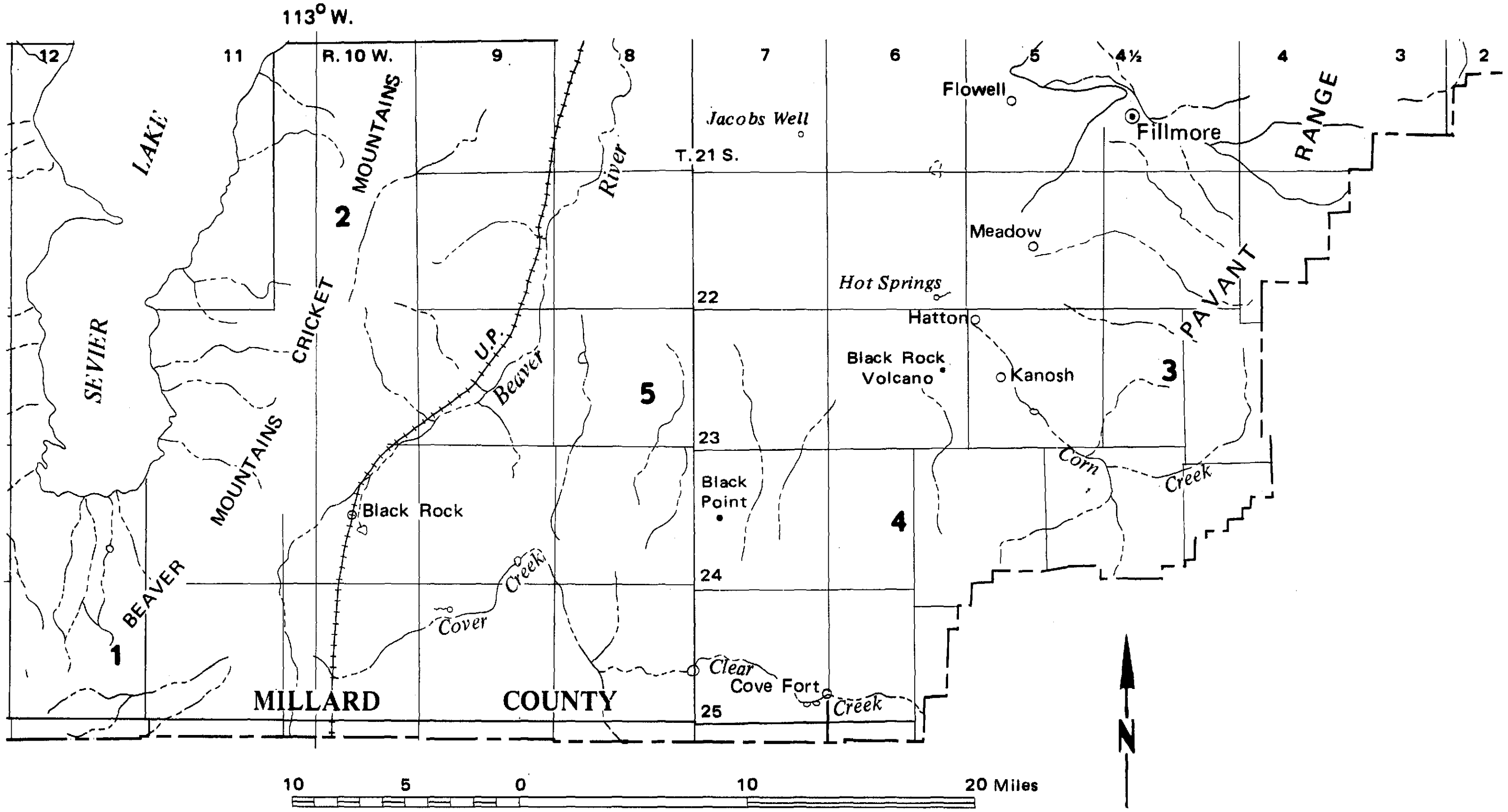
Beaver Mountains Deposits

Iron Mine Pass prospects are situated in the Beaver Mountains which lie on the southeast side of the Sevier Lake playa, 18 miles northwest of Milford along the common boundary of secs. 23 and 24, T. 25 S., R. 12 W. (figure 21). The area is accessible from Utah Highway 21 one mile west of Milford, where a dirt road extends northwest for 18 miles to the Beaver Mountains. The Iron Mine Pass prospects occur near a low pass along this road on the east side of the ridge. The occurrence was staked and held by assessment work by various owners, but is unclaimed now.

The Iron Mine Pass prospects follow a major fault in Precambrian strata which consist of undifferentiated metasedimentary rocks, composed chiefly of reddish brown to purple quartzite and argillite. They are Proterozoic in age and comparable to Precambrian strata exposed in the Canyon Range, Sheeprock Mountains and Big Cottonwood series in the Wasatch Mountains. Dolomitic beds interstratified with quartzite are the host rock for iron mineralization.

The iron occurrence is a gossan type of oxidized ore, containing varying mixtures of hematite, goethite, limonite and small amounts of manganese oxides. The deposits consist of small scattered pods of ore along a fault zone of unknown displacement. The ore occurs as fissure and breccia fillings and as small replacement bodies in dolomitic beds. A few feet of argillic alteration are exposed in the workings and form a white clay adjacent to and mixed with the iron mineralization.

Three small mine workings, on the east side of Iron Mine Pass road, lie within 10 feet of the road



Base map from United States
Department of the Interior
Geological Survey "State of Utah"
1959. 1:500,000.

Figure 21. Millard County iron occurrences.

1. Iron Mine Pass prospects, Beaver Mountains
2. Ferruginous quartzite occurrences, Cricket Mountains
3. North Fork iron prospects, Pavant Range
4. Widemouth Canyon prospects, Pavant Range
5. Twin Peaks prospects, Twin Peaks

within 300 feet along the road. The first excavation is a 12-foot-deep shaft or pit with a 4-foot diameter, and the second is a shallow pit about 6 feet deep and 10 feet long. The third excavation is about 8 feet deep, 10 feet wide and 20 feet long. The last few feet of workings form a short adit. A fourth excavation, on the west side of the road about 300 feet away, is the largest operation, measuring 15 feet deep, 10 feet wide and 30 feet long. A short adit forms the westernmost portion of this working. A few tons of ore appear to have been shipped. The potential of the property is small, less than 100 tons of low-grade iron ore. Two chemical analyses are given for the ores in table 1.

Cricket Mountains Deposits

The Cricket Mountains are situated about 25 miles southwest of Delta on the east side of the Sevier Lake playa (figure 21). The range is 26 miles long with a maximum width of 12 miles, and the highest peak rises from the valley floor 2,440 feet to an elevation of 7,040 feet. The area is accessible from Utah Highway 257 from Delta or Milford.

Cambrian strata comprise the bulk of the Cricket Mountains which have been cut by a series of north-trending normal faults, tipping sedimentary blocks eastward and producing displacements up to 3,000 feet. Escarpments are well exposed on the west side of each ridge, and dip slopes are characteristic of the east side of the ridges. The age of the faulting cannot be easily determined owing to the predominance of early Paleozoic strata, but the faulting is typical of Basin and Range block-fault structures. Tear and transverse faults of small to large displacement are scattered throughout the range.

The Cricket Mountains are composed of five block-fault mountain ridges which strike about north 15° east; the strata dip generally from 15° to 25° east. The easternmost block consists of a synclinal structure whose trough passes through George's Valley and whose limbs each form elongate ridges. Topographically, the Cricket Mountains are formed by five ridges outlined by Basin and Range faulting and one ridge formed by erosion of a synclinal limb. Other flexures and numerous low hills occur throughout the range.

Cambrian strata have an aggregate thickness of about 7,800 feet in the Cricket Mountains. The Lower Cambrian is represented by 3,050 feet of Prospect Mountain quartzite whose base is not exposed, by 225 to 255 feet of Pioche shale measured by the writer in Headlight Gap Canyon and Fillmore Canyon, and by 230 feet of overlying Ophir Formation. Predominately carbonate rocks of Middle and Upper Cambrian age measure 2,265 and 2,000 feet respectively. A Tertiary breccia and conglomerate up to 200 feet thick is distributed sparsely through the range and lies unconformably on Cambrian strata.

Prospect Mountain quartzite on a fresh surface exhibits colors of white, pink, red and brown to maroon in the upper section. On a weathered surface the color is light to dark brown. Prospect Mountain quartzite is massive, cross-bedding is prominent, and its texture varies from fine to coarse. It contains some pebble conglomerate and thin beds of shale, especially near the top of the formation. The upper boundary is arbitrarily assigned at the top of a dark maroon ferruginous quartzite which averages 18 feet in thickness and is regarded as a low-grade iron formation. Conformable overlying Pioche shale is composed of olive green, thin-bedded shale that is micaceous and fucoidal. This is overlain by the Ophir Formation composed of interbedded olive green thin-bedded shale and thick beds of pinkish, buff and green quartzite. Thin limestone beds occur near the top of the formation.

The upper boundary of the Prospect Mountain quartzite is best described as a ferruginous quartzite and represents a low-grade syngenetic sedimentary iron occurrence. It varies from 5 to more than 25 feet in thickness, with an average of about 18 feet. In some outcrops the ferruginous horizon appears to be absent; in places it is separated into two members by a one- to three-foot phyllitic shale member. The ferruginous quartzite is well exposed in the three western ridges for much of the length of the Cricket Mountains. In Fillmore Canyon a one-foot ferruginous bed lies 30 feet above the base of the Pioche shale.

James (1954) defined an iron formation as a chemical sediment, typically thin-bedded or laminated and containing 15 percent or more iron of sedimentary origin. On this basis the ferruginous quartzite could qualify as an iron formation, and is regarded to have accumulated in a strongly oxidizing near-shore environment. The site of accumulation was receiving detrital sediments and was favorable to chemical precipitation of iron oxide in the form of hematite.

The only ore mineral observed in the ferruginous quartzite is hematite, occurring as a cement forming a thin coating around the mineral grains, filling voids between the grains and forming thin bands, and occasional oolites. The oolites commonly contain tiny detrital grains of quartz ranging in size from fine- to coarse-grained. The massive quartzite layers typically contain coarse-grained quartz and contain hematite as a thin film around individual sand grains. Thin-bedded layers of ferruginous quartzite contain much larger quantities of hematite which occurs as a cement filling the voids, forming thin hematite layers, and oolitic grains. Chemical analyses of the ferruginous quartzite in the Cricket Mountains are given in table 4.

Thirty miles to the north in the Drum Mountains, the upper limit of the Prospect Mountain quartzite is drawn at the top of a massive 50-foot member of maroon coarse-grained hematitic quartzite (Crittenden and others, 1961). The weathered surface of this member ranges in color from red to almost black. Outcrops form a prominent stratigraphic marker throughout the east side of the range. Only two layers, each about two feet thick, in this hematitic quartzite contain sufficient iron concentration to be comparable to the iron deposit in the Cricket Mountains. This occurrence, however, indicates that the site of deposition extends at least 30 miles north of the Cricket Mountains.

Table 4. Analyses of ferruginous quartzite member, Prospect Mountain quartzite, Cricket Mountains, Millard County.

Location	Thickness in feet	Percentages Fe	Insol.	S	P	Mn
Red Rock Pass	12	21.3	56.0	0.08	0.45	0.01
Headlight Canyon 1	15	18.6	60.2	0.04	0.05	0.01
Headlight Canyon 2	10	22.4	55.2	0.09	0.20	0.01
Headlight Gap 1	5	12.2	76.3	0.04	0.14	0.01
Headlight Gap 2	15	17.3	65.1	0.06	0.24	0.01
Headlight Gap 3	24	25.6	48.8	0.10	0.18	0.02
Fillmore Canyon 1	25	14.0	64.7	0.04	0.17	0.01
Fillmore Canyon 2	22	13.8	73.9	0.08	0.20	0.04
Fillmore Canyon 3	22	19.3	62.5	0.07	0.39	0.01
Rogers Spring 1	25	15.0	67.9	0.08	0.24	0.02
Rogers Spring 2	25	27.3	46.6	0.07	0.20	0.02
Average	18	18.8	61.6	0.07	0.22	0.015

Pavant Range Deposits

North Fork prospect lies in the Pavant Range seven airline miles east of Kanosh in sec. 13, T. 23 S., R. 4½ W. (figure 21). The area is accessible by a dirt road west of Richfield through Deer Creek, past Redview Guard Station, to Sunset Peak, and south for two miles. The road passes within one mile of the property. The area can also be reached, but with difficulty, from Corn Creek, then along a jeep trail up the North Fork and along Woolsey Ridge. The property was staked as King and Pinto claims by Joshua S. Robinson of Fillmore; no assessment work has been done for many years.

Sedimentary rocks in the vicinity of the King and Pinto claims consist of Cambrian quartzite and limestone. These strata include about 3,000 feet of Tintic quartzite that is thick-massive to medium-bedded metaquartzite. It is white to pink in color, grading into buff, red and purple, with greenish quartzite toward the top of the formation. Overlying undifferentiated limestone strata up to 2,500 feet thick are of Middle and Upper Cambrian age; possibly other Lower Paleozoic strata occur also. The lower limestones are light to dark gray, thin- to medium-bedded limestone. The upper two-thirds of the strata are composed of dark to medium gray, medium- to massive-bedded limestone, interbedded with dolomitic limestone and dolomite.

The Pavant overthrust sheet formed by these lower Paleozoic strata was thrust over Mesozoic and Permian rocks after late Jurassic time. The trace of the thrust fault crops out in Corn Creek southeast of Kanosh and can be traced for many miles northeast through the Pavant Range. The thrust fault dips approximately 20° east.

The iron mineralization is associated with a sheared zone in Cambrian limestone, and is a typical gossan-type deposit with fissure fillings and replacements in limestone. The principal minerals are goethite and limonite, oxidized from pyrite. The ore is mostly hard and spongy, with some ocher. The property lies in a coved area that is heavily wooded by scrubby oak brush. Bulldozer cuts have exposed limonite outcroppings discontinuously for more than 200 feet. There are a few hundred tons of gossan ore available on this property that may be useful as ocher. A chemical analysis of the North Fork prospects is given in table 1.

Widemouth Canyon prospect lies in the south Pavant Range about 12 miles by road southwest of Kanosh, nearly one-half mile southwest of Widemouth Canyon in sec. 16, T. 24 S., R. 6 W. (figure 21). This prospect was originally known as the Elephant mine, later as the Bullawana, and recently was restaked as the Iron Jack claim by Taft Paxton of Kanosh.

Iron mineralization outcrops across the top of a small prominent hill along the mountain front. Iron float is scattered over a radius of about 500 feet. Ore is found in place in the form of several small gossan cappings, all measuring less than 20 feet long. The ore is mostly limonite, with some hematite and occasional showings of manganese oxides. Mineralization occurs as fissure fillings and replacements in Ordovician limestone and as breccia filling along a prominent fault which brings quartzite in fault contact with limestone.

The property was developed by a shaft and a few prospect holes down to 20 feet. Two small prospect holes were excavated in quartzite breccia along the fault contact. Most of the iron mineralization occurs in light gray limestone. The largest development is a century-old 80-foot shaft sunk into the largest outcrops in search of silver, gold and copper ores. All the outcrops combined probably contain fewer than 500 tons of gossan ore. Chemical analyses of these ores are given in table 1.

Twin Peaks Deposits

Twin Peaks prospect, also known as Black Diamond and Black Crystal, lies 19 miles by an oiled and dirt road west of Kanosh, on the north side of north Twin Peak in sec. 27, T. 23 S., R. 8 W. (figure 21). The Twin Peaks rise prominently above the low-lying desert hills west from the Pavant Range into the Sevier Desert, and are separated geographically by about five miles, each peak forming a separate mountain mass and rising approximately 1,000 feet above the basin floor.

The Twin Peaks are composed of quartz latite and rhyolite volcanic rock of Late Tertiary age. In the vicinity of the Twin Peaks prospect the volcanic rocks contain large phenocrysts of feldspar and smaller crystals of quartz, and hornblende, biotite and accessory minerals, all in a glassy matrix. The color of the rocks varies from light gray to pink and buff.

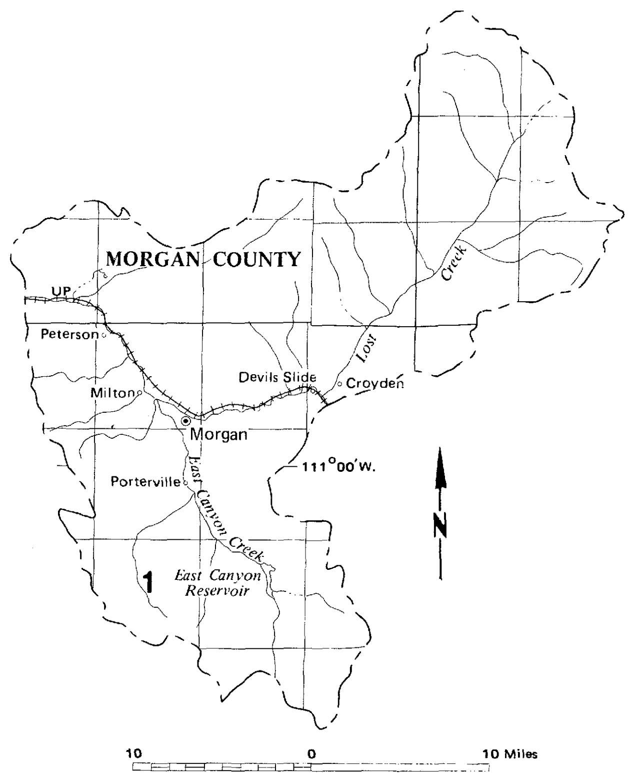
Of the three outcrops of iron mineralization on north Twin Peak, only one contained commercial amounts of ore. The largest outcrop was developed by an inclined shaft about 200 feet deep, now inaccessible. Two diverging magnetite veins up to two feet wide are exposed at the surface. They can be traced only 10 feet on the surface and represent branches of a slightly larger vein that has been mined for a short distance along the inclined shaft. The exposed veins contain abundant wall fragments of volcanic rocks, some of which are cut by small veinlets of magnetite.

The ore is composed principally of magnetite, with some hematite and martite crystals altered from the magnetite. A large slickenside surface is exposed in the workings. Mineralization was controlled by a fault of small displacement and along fissures in volcanic rock. The deposit was formed mainly by fissure filling, but some replacement has taken place. A magnetometer survey was conducted over the property; the magnetic profiles suggest very limited near-surface iron ore. About 50 tons of ore were shipped from this property in 1940 to the Ironton Works in Provo. From limited outcrops and negative results of the magnetometer survey, the iron ore potential is estimated at probably less than 200 tons. Chemical analyses of Twin Peaks iron ore are given in table 1.

MORGAN COUNTY

Queen of the West mine is located in the Hardscrabble (Mill Creek) district on the east side of the Wasatch Mountains, nine miles south of Morgan in NE¼ sec. 9, T. 2 N., R. 2 E. (figure 22). The property is reached by three miles of oiled road to Porterville and six miles of dirt road along Hardscrabble Creek. The property lies on the east side of the canyon at an elevation of 6,400 feet. The topography is comparatively steep.

The Queen of the West mine was first operated by Norway Iron Mining and Manufacturing Company in 1879. Several hundred tons of iron ore were shipped to an experimental iron furnace at Ogden in the eighties. Several carloads of ore were shipped to various smelters for use as a flux. In 1923 a few test carloads were shipped to American Smelting and Refining Company, and a few years ago some ore was shipped to the Ideal Cement Plant at Devils



Base map from United States Department of the Interior Geological Survey "State of Utah" 1959. 1:500,000.

Figure 22. Morgan County iron occurrences.
1. Queen of the West mine, Wasatch Mountains.

Slide. These operations all proved unprofitable, and the property has remained idle for a number of years. Mine property consists of four unpatented claims. Property ownership has changed several times. The present owner is Russel C. Porter of Morgan.

The deposit was explored and developed by five adits, shallow shafts and prospect holes, and several short crosscuts. Total length of mine workings aggregates about 1,000 feet. Several of the mine workings have caved and are not accessible. The iron mineralization, associated with east-dipping undifferentiated Cambrian limestone, occurs along steeply dipping northeast-trending fissures as fracture fillings and limestone replacements. Cambrian rocks in the mine area are composed of 1,300 feet of limestone and dolomite. The rocks are dark gray in color, pisolitic and oolitic in certain beds, and contain interbedded gray to olive-gray shale and white dolomite.

The ore consists of limonite and goethite gossan with some hematite, is typically brown in color, and varies from hard compact ore to porous and friable masses to earthy varieties. Small bodies of hard massive magnetite are present, containing small amounts of chalcopyrite and considerable calcite. Gossan ore bodies, varying in thickness from two to several feet wide, occur along parallel fissures as discontinuous ore bodies. Mineralization cannot be traced far on the surface because it occurs in lenses and pods. From surface exposures and underground workings, the ore potential of Queen of the West property is estimated to be about 25,000 tons or more. Chemical analyses of the ores are given in table 1.

SALT LAKE COUNTY

Big Cottonwood mine lies at the head of Big Cottonwood Canyon, Big Cottonwood district, in the Wasatch Mountains. It is located in the SW¼ sec. 2, T. 3 S., R. 3 E. (figure 23), about one mile south of Brighton and about 1,200 feet south of Dog Lake, near the Salt Lake-Utah County line. Mountain Lake (Jack) mine lies about 350 feet east of Big Cottonwood mine. The area is accessible from Salt Lake City to Brighton on Utah Highway 152 along Big Cottonwood Canyon. A dirt road in poor condition and a mountain trail lead from Brighton to the mine. The portal of the adit is approximately 9,650 feet in elevation. The slopes are steep and the topography rugged.

The Big Cottonwood mine is owned by Great Western Mines Company, which controls about 100 claims in this area. Original interest in this property was in copper and precious metals. Small shipments of ore were made soon after its discovery in 1875. In 1907 small shipments of copper ore went to the Tintic smelter. Value of the iron ore as a flux made it possible to ship profitably. Total production of ore was not significant.

The Big Cottonwood mine is a low-grade copper-bearing magnetite deposit and consists of three separate lens-shaped ore bodies. The ore formed by contact metasomatism through replacement of carbonate rocks. Sedimentary rocks near the mine are the Mississippian Gardison and Deseret limestones. The Gardison limestone is blue-gray in color, has distinct bedding, contains some light gray chert, is highly fossiliferous, and measures about 450 feet thick. Overlying Deseret limestone consists of dark gray to black limestone and some dolomite, characterized by its abundance of chert; it measures about 900 feet in thickness. The Gardison and Deseret limestones were intruded by masses of granodiorite of the Clayton Peak and Alta stocks. A skarn zone approximately 50 feet wide developed along much of the contact zone. The skarn contains garnet, magnetite, ludwigite and forsterite, with lesser amounts of enstatite, chlorite, plagioclase, calcite, pyrite, chalcopyrite, bornite and scheelite. The copper minerals have partly altered to malachite.

The Big Cottonwood mine lies near the southwest end of Dog Lake, and surface outcrops of magnetite form prominent exposures on the ridge between Dog Lake and Lake Martha. A large body of Gardison and Deseret limestones occurs as a roof pendant in granodiorite. Two separate bodies of magnetite ore occur at the surface between the granodiorite and the skarn zone. The east end of the north ore body lies about 400 feet southwest of the mine portal. It is somewhat crescent-shaped and is approximately 375 feet long with a maximum thickness of about 50 feet. The ore body lies in an east-west direction, then extends toward the southwest. The north end of the south magnetite ore body lies 650 feet southwest of the mine portal. This ore body extends in a south-southeast direction for 315 feet and has an average thickness of 20 feet.

The third body of magnetite ore occurs underground in the Big Cottonwood mine adit. The portal of the mine is cut in granodiorite. The adit extends southwest for 700 feet in granodiorite, then a crosscut passes through 110 feet of skarn rock containing some magnetite and weak copper mineralization. A drift then cuts about 30 feet of magnetite. This ore body extends in a north-northwest direction for an undetermined distance. The drift ends in granodiorite about 860 feet from the portal.

Detailed metallurgical tests on samples of magnetite ore from the mine by the U. S. Bureau of Mines indicate that fine grinding is necessary to liberate iron and copper minerals. The chief mineral constituents of the ore are magnetite, enstatite, chalcopyrite and bornite. Chalcopyrite and bornite occur as inclusions in magnetite and enstatite and along fractures. Enstatite and magnetite are intimately intergrown. The copper content of the ore averages 1.67 percent. Straight magnetic separation and flotation successfully removed sulfur and copper from the iron ore; grinding to 100-mesh was necessary. Magnetic separation gave high iron recoveries with more than 60 percent iron and low sulfur and copper content.

Iron ore potential of the Big Cottonwood deposit is estimated to be more than 200,000 tons with an average grade of 37.35 percent iron. The ore body is low-grade, copper-bearing and highly siliceous. The chemical character of the ore is given in table 1. Other low-grade magnetite deposits similar to the Big Cottonwood deposit occur in the Michigan-Utah mine, Alta Consolidated mine, South Hecla mine, Grizzly Gulch, along the south contact of Alta and Clayton Peak stocks near Lake Catherine, and in the basin at the head of Little Cottonwood Canyon. Most of these occurrences have not been extensively prospected and have yielded comparatively little or no ore.

SEVIER COUNTY

Krotki iron deposit lies six miles directly north of Marysvale in the central part of the Antelope Range, near the Piute County line in sec. 15, T. 26 S., R. 4 W. (figure 24). The deposit occurs near the summit of the Iron Peaks. The property has been

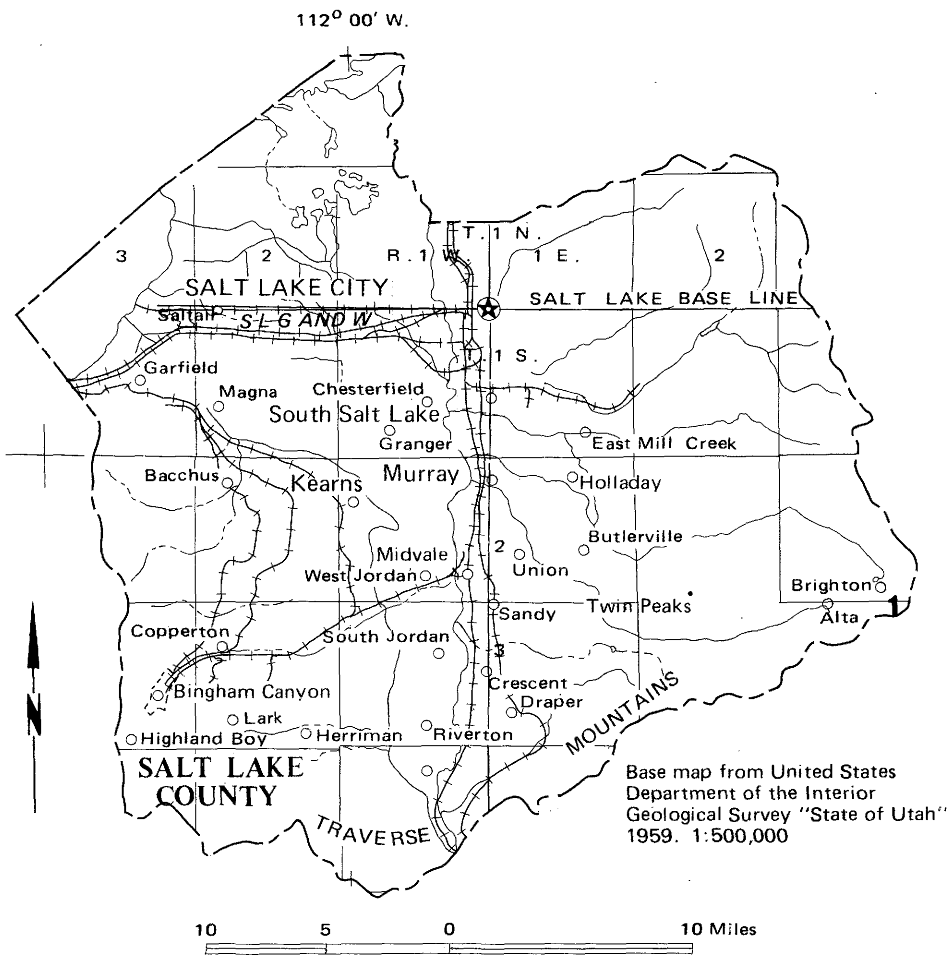


Figure 23. Salt Lake County iron occurrences.
1. Big Cottonwood mine, Wasatch Mountains

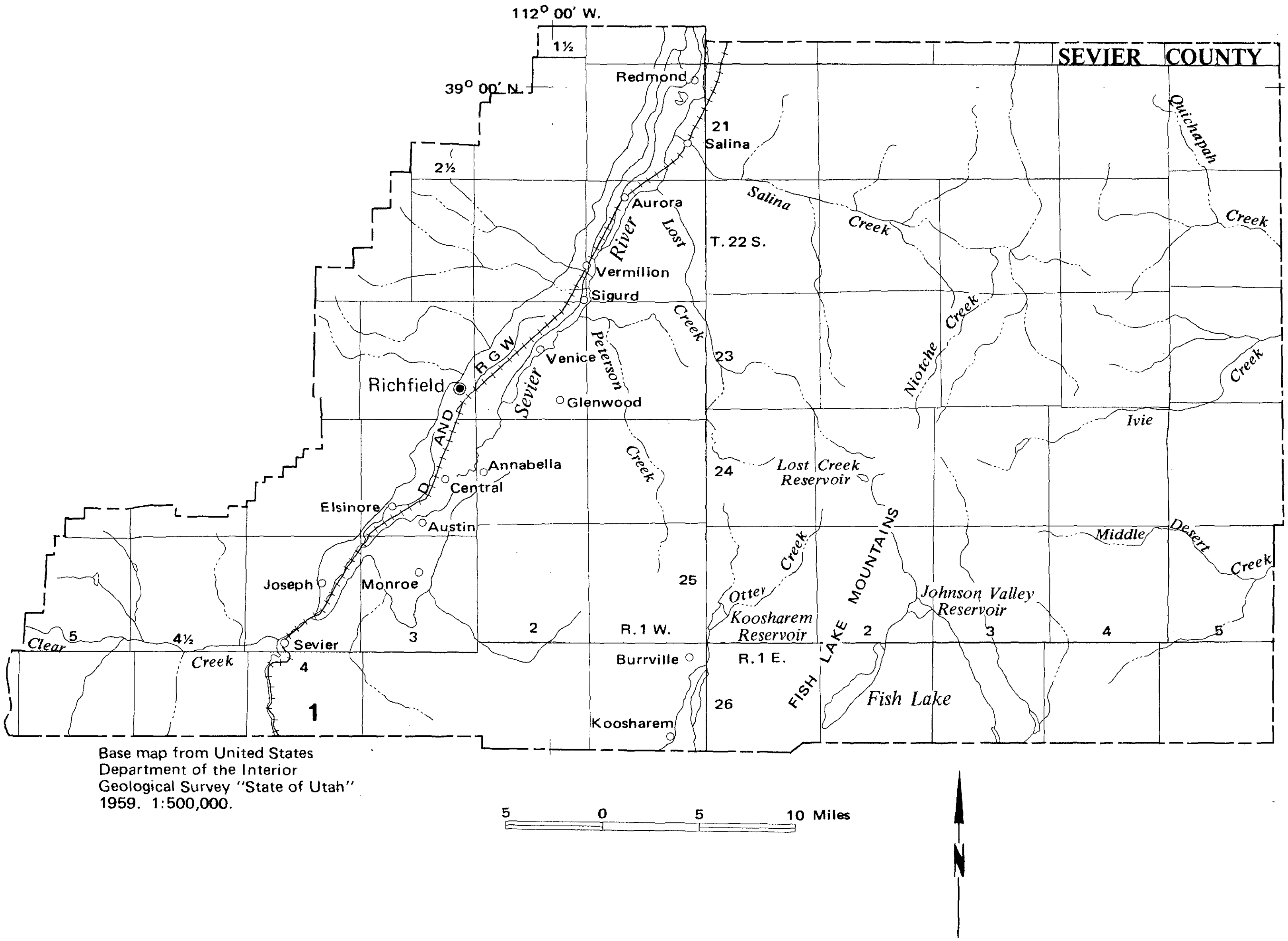


Figure 24. Sevier County iron occurrences.

1. Krotki Iron mine, Antelope Range

variously called Krotki, Iron Peaks and Iron Cap deposits. The property is held by assessment work by Ronald and Garfield James of Marysvale.

Iron mineralization occurs in Bullion Canyon volcanics of Tertiary age. The basal portion of Iron Peaks consists of 700 to 800 feet of volcanic tuff; the upper portion of the peak is made up of 250 feet of pyroxene andesite which has been silicified. The tuff has been affected mainly by argillic alteration, but both members show each type of alteration.

Iron mineralization occurs here under two quite different physical conditions. The upper ore body near the summit of Iron Peak occurs along irregular fissures. The ore, in silicified pyroxene andesite, has been explored by several prospect pits and one long adit. Most of the ore is dense and stalactitic and is composed of limonite and goethite. It appears to be a typical gossan resulting from the oxidation of pyrite.

The lower Krotki occurrence lies in volcanic tuff and was explored by several prospect pits, a short adit and a small room-and-pillar development from an open face. A small amount of massive gossan appears near surface fissures. The main iron occurrence consists of a four- to five-foot zone of bedded replacement ore in volcanic tuff which dips gently into the hill. The ore is composed of yellow and reddish layers of ocherous limonite and hematite, and layers of black manganese and iron oxides. Alternating layers and mixtures of limonite, goethite, hematite and manganese oxides are somewhat puzzling, but are regarded as resulting from oxidation of primary sulfides that have selectively replaced a narrow zone in volcanic tuff. An adit about 50 feet lower in elevation was driven about 225 feet eastward beneath this ore body, but it failed to encounter iron mineralization. Only argillic alteration of tuff with a high alunite content was exposed in the adit.

About 500 tons of massive stalactitic fluxing iron ore were shipped to smelters near Salt Lake City. Apparently little of this type of ore remains on the property. The potential of the Krotki iron deposit is a few hundred tons of ocherous-type ore; the potential might be increased by drilling. Chemical analyses of the Krotki deposits are given in table 1.

TOOELE COUNTY

Deep Creek Range Deposits

Iron Claims prospects lie on the south end of Ochre Mountain in the Deep Creek Range, in the Gold Hill district eight miles southwest of Gold Hill in sec. 20, T. 8 S., R. 18 W. (figure 25). Gold Hill is 60 miles south of Wendover and is accessible on alternate U. S. Highway 50. The Iron Claims prospects are reached by a jeep road that joins the Gold Hill-Ibapah road at its summit, and then extends for two miles to the northwest. The property contains four unpatented claims held by assessment work by George Rupp and Alma Watkins.

Ore occurrences consist of several small gossan-type deposits, the largest of which measures 15 feet long and 5 feet wide. Mineralization lies along a wide east-west trending fault zone which dropped the Oquirrh Formation down against Ochre Mountain limestone. The fault zone measures about 500 feet wide and is composed of highly brecciated limestone and orthoquartzite from these formations. Ochre Mountain limestone is Mississippian in age and is composed of about 4,500 feet of fine-grained, cherty, thick-bedded limestone. The Oquirrh Formation is Pennsylvanian in age and consists of 8,000 feet of orthoquartzite, sandy limestone, shale, limestone and some dolomite (Nolan, 1935).

Gossan ore is composed mainly of limonite and goethite with some hematite, and ranges from hard siliceous to soft friable varieties. Mineralization is spotty and weak. The ore potential of the exposed gossans is less than 200 tons of highly siliceous ores. A typical chemical analysis is given in table 1.

Gold Hill barite-limonite prospects lie about three miles southwest of Gold Hill on the east end of Ochre Mountain in the Deep Creek Range, in secs. 14 and 15, T. 8 S., R. 18 W. (figure 25). The property is composed of several unpatented claims.

Iron mineralization consists of several large gossan-type occurrences which outcrop on two closely spaced spurs in Ochre Mountain limestone. This formation comprises much of Ochre Mountain which has been cut by numerous faults of varying magnitudes. In the immediate area of mineralization, the Ochre Mountain limestone strikes northwest and dips about 27° northeast. The formation is composed of 4,500 feet of fine-grained, cherty, thick-bedded limestone of Mississippian age.

Gossan ore occurs along faults of small displacement, fills brecciated zones and replaces favorable carbonate beds. The ore is mainly goethite and limonite, with some hematite. The deposit is highly silicified and contains an abundance of barite. Gossans outcrop intermittently in a zone about 1,600 feet long and 500 feet wide; individual outcrops measure from a few feet to one which is 200 feet long and 30 feet wide. Several prospect holes and one short adit were cut during exploratory work. The ore potential indicated by outcrops probably exceeds 25,000 tons of highly siliceous iron ore of poor quality. A chemical analysis is given in table 1.

Sheeprock Mountains Deposits

Iron King mine lies on the northeast side of the Sheeprock Mountains on the south side of East Government Canyon, in the Columbia district in sec. 20, T. 9 S., R. 6 W. (figure 25). The mine is held by assessment work by E. T. Hansen of Vernon and John R. Edwards of Provo.

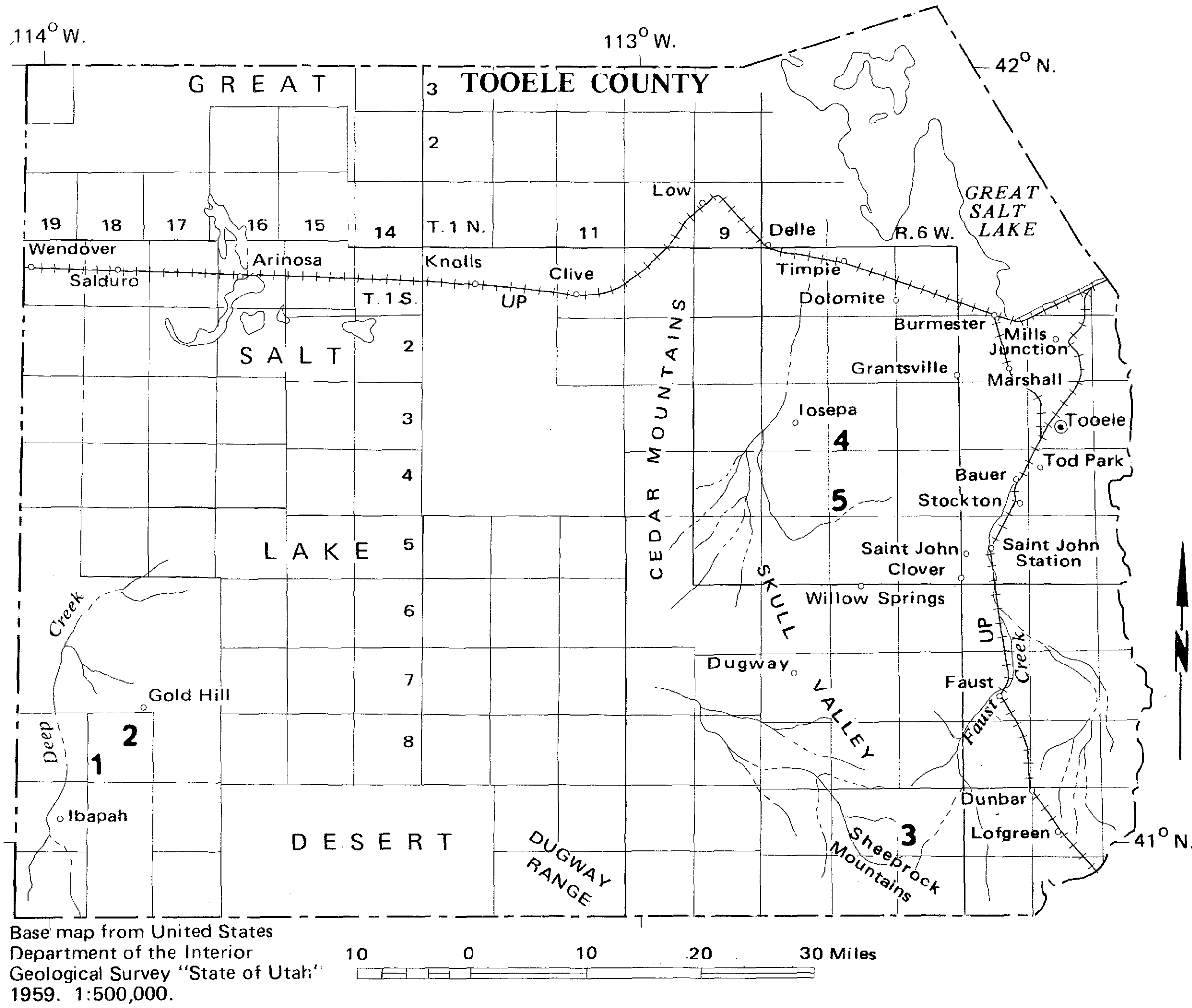


Figure 25. Tooele County iron occurrences.

1. Iron Claims prospects, Deep Creek Range
2. Gold Hill barite-limonite prospects, Deep Creek Range
3. Iron King mine, Sheeprock Mountains
4. Consolidated Lela prospects, Stansbury Mountains
5. Skull Valley Indian Reservation prospects, Stansbury Mountains

The iron mineralization is associated with Cambrian Tintic quartzite, a buff-colored, highly jointed and fractured formation, massive with indistinct bedding and with an aggregate thickness of about 2,600 feet. The mine is located along the Government Creek fault zone which strikes east-west and dips about 70° south. Ore mineralization consists of specular hematite and quartz gangue occurring in fault breccia. The main ore body lies at the intersection of two steeply inclined faults where a small chimney-shaped ore body was formed.

The property was developed by a 30-foot shaft and two drifts along intersecting faults. The drifts are about 40 and 100 feet in length. Mineralization ranges from two to three feet wide along the longer drift. The ore body is composed of fissure fillings and limited fissure replacements of brecciated Tintic quartzite. Approximately 80 tons of ore were shipped in 1924 to American Smelting and Refining Company at Murray. The ore potential of the property is probably less than 1,000 tons. Chemical analyses of the better grade ore are given in table 1.

Stansbury Mountains Deposits

Consolidated Lela and Skull Valley Indian Reservation prospects. Considerable prospecting, mainly for copper, gold, lead and silver, has been done along the base of the western escarpment of Stansbury Mountains between Monument Canyon on the north and Indian Hickman Canyon on the south. Prospecting has been mostly in T. 3 and 4 S., and R. 7 and 8 W., in the Grantsville district. The area can be reached by U. S. Highway 40 to Timpie on the northwest end of the range. A hard-surfaced road extends south 15 miles to Iosepa.

Limited iron mineralization occurs in the Pioche shale, the limestone beds of the Ophir Formation, and Teutonic limestone, where they are in contact with the Stansbury fault. Many shallow pits, adits, tunnels and shafts were developed in altered zones and gossans. The Pioche shale, Ophir Formation, and Teutonic limestone are all Cambrian in age. The Pioche shale is composed of interbedded shale, phyllitic shale, graywacke and quartzite, and is approximately 225 feet thick. This is overlain by the Ophir Formation, composed of interbedded quartzite, shale and limestone, with an average thickness of about 1,000 feet. The overlying Teutonic limestone consists of a dolomitic limestone unit, an interbedded limestone and shale, a dolomite and an upper argillaceous mottled limestone, and has an average thickness of 1,100 feet. These strata along with other Paleozoic strata in the Stansbury Mountains were subjected to broad folds with localized minor reverse faults, thrust faults and later major normal faults.

Iron mineralization is associated with the Stansbury fault, a major normal fault outlining the west flank of much of the range. Its position is clearly marked by a recent fault scarp which can be traced from Deadman Canyon north for 17 miles to Box Canyon. Throughout much of its trace the fault forms contact between Pioche shale, Ophir Formation, or Teutonic limestone. Displacement along the Stansbury fault may be as much as 10,000 feet (Rigby, 1958).

Limonite, goethite, hematite and some magnetite constitute iron minerals found along the Stansbury fault. Numerous small gossans outcrop along the trace of the fault, normally measuring less than 50 feet long and 10 feet wide. Goethite and limonite form hard spongy ore, and hematite gossans are usually earthy. Highly brecciated zones occasionally are stained with iron minerals. Exposures are a few feet wide and up to 100 feet long. A few disseminations of magnetite and hematite were observed in limestone and shaly limestone, and a small replacement ore body is found on Consolidated Lela property. Some iron occurrences are stained by malachite and have given an incentive for exploratory work on the outcrops. Small amounts of pyrite and chalcopyrite were found in some exposures. Most of the gossan outcrops are regarded as alteration products from pyrite. Only two deposits are worthy of describing briefly, the Consolidated Lela and the Skull Valley Indian Reservation prospects.

Consolidated Lela prospect lies in sec. 31, T. 3 S., R. 7 W., near Big Pole Canyon (figure 25), and is reached by an unimproved dirt road two miles south of Iosepa that extends eastward for 3½ miles along a section line between T. 3 and T. 4 S. The claims are held by Conie Hoopiiaina of Murray. One magnetite and hematite outcrop measures 10 by 40 feet. A magnetometer survey of the area showed a small magnetic anomaly a few hundred feet west from the outcrop ore. The ore potential is small, probably less than 10,000 tons of ore. Chemical analyses are given for the Consolidated Lela ore in table 1.

Skull Valley Indian Reservation prospects lie in sec. 21, T. 4 S., R. 7 S., less than one mile north of the mouth of Indian Hickman Canyon (figure 25). This property is accessible by a dirt road extending northeast from the reservation headquarters for five miles to the mouth of Indian Hickman Canyon. Iron outcroppings lie from one-half to one mile northward along the trace of the Stansbury fault in Teutonic limestone. No access road is available north from Indian Hickman Canyon. Iron outcrops are low-grade gossans. Mineralization is scattered over a relatively wide area, but the ore is poor and high in silica, and the ore potential does not exceed a few thousand tons. A chemical analysis is given for Skull Valley Indian Reservation prospects in table 1.

UINTAH COUNTY

Black Canyon prospects lie at the bottom and on the east side of Black Canyon in the Uinta Mountains, in unsurveyed sec. 8, T. 2 S., R. 20 E., S. L. B. M. (figure 26). The area is reached by 26 miles of road from Vernal, via Dry Fork Canyon on Red

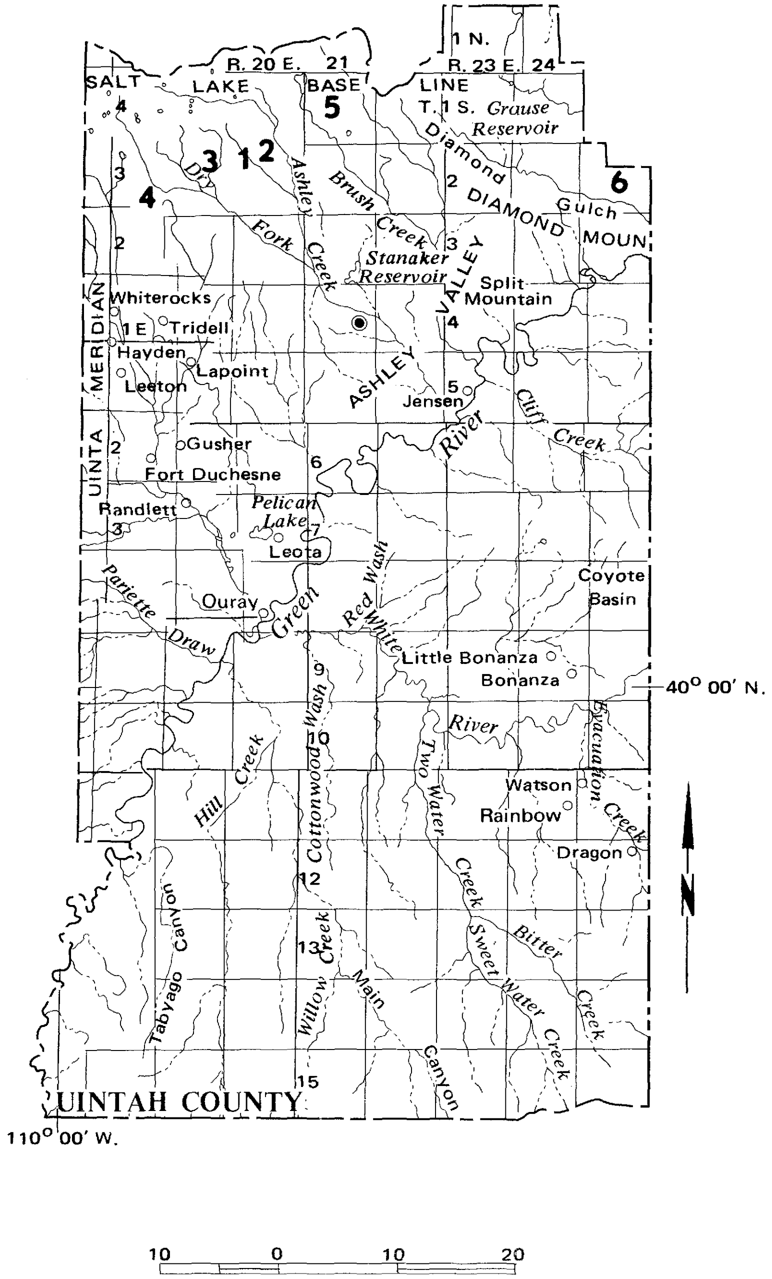
Cloud Loop road and by a 1½-mile forest trail which extends eastward from the point where Alma Taylor road joins Red Cloud Loop road, nine miles north of the Ashley National Forest boundary in Dry Fork Canyon. The principal prospect is the Goat Claim, held by Clyde L. Burns of Vernal.

Kinney (1955) incorrectly correlates the Black Canyon prospects with the Woodside deposit as described by Boutwell (1904). The Woodside is equivalent to the Cow Hollow deposit. The Black Canyon prospects, along the South Flank Uinta fault zone, consist of goethite and limonite which cement a coquina-like limestone containing brecciated sandstone pebbles. A shallow prospect hole was dug in the black shale unit of Mississippian age along the bottom of Black Canyon. The prospect is very low in iron and high in silica. The shale unit is composed of about 200 feet of shale with thin beds of coquina limestone and some sandstone.

Immediately east of this mineralization and extending for nearly one mile, the limestone unit of Mississippian age is down-faulted against the Precambrian Uinta Mountain group by the South Flank Uinta fault. Occasional limonite and siliceous hematite rubble is associated with limestone along the fault zone, but no iron exposures are found in place. A few shallow prospect holes and a shallow shaft were made during iron exploration. The iron ore potential of Black Canyon prospects is insignificant. A chemical analysis of the goethite and limonite is given in table 1.

Cow Hollow (Woodside) prospect lies in the Uinta Mountains in unsurveyed sec. 3, T. 2 S., R. 20 E., S. L. B. M. (figure 26), southwest of Taylor Mountain about 16 airline miles northwest of Vernal. The area is accessible from Red Cloud Loop road between Trout Creek Park and Government Park and by a poor jeep road that extends seven miles south to the bottom of Cow Hollow. The prospect lies about one-half mile west of the junction of Cow Hollow and Ashley Creek and about two miles west of Red Pine Setting. This deposit was first opened in 1913 and was briefly described by Boutwell (1904) as the Woodside deposit. In 1955, six claims, called Iron Crown claims, were staked by Frank Watkins of Vernal. A shaft about 30 feet deep was sunk, but it is now caved and partly filled with surface debris. In 1963 the property was relocated by Edward H. Abplanalp of Vernal.

A hematite outcrop measures about 25 feet long and up to 15 feet wide. A small quantity of float lies



Base map from United States Department of the Interior Geological Survey "State of Utah" 1959. 1:500,000

Figure 26. Uintah County iron occurrences.

1. Black Canyon prospects, Uinta Mountains
2. Cow Hollow prospects, Uinta Mountains
3. Dry Fork prospects, Uinta Mountains
4. Mosby Park mine, Uinta Mountains
5. Pope Iron mine, Uinta Mountains
6. Wild Mountain prospects, Uinta Mountains

on the slope below the outcrops. A shaft extends through the ore, bottoming in iron-stained quartzite. The ore is reddish brown to black hematite which has replaced the limestone unit of Mississippian age. A three-foot cap of limonite and goethite gossan outcrops on the up-slope side of the hematite. The gossan is about 25 feet south of the hematite and appears to be overlying it. Hematite and limonite have replaced brecciated limestone or occur as breccia fillings of limestone; traces of malachite are present. Iron mineralization occurs along a brecciated zone of the South Flank Uinta fault. The ore potential of the Cow Hollow prospect is a few hundred tons of hematite and negligible amounts of gossan. Chemical analyses of these ores are given in table 1.

Dry Fork prospects lie in secs. 10 and 11, T. 2 S., R. 19 E., S. L. B. M., 22 miles northwest of Vernal along the East Fork of the Dry Fork in the Uinta Mountains (figure 26). The area is accessible on Dry Fork along Red Cloud Loop road to Brownie Canyon along a short unimproved dirt road, five miles north of the Ashley National Forest boundary, northwest from Red Cloud Loop road.

A small gossan cap in sec. 10 was exposed by a shallow shaft. Limonite and goethite mineralization, occurring as a cement in fault breccia of sandy shale, is associated with a black shale unit of Mississippian age. The ore potential is negligible. A second iron outcrop lies in the southwest part of sec. 11 in the Uintah Basin Youth Reforested area. Rubble, consisting of brecciated limestone and sandy limestone which has been cemented or partially replaced by hematite, is scattered over a steep slope. Mineralization is associated with the limestone unit of Mississippian age. The occurrence has no commercial potential. A chemical analysis of the hematite ore is given in table 1.

Mosby Park prospect lies in sec. 26, T. 2 S., R. 18 E., S. L. B. M., 36 miles northeast of Roosevelt (figure 26). The prospect is on the northeast side of Mosby Mountain and on the west edge of Mosby Park, and is accessible by Mosby Mountain road. Five miles north of the Ashley National Forest boundary at Loggers Cabin Park, an unimproved dirt road forks to the northeast and extends 0.6 miles to the prospect in Mosby Park. The Iron Mask claim was staked over a small iron occurrence by Neal V. Schaefermeyer of Roosevelt.

The iron occurrence consists of a small limonite and goethite gossan; mineralization occurs as widely spaced rubble over an area a few feet wide and 100 feet long. No ore is in place as an outcrop. A 200-foot adit was cut into the hillside exposing brecciated limestone. Only slight mineralization was detected near the portal. Gossan occurs with the limestone unit of Mississippian age; the rock is somewhat brecciated and iron mineralization serves as breccia fillings and partial replacements. Mississippian limestone is in fault contact with the Uinta Mountain group of quartzite and shale. The iron potential is insignificant. A chemical analysis of the gossan rubble is given in table 1.

Pope Iron mine is located in the eastern Uinta Mountains, 28 miles north of Vernal in sec. 16, T. 1 S., R. 21 E., S. L. B. M. (figure 26). The area is accessible from the Vernal-Manila road, Utah Highway 44. The mine lies on the northeast side of Brush Mountain on Dyer Ridge at an elevation 9,900 feet, below a peak of Mississippian limestone, and adjoins the more famous Dyer Copper mine at a slightly lower elevation. The Dyer Copper mine prior to the turn of the century was operated for oxidized copper ore. The original minerals probably were chalcopyrite and chalcocite that had altered to malachite. The deposit has been largely exhausted. The mine was operated during World War I, in 1937-39, and again in the early 1960's. The fact that Pope Iron and Dyer Copper mines join suggests a genetic relationship. A small limonite and goethite gossan caps the Dyer Copper deposits, and small amounts of malachite are found at the Pope Iron mine. These properties lie on patented land owned by Lora Sannes of Salt Lake City.

Iron mineralization occurs near the contact between a shale member in the upper part of the Uinta Mountain group and undifferentiated Mississippian limestone. Several thousand feet of Proterozoic quartzitic sandstone and interbedded sandy shale comprise the Uinta Mountain group. The Mississippian strata consist of about 1,000 feet of light gray cherty limestone and dolomitic limestone, which unconformably overlie the Uinta Mountain group.

The Pope Iron deposit is largely massive and subspecular hematite with small amounts of limonite, magnetite and malachite. Some ore shows a mammallary structure, and part of the ore is slightly magnetic. Iron replacement ranges from slightly altered to partially replaced rock, to high-grade subspecular hematite. The mineralization lies in a northeast-trending belt up to 40 feet wide and traceable intermittently for 400 feet. A few tons of high-grade iron ore were shipped prior to the turn of the century to the Dyer Copper smelter for flux. Recent exploratory works on the Pope Iron deposit are a series of bulldozer cuts, trenching, prospect pits and churn drill holes. The depth of iron mineralization is limited and averages about twenty feet deep.

Some iron outcrops occur in the shale of the upper part of the Uinta Mountain group, but the exposures are poor. Most of the recent exploratory work shows mineralization in Mississippian limestone, ranging from partly altered to partial replacement of rock, to limited pockets of complete replacement. One recent churn drill hole passed through the main high-grade hematite outcrop and bottomed in light gray dolomitic limestone. Mineralization is located at or near the contact between the Precambrian Uinta Mountain group and the overlying Mississippian limestone. Ore was localized by each rock type; dolomitic limestone has been the principal host rock. Faulting appears to be an important structural control. The occurrence of ore is probably genetically related to the South Flank Uinta fault which traverses the south slopes of the Uinta Mountains. Small faults cut the Pope Iron mine property, and it is along these fractures that ore solutions have ascended, filling fractures and replacing the strata. Some ore shows slickensided surfaces, indicating post-mineralization faulting. Pre-Mississippian faults in the Uinta Mountain group are not exposed locally, but if they are present, they could have served as channelways for ascending ore solutions. No major faulting was observed in the vicinity of the Pope Iron mine.

A magnetometer survey across the property indicates deposits of commercial importance. A geologic survey of the small pockets of high-grade, hard, subspecular hematite ore with an iron content of more than 50 percent suggests an ore potential of less than 5,000 tons for the Pope Iron mine. A few thousand tons of partially replaced limestone with an average grade of about 12 percent iron content outcrop along the mineralized belt. Chemical analyses of the Pope Iron mine deposits are given in table 1.

Wild Mountain prospects lie in the northeast corner of Uintah County near the Utah-Colorado boundary line in sec. 11, T. 2 S., R. 25 E., S. L. B. M. (figure 26). The area is accessible by the Diamond Mountain road and is 35 miles northeast of Vernal. The main iron mineralization lies on the southwest slope of Wild Mountain. Three claims are held by assessment work by Melvin E. Richins of Vernal.

Iron mineralization occurs in Mississippian brecciated limestone which dips gently southwest and overlies the Cambrian Ladore Formation and the thick Precambrian Uinta Mountain group of reddish sandstone and shale. Hematite has partially replaced Mississippian limestone and also occurs as a breccia filling. Calcite crystals and a trace of malachite were observed. A second prospect lies on the north side of Wild Mountain near the divide, but only minor hematite mineralization occurs as breccia fillings and limestone staining. The property was prospected by shallow pits and bulldozer cuts. The iron potential of the Wild Mountain prospects is insignificant. A chemical analysis of the ore is given in table 1.

UTAH COUNTY

East Tintic Mountains Deposits

Iron King mine lies in the East Tintic Mountains, in sec. 21, T. 10 S., R. 2 W., in southwest Utah County, about two miles southeast of Eureka and one mile southwest of Dividend (figure 27). The property is accessible from U. S. Highway 6 two miles east of Dividend. A dirt road extends south for about four miles to the mine. The Iron King mine was developed by two shafts, underground workings, several adits, and prospect pits. Most of the exploratory and development work was in search of gold and silver ores.

A thick section of Lower Paleozoic limestones and dolomites outcrops in the vicinity of No. 1 shaft of the Iron King mine and forms the gently west-dipping limb of the main Tintic syncline. Several north-south and east-west trending faults cut the strata. No. 1 shaft is located near the east-trending Iron King fault. In the vicinity of No. 2 shaft there is a great complexity of structure where the Iron King and Eureka Lily faults intersect. A swarm of monzonite porphyry dikes cuts the center portion of the Iron King property.

Metallic production from the Iron King mine has been small, and consisted of two types of ore, gold-silver and iron-manganese. Most of the gold and silver came from fissure-type deposits at No. 2 shaft area. A total of 14,000 tons of gold-silver ore was removed. No. 1 shaft was sunk in a large iron-manganese deposit at or near the surface along the Iron King fault. Several thousand tons of iron ore were shipped to smelters for flux and to the Ironton blast furnace south of Provo.

The Iron King iron-manganese ore body is a gossan deposit. The main minerals are goethite and limonite, but hematite is present in considerable quantities. Most of the ore contains pyrolusite and other manganese oxides, and varies from hard massive or spongy varieties to soft friable types. Mineralization occurs as fissure fillings and replacements of carbonate rocks adjacent to monzonite dikes. The ore was mined from open pits, adits and underground workings. The deposit contains abundant argillic alteration. A few thousand tons of iron-manganese ore probably remain on the property. Chemical analyses of the Iron King ores are given in table 1.

Wasatch Mountains Deposits

Diamond Fork prospect is located in sec. 4, T. 9 S., R. 4 E., five miles north of Thistle on the east side of the Wasatch Mountains and seven miles by road north of Thistle in Diamond Fork (figure 27). The property is accessible from U. S. Highway 6 in Spanish Fork Canyon and consists of four unpatented claims held by Ilyn D. Garrick of Provo.

The iron mineralization is a shallow gossan-type ore body; the ore occurs along a brecciated fault zone in Thaynes limestone, Triassic in age. This limestone is composed of pink and gray sandy limestone, sandstone and variegated shale, and measures about 1,300 feet in Spanish Fork Canyon. A fault of small displacement has brecciated the Thaynes limestone. A limited amount of spongy gossan ore occurs along the fault as breccia fillings and replacements of limestone. Boulders of float are scattered over a broad area, and a few bedrock outcrops may be found along the fault zone. The largest outcrop measures 3

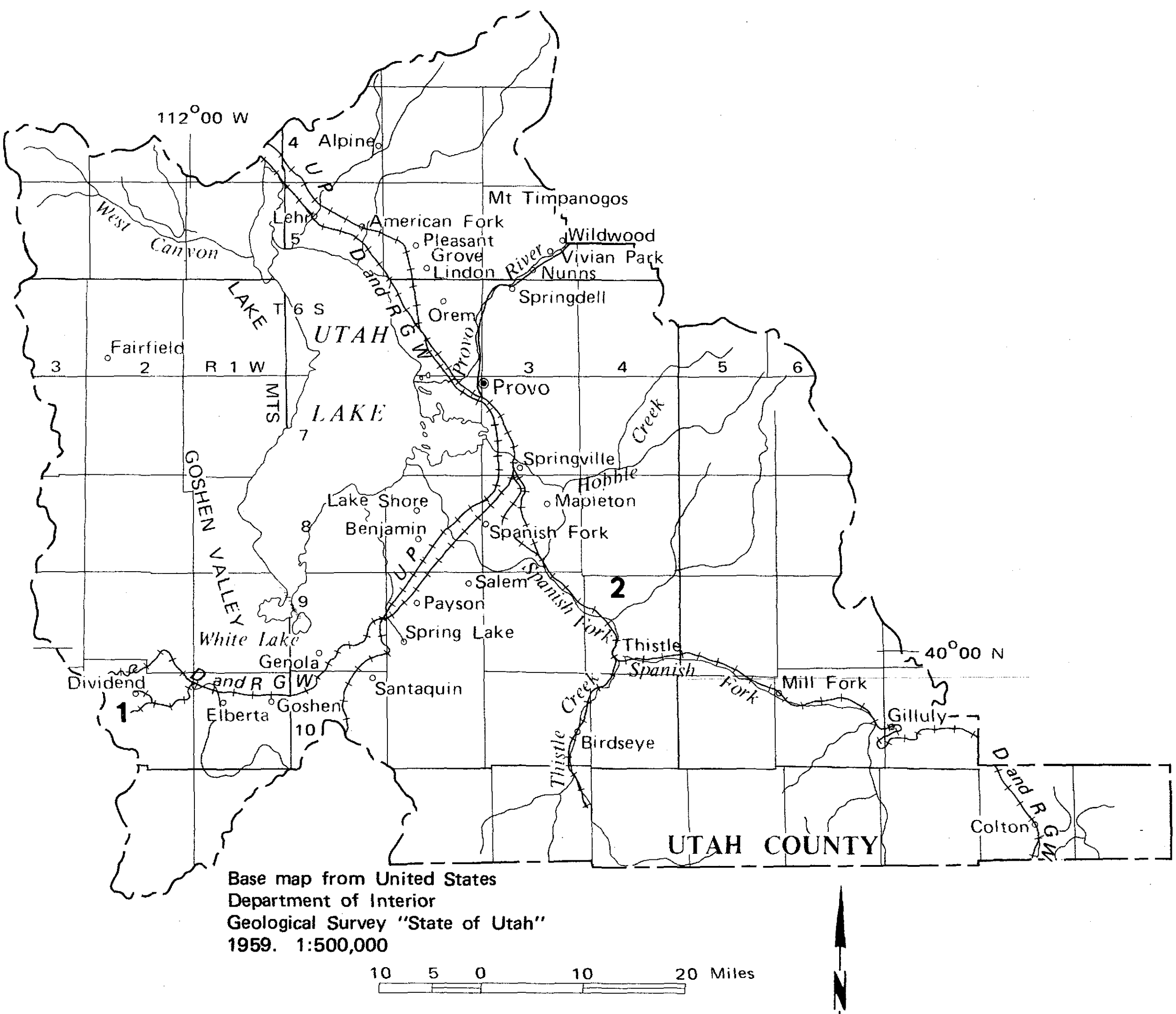


Figure 27. Utah County iron occurrences.

1. Iron King mine, East Tintic Mountains
2. Diamond Fork prospect, Wasatch Mountains

by 30 feet. Iron minerals are goethite and limonite. The ore potential of the Diamond Fork prospect does not exceed a few hundred tons. A chemical analysis of the ore is given in table 1.

WASATCH COUNTY

Ferry (Rhodes Plateau) Iron mine is situated on the west end of the Uinta Mountains, about 20 miles southeast of Kamas, near the head of Soapstone Basin at an elevation of 9,600 feet. The deposit occurs on Iron Mine Creek near the divide separating the Provo and Duchesne River drainages. The principal outcrops lie in NE¼ sec. 19, T. 2 N., R. 9 W., U. B. M. (figure 28), and are accessible from Kamas via Utah Highway 150 to Soapstone Guard Station, then eight miles of dirt road to the head of Soapstone Basin.

The Ferry Iron deposit is held by Assets Corporation of Salt Lake City and consists of seven patented claims covering 140 acres. In 1879 and 1880, approximately 500 tons of iron ore were mined and shipped to the Park City smelter where it was used as a flux. Operations ceased with the closing of the smelter, and the property has been idle since that time. The deposit was surveyed for patent in 1882 and patented by E. P. Ferry in 1890. Assets Corporation is the executor for the Ferry estate. Although the deposits have been known since 1879, only intermittent exploration and development work have been done. Workings consist of an open cut 45 by 25 feet, a caved shaft, several prospect holes and two short adits that have no relationship to iron outcroppings.

The ore is composed of gray, massive, semispecular hematite and red hematite ocher. The hematite is extremely hard, slightly magnetic, and makes up most of the deposit, and the ocherous ore is soft, friable, and has a distinct Indian red color. The ore is composed of high-grade replacements, partial replacements, breccia fillings, ocher and slightly stained country rock.

Iron mineralization occurs along a wide brecciated zone associated with a branch of the South Flank Uinta fault that traverses the south slopes of the Uinta Mountains. The breccia zone has an east-west trending strike and measures from 600 to 1,500 feet wide. Iron mineralization occurs as breccia fillings and as partial to complete replacements in fractured carbonate rocks. The breccia is mainly Deseret limestone in the vicinity of the Ferry Iron mine but includes some Madison limestone. Both formations are Mississippian in age.

The largest iron occurrence at the Ferry Iron mine is near an open cut and shaft, where the ore measures about 15 feet thick, then thins rapidly laterally. All iron outcrops are confined to the brecciated fault zone, but in each case the mineralization is sparse except near the open cut and shaft. Several magnetometer lines were run across the property, but only one small anomaly was found near the shaft. From the general geology of the deposit and a magnetometer survey, the iron ore potential is estimated to be less than 1,000 tons on this property. Chemical analyses of the Ferry Iron mine ores are given in table 1.

WASHINGTON COUNTY

Bull Valley District

Location and Geologic Setting

The Bull Valley district is located in the east part of the Basin and Range province in southwest Utah, immediately south of Enterprise in the northwest part of Washington County in the Bull Valley Mountains. The principal iron ore deposits lie in T. 38 and 39 S., and R. 17 and 18 W. (figure 29). The area is accessible from St. George on Utah Highway 18, and from Cedar City on Utah Highways 58 and 18. The Bull Valley district lies in a mountainous region with steep slopes and isolated peaks. Iron occurrences in the district have been known since 1903, but no production has been recorded. The Bull Valley district is the only area in Utah outside of the Iron Springs district that possesses iron ore potential.

The geology of the Bull Valley district is essentially an eruptive-tectonic complex. An aggregate thickness of about 6,700 feet of volcanic materials accumulated intermittently over the district during Oligocene-Miocene time. Hypabyssal intrusive bodies of quartz monzonite porphyry were emplaced, some of which erupted to the surface. Prevolcanic sedimentary rocks are largely exposed where they have been arched by intrusions. Sedimentary rocks include the Carmel Formation and Entrada sandstone of Jurassic age, Iron Springs Formation of Cretaceous age, and Claron Formation of Tertiary age.

The iron mineralization is related to quartz monzonite porphyry intrusions. Hematite and magnetite, the ore minerals, are replacements of volcanic and limestone rocks, fissure and breccia fillings, and chemical precipitates from thermal springs.

A reconnaissance of the Bull Valley district was made by Leith and Harder (1908) who made a few comparisons of iron occurrences in the Bull Valley and Iron Springs districts. Wells (1937, 1938, 1941) mapped an area that included the main Bull Valley intrusion and made a limited study of the ore deposits. He established the intrusive-extrusive relationship and the major stratigraphic divisions. Zoldock and Wilson (1953) investigated the Pilot and Cove Mountain iron deposits in the district for U. S. Bureau of Mines. Blank (1959) studied the general geology of the district in detail but made no attempt to study the iron ore deposits. This writer will review the geology of the district and give a detailed account of the principal iron ore deposits.

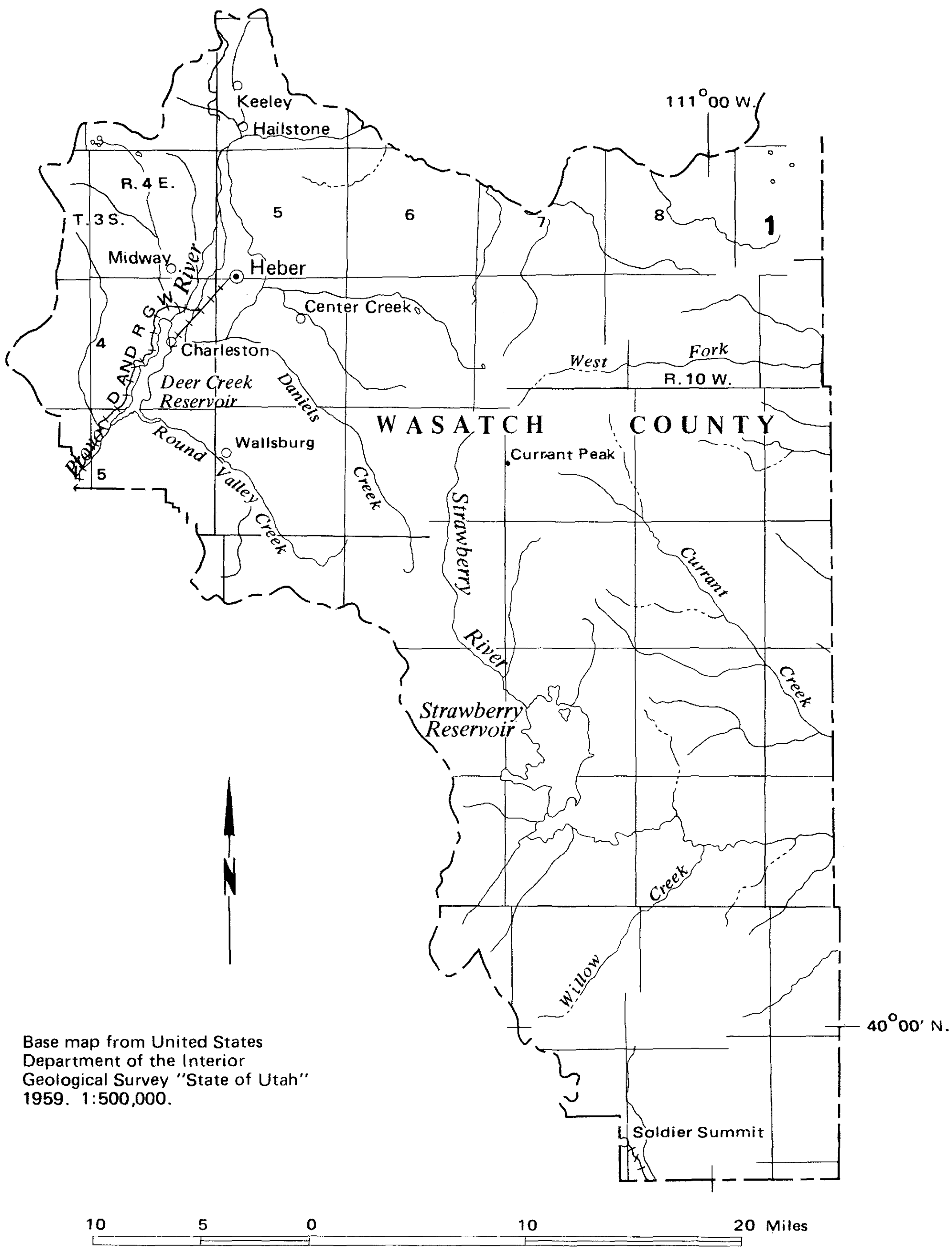
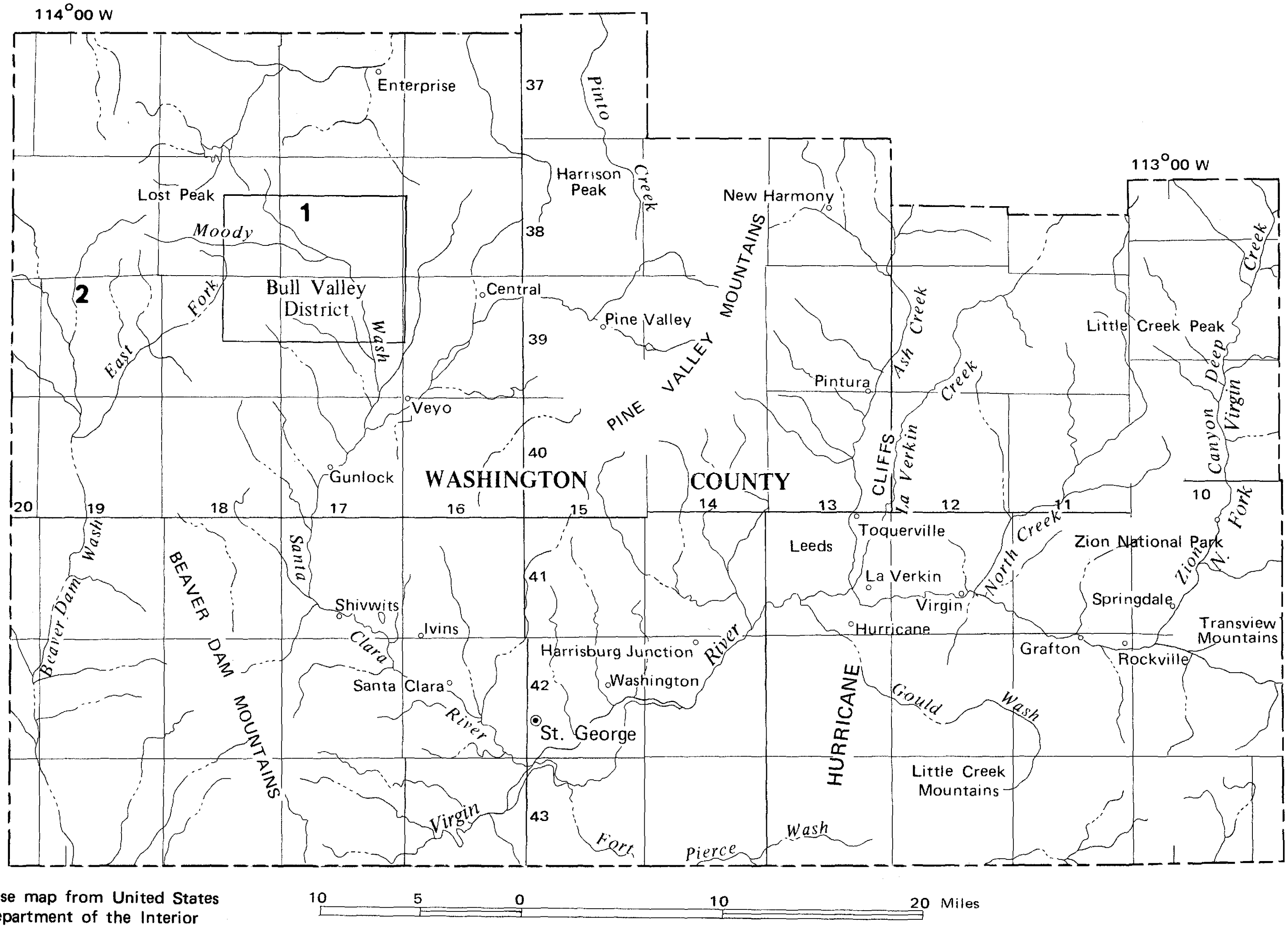


Figure 28. Wasatch County iron occurrences.
1. Ferry Iron mine, Uinta Mountains



Base map from United States Department of the Interior Geological Survey "State of Utah" 1959. 1:500,000.

Figure 29. Washington County iron occurrences.

1. Bull Valley district, Bull Valley Mountains
2. Emma mine, Mineral Mountain

Sedimentary Rocks

Sedimentary rocks in the Bull Valley district are the Carmel Formation and Entrada sandstone of Jurassic age, Upper Cretaceous Iron Springs Formation, and Lower Tertiary Claron Formation. They are buried beneath a volcanic cover over most of the district and are exposed only on structural highs such as the Bull Valley-Big Mountain intrusive arch.

Carmel Formation is the oldest (Jurassic) sedimentary rock exposed in the district, and is made up of four members with an aggregate thickness of about 550 feet. A basal siltstone member is exposed in places and is in concordant contact with the Bull Valley intrusion. It averages about 30 feet in thickness and consists of gray, massive to thick-bedded, calcareous siltstone. It can be considered for the most part a fine-grained skarn rock, resistant to weathering and forming outcrops with brownish colors. Much of the Carmel Formation consists of the overlying Homestake limestone member which measures approximately 315 feet thick. It is a blue-gray, massive to thick-bedded limestone with shaly partings and beds of argillaceous limestone. Some of the lower beds contain abundant star-shaped columnals of the fossil echinoderm *Pentacrinus*. An overlying shale member about 75 feet thick is composed of calcareous shale which weathers into small angular chips. The upper member of the Carmel Formation is composed of massive limestone averaging about 130 feet thick. The lower beds are blue-black argillaceous limestone, and the upper beds are pink, gray, yellow and buff limestone that resembles some of the massive limestone beds of the Tertiary Claron Formation. This upper limestone member is a cliff-former and weathers with a rough pitted surface.

Entrada sandstone was not recognized in exposures at the Bull Valley intrusion; it probably was removed by erosion along this structural high before the Iron Springs deposition. About 50 feet of deep maroon to olive-green shale are exposed at the surface on the southeast side of Big Mountain in the northeast part of the district and are regarded as Entrada. Drill core data around the periphery of the Big Mountain intrusion show the presence of about 130 feet of these strata at depth.

Iron Springs Formation (Cretaceous) disconformably overlies the Carmel Formation and the Entrada sandstone. In the vicinity of Big Mountain the formation is well exposed and is composed of light brown, buff and white massive to thick-bedded sandstone and siltstone, with a few thin interbeds of maroon or gray shale. Locally, the basal unit of the Iron Springs Formation is a conglomerate. Toward the Bull Valley intrusion the colors of the formation are more variegated, with orange, reddish brown and purple the common colors. A full unfaulted section of the Iron Springs Formation was not observed in the district. A thickness of about 1,000 feet is exposed in Moody Wash south of the Bull Valley intrusion, and up to 2,000 feet are exposed in the Big Mountain area.

The Iron Springs Formation was upfolded into the Bull Valley-Big Mountain anticlinal arch prior to the deposition of the *Claron Formation*. Deposition of the Claron took place first along the flanks and away from the topographic high, but it ultimately buried the arch so that Upper Claron limestone was deposited across the crest. Angular discordance between the Iron Springs Formation and the overlying Claron varies from zero along the crest to about 30° along the flanks. In the southeast part of the district several miles from the arch there is no apparent disconformity separating the two formations.

The Claron Formation consists mainly of conglomerate, siltstone and limestone. It is generally divisible into three principal members with an aggregate thickness of about 650 feet in the district. These members are a basal conglomerate, a middle red siltstone and an upper gray limestone. The basal conglomerate is made up of pebbles and cobbles of gray limestone and tan quartzite which varies from gray to yellow and red. It is very thin or absent near the crest of the anticlinal arch; away from the arch it thickens to several hundred feet. The middle Claron member is an easily weathered red siltstone with interbeds of pink limestone and pebble conglomerate up to ten feet thick. This member is absent or subordinate on the crest of the arch and is well developed in areas remote from that structure. Gray massive and thick-bedded freshwater limestone composes the upper Claron Formation. Individual beds range from six inches to 10 feet in thickness and form prominent ledges. The limestone is interbedded with thin layers of friable siltstone. Algal structures appear locally in this limestone. The upper beds are somewhat lighter in color and thinner, and are marked by delicate pink and white mottling and banding.

Igneous Rocks

The first period of major volcanic activity developed during Oligocene time, when about 2,550 feet of volcanic rocks were spread over the Bull Valley district. These rocks are represented by the Needles Range and the Isom and Quichapa formations. Toward the end of this volcanic activity, the axial portion of a Laramide arch from Bull Valley to Big Mountain became a site of intrusions of quartz monzonite porphyry, forming the Bull Valley, Hardscrabble and Big Mountain intrusions. Following this period of intrusive activity, about 4,150 feet of volcanic rocks accummulated in the area during Late Oligocene-Miocene time. These rocks appear in the Rencher Formation, Shoal Creek breccia, Maple Ridge porphyry, Cove Mountain Formation and Ox Valley tuff. The geology of the intrusive-extrusive complex of the Bull Valley district has been described in detail by Blank (1959).

Needles Range Formation was named by Mackin (1960) from a thick volcanic tuff sequence in the

Needles Range, 40 miles northwest of the Bull Valley district. The formation measures up to 130 feet thick and is represented in Bull Valley district by a hornblende-biotite quartz latite tuff interbedded with lacustrine limestone. The tuff is about 60 feet thick on the south side of Moody Wash, where it rests conformably on Claron limestone beds. It is conformably overlain by 70 feet of white to gray massive limestone, followed by younger volcanic rocks.

Isom Formation overlies the upper limestone member of the Needles Range Formation, and is composed of lava flows, ignimbrites and thin interbeds of sedimentary rocks. The name is based on correlation of ignimbrite members with those of the Isom Formation in the Iron Springs district (Mackin, 1960). The total thickness in the Bull Valley district probably does not exceed 170 feet. Three members of the Isom Formation are recognized. The lower member consists of vesicular latite lava flows up to 130 feet thick, bluish gray to purple or brown in color with elongate vesicles commonly filled with calcite. A 20-foot middle member found only on the west side of Big Mountain is correlated with Baldhills tuff in the Iron Springs district. It is a very dense, highly welded, dark chocolate brown latite tuff, containing phenocrysts of plagioclase and biotite. The upper member is represented by Hole-in-the-Wall tuff to 20 feet thick. It is a salmon-colored to purple welded latite tuff, overlying the lower Isom vesicular lava flows at several localities in the district.

Quichapa Formation consists of a succession of sheet ignimbrites with local intercalated lava flows extending throughout southwest Utah. It was named by Mackin (1960) from occurrences in the Iron Springs district. The formation consists of four members with an aggregate thickness of about 2,250 feet in the Bull Valley district. The lowermost member is the Leach Canyon tuff which rests variously on the Isom, Needles Range, and Claron formations with a maximum thickness of about 350 feet. The Leach Canyon tuff is a pink, moderately welded rhyolite tuff with an abundance of red lithic fragments averaging about one and one-half inches in diameter. Occasional pumice fragments may occur in the ignimbrite. The overlying Bauer tuff member is red to bluish purple, highly welded rhyolite measuring up to 200 feet thick. The lower portion contains flattened white pumice fragments and white streaks or schlieren. The overlying Little Creek breccia is a thick succession of variegated augite-hornblende andesite flows and breccia. Outcrops are typically colored dark red to dark purple with gray, green, brown and black phases. A maximum thickness of 1,200 feet has been estimated in the Bull Valley district. The uppermost Quichapa is composed of Harmony Hills tuff, a biotite-hornblende-augite quartz latite tuff measuring up to 500 feet thick. Most rocks of the Harmony Hills tuff are slightly to moderately welded ignimbrite, which forms dark pink to red-brown outcrops and contains at the base a black vitrophyre.

Quartz monzonite porphyry intrusions appeared toward the end or following the conclusion of the accumulation of the Quichapa Formation in the axial portion of the Laramide arch extending 10 miles from Bull Valley northeast to Big Mountain. These intrusions arched their sedimentary and volcanic cover, forming three stocks trending northeast across the district. The Big Mountain intrusion occurs at the northeast end of the district and forms a concordant stock about three-fourths mile long and one-fourth mile wide. The Hardscrabble Hollow stock lies in the central part of the district and is about two-thirds mile long and one-third mile wide. The Bull Valley stock lies in the southwest end of the district and forms a semiconcordant body about four and one-half miles long and one and one-half miles wide. Aeromagnetic data and structural evidence suggest that the entire Bull Valley-Big Mountain arch has an intrusive core of huge dimensions. The Big Mountain and Hardscrabble Hollow intrusions are small stocks or cupolas, and the Bull Valley intrusion is a sizeable stock. All evidence indicates that the three merge at depth into an intrusive body approaching batholitic dimensions.

The Big Mountain intrusion is roofed concordantly by the Carmel Formation, except on the north and northwest sides where it is in fault contact with the Iron Springs Formation. The intrusive is a gray to tan hollocrystalline porphyry. The Hardscrabble Hollow intrusive is bordered and appears to be concordantly roofed by the Carmel Formation. The intrusive is white, gray or reddish porphyry in crumbly rounded knolls. The larger Bull Valley porphyry is a semiconcordant stock. The south and part of the east borders are concordant and roofed by the Carmel Formation, and the other contacts are bordered by faults and various volcanic rocks. The Bull Valley porphyry is hollocrystalline and is usually white or light gray in color; its peripheral phase is light pink, greenish or purple.

The mineralogical and textural relationships of the three intrusives are similar. Phenocrysts compose about one-third of the porphyrys and range in size from 1 mm. to 1 cm. in length. Phenocrysts of essential minerals consist of plagioclase, hornblende and augite. Phenocrysts of accessory minerals are magnetite, apatite, zircon and sphene. Quartz and potash feldspar constitute most of the groundmass.

The Bull Valley intrusion differs from the other two intrusions in that the magma continued to rise, causing failure of part of the roof. Violent eruptions of large quantities of quartz latite magma gave rise to the rocks of the Rencher Formation (Blank, 1959). The Bull Valley intrusion is, therefore, composed of a quartz monzonite porphyry phase followed by an intrusive and vent phase of quartz latite magma. Igneous rocks belonging to the intrusive and vent phase form the central and northeast side of the Bull Valley stock and a second area in the structurally complex area southwest of the stock. The intrusive and vent phase rocks are normally dense, purple, and generally cryptocrystalline.

Rencher Formation covers large areas of the Bull Valley district with a biotite-hornblende-augite quartz latite. This formation represents an extrusive phase largely from Bull Valley stock. The name Rencher was first used by Cook (1957) from outcrops in the Pine Valley Mountains southeast of the district. The formation in much of Bull Valley district is not subdivided, but in a few places it can be divided into white tuff breccia and rusty tuff phases. The Rencher Formation measures about 1,000 feet thick.

After the solidification of the upper part of the Bull Valley quartz monzonite porphyry stock, magmatic pressures increased, producing a sudden violent rupture of the intrusive roof. A gaseous Peléan *nuée ardente*-type eruption gave rise to a thick deposit of ignimbrite materials exposed chiefly on the southeast side of the stock. This eruption formed the lower member of the Rencher Formation, the friable quartz white tuff breccia.

A large dislocation of the roof of the Bull Valley stock occurred later, and great quantities of magma rose in a Katmaian *nuée ardente*-type eruption, giving rise to the upper or rusty tuff phase of the Rencher Formation. It is composed of a rust-colored quartz latite tuff locally overlying the white tuff breccia phase. The extrusive rocks become increasingly tuffaceous with distance from the source area at the vent. Rusty tuff can be traced from typical rusty tuff through lava with pyroclastic textures, to lava flows, to cryptocrystalline vent phase quartz latite.

Shoal Creek breccia rests on the eroded surface of the Rencher Formation. Much of the Rencher and some Quichapa rocks were removed previously from the western area of the Bull Valley district. The breccia is a dark, variegated hypersthene-augite-hornblende andesite about 200 feet thick.

Maple Ridge porphyry is a dark biotite-augite andesite flow about 300 feet thick overlying the Shoal Creek breccia at Maple Ridge. It evidently represents a frontal lobe of a lava flow which entered the district from the west. Large white plagioclase phenocrysts in a dark red-brown to purple groundmass give the rock a distinctive appearance.

Cove Mountain Formation is represented by 2,250 feet of volcanic rocks in the western portion of the Bull Valley district. It is divided into four members (Blank, 1959): Willow Spring, Racer Canyon tuff, Pilot Creek basalt and Cedar Spring. The bottom and top members are thinner and are limited in their distribution. Representatives of all four members are well exposed on Cove Mountain in the southwest part of the district.

The Willow Spring member has an estimated thickness of about 50 feet. It consists of white or gray cross-bedded tuffaceous sandstone, reddish volcanic breccia of possible mudflow origin, ash deposits and volcanic pebble conglomerate. On Cove Mountain the Willow Spring member contains detrital pieces of hematite ore, demonstrating that the basal units of the Cove Mountain Formation postdate iron mineralization.

The Racer Canyon tuff is a succession of rhyolite ignimbrite and tuffaceous interbeds. It is composed of four or more ignimbrites, correlating with the Kane Point tuff member of the Page Ranch Formation in the Iron Springs district (Mackin, 1960). The rock is white, gray, pink and yellow, and is made up of nonwelded to moderately welded tuff. It commonly weathers into massive hoodoo landforms. Red or purple lithic fragments are generally present.

Resting on an erosion surface cut on the Racer Canyon tuff and older rocks is a member of the Cove Mountain Formation designated Pilot Creek basalt. It has a total thickness of about 400 feet. The lower half is dark-colored basalt, and the upper half basaltic breccia. The basalt is dense and reddish-purple near the base, and brown or black and vesicular in the upper portions.

The uppermost Cove Mountain Formation is the Cedar Spring member, composed of about 300 feet of volcanic conglomerate, clastic breccia, tuff and ash. The thickest deposits are loosely consolidated, massive to thick-bedded conglomerate and breccia derived from the Pilot Creek member. Some rock may have originated by volcanic eruptions. The uppermost part of the Cedar Spring member is 10 to 20 feet of pink massive airfall tuff, overlain by about the same thickness of white tuff.

Ox Valley tuff is widely distributed in the Bull Valley district and represents the youngest volcanic eruption in the immediate vicinity of iron mineralization. It is a rhyolite tuff up to 400 feet thick and rests on eroded surfaces of the Cove Mountain and Rencher formations. The tuff is light grayish-blue to pink or purple, slightly to highly welded, and contains few lithic fragments. It contains clear phenocrysts of sanidine showing blue iridescence. The lower part of the tuff is more welded than the upper, is darker in color, and weathers into bold ledges and cliffs.

Structural and Age Relationships

The Bull Valley district is essentially an eruptive-tectonic complex. Prevolcanic sedimentary rocks are exposed largely where they have been arched by intrusions, particularly on the structural high extending from Bull Valley to Big Mountain, a distance of 10 miles. The oldest strata exposed are marine limestone, siltstone and shale of the Jurassic Carmel

Formation. Jurassic Entrada sandstone conformably overlies this formation. Drill core data indicate the Entrada to be 130 feet thick at Big Mountain, but it is apparently missing in other areas of the district. The region was gently uplifted with minor warping in Upper Jurassic and Early Cretaceous time, resulting in partial erosion of the Carmel and Entrada formations. In early Upper Cretaceous time the Iron Springs Formation was deposited unconformably over earlier Jurassic strata.

In late Upper Cretaceous to Early Eocene time, the Laramide deformation produced a major anticlinal structure in the Bull Valley district, extending from Bull Valley to Big Mountain. Partial planation of the Iron Springs Formation on the fold followed the uplift. On and adjacent to the anticlinal structure, the Iron Springs Formation was overlain unconformably by conglomerate, siltstone and limestone of the Tertiary Claron Formation. Angular discordance varies from zero on the crest of the arch to about 30° on the flanks. A few miles away in the southeast part of the district, no apparent disconformity separates the Iron Springs and Claron formations.

The first major volcanic activity developed during Oligocene time when about a 2,550-foot thickness of volcanic rocks spread over the district. The first evidence of eruptive activity recorded by the Needles Range formation consists of quartz latite tuff interbedded with lacustrine limestone, indicating that volcanism was initiated while a lacustrine environment still prevailed in the district. This is followed by the Isom formation, composed of lava flows, ignimbrites and thin sedimentary interbeds. The Isom is overlain by the Quichapa Formation, a succession of sheet ignimbrites with local intercalated lava flows with an aggregate thickness of about 2,250 feet.

Toward or after the end of accumulation of the Quichapa rocks, the axial portion of the Laramide anticline was the site of quartz monzonite porphyry intrusions. The intrusions arched their sedimentary and volcanic covers from Bull Valley to Big Mountain into three exposed bodies. Concordant stocks or cupolas were formed at Big Mountain and Hardscrabble Hollow, and a semiconcordant stock was formed at Bull Valley. The intrusive mass at Bull Valley continued to rise, causing violent eruption of large quantities of quartz latite magma. The earliest ejecta were tuffs and tuff breccias; they were followed by extrusion of more liquid magma, suggesting a transition from ignimbrite to ordinary lava flows. These volcanic ejecta are known as the Rencher Formation and measure up to 1,000 feet thick. Iron mineralization of the Bull Valley district is closely related to the final stages of this magmatic activity.

Quartz monzonite-quartz latite eruptive activity apparently was followed by a considerable period of erosion. The northwest portion of the district was ultimately depressed by downwarping or high-angle faulting, permitting an accumulation of about 3,150 feet of basic and intermediate flows and breccias, rhyolite tuffs and volcanic-derived sediments. Most of the material appears to have spread into the area from the west and northwest. The upper units completely buried the intrusive arch. The outcrops southeast of that structure are evidence of this event. The oldest unit is the Shoal Creek breccia, measuring 200 feet thick and consisting of dark-colored intermediate and basic volcanic deposits. Maple Ridge porphyry is inferred to rest on Shoal Creek breccia and is composed of 300 feet of dark biotite-augite andesite. The overlying Cove Mountain Formation is composed of a basal Willow Spring member made up of 50 feet of volcanic sediments, ash and mudflows, Racer Canyon tuff and tuffaceous sediments up to 1,500 feet thick, Pilot Creek basalt measuring 400 feet thick and a Cedar Spring member of tuff and volcanic sediments 300 feet thick. The youngest volcanic sequence in the immediate area of Bull Valley iron occurrences is the Ox Valley tuff which consists of bluish purple rhyolite tuff 400 feet thick with blue iridescent sanidine crystals.

The Racer Canyon tuff is correlated with the Kane Point tuff in the Iron Springs district, giving an age determination of 19 million years (Jaffe, 1959). This dates the Cove Mountain Formation as Miocene. Younger volcanic activity of Pliocene, Pleistocene and Recent ages are recorded north and northwest of the main Bull Valley district.

Mineralogy and Mode of Occurrence

The principal iron ore minerals in the Bull Valley district are hematite and magnetite. The hematite varies from soft and ocherous to hard and massive. The magnetite is found in fissure veins and in intimate admixtures with hematite. Small quantities of martite, goethite, limonite and turgite are present.

Iron ore bodies are found as contact metasomatic replacements, breccia fillings and replacements, fissure vein fillings and thermal springs deposits. The major iron occurrence in the Bull Valley district is the Pilot deposit, a contact metasomatic-hydrothermal replacement of volcanic rocks and thin interbeds of limestone. Breccia fillings and replacements of brecciated rock are found at several deposits. Fissure vein fillings occur in quartz monzonite porphyry and in the Rencher Formation. The Cove Mountain iron occurrence is unusual in that the ore body is the result of iron deposition by thermal springs in a shallow lake basin. Details on the mineralogy and mode of occurrence of the Bull Valley iron deposits are given in discussion of individual ore bodies.

Ore Deposits

The Iron Springs district is the only area in Utah containing commercial iron ore deposits and the Bull Valley district is the only other district in the state with potentially commercial iron ores. The Pilot deposit in the Bull Valley district contains from 15 million to 20 million tons of ore with an overall weighted average of 31 percent iron content. The ore would require considerable beneficiation to be commercially profitable. Cove Mountain has a potential of about 1 million tons of highly siliceous hematite with an iron content of about 45 percent and silica content of about 32 percent. All other known iron occurrences in the Bull Valley district are insignificant. The geographic location of deposits in the Bull Valley district is shown on figure 30.

Buckey group of claims is located on the north and south side of Moody Wash in the Bull Valley district, with two Buckey claims in sec. 31, two Johnson claims in secs. 30 and 31, and two Iron Cap claims in secs. 29 and 32, T. 38 S., R. 17 W. (figure 30). The claims are accessible by a U. S. Forest Service road extending 13 miles northwest of Veyo and three miles of unimproved road northwest to the area. The property is held by assessment work by Jay R. Johnson of Salt Lake City.

Rocks in the vicinity of the Buckey group are sedimentary and volcanic. The oldest sedimentary strata exposed belong to the Tertiary Claron Formation. Overlying volcanic sequences are Isom, Quichapa, Rencher and Cove Mountain formations. The Rencher Formation shows an intrusive or vent phase into Quichapa volcanics. The Cove Mountain Formation is in fault contact with the Rencher Formation. The many faults and variable attitudes of sedimentary and volcanic sequences suggest that the nearby Bull Valley stock and the intrusive phase of the Rencher Formation strongly folded and faulted overlying rocks. Most faults trend northerly and have steep dips.

Iron mineralization occurs in the Rencher Formation on the Buckey claim where two minor zones of mineralization occur. Iron ore occurs in small fissure veinlets, breccia replacements up to six inches in diameter, and as small replacement pods in fine-grained gray tuff-breccia. The mineralized zone in the south central part of the Buckey claim was exposed in two places by bulldozer excavations. The exposed area does not exceed 500 square feet. The largest outcrop is 12 feet long and 8 feet high and contains small fragments of hematite ore as breccia fillings and replacements of tuff-breccia. The outcrop is overlain by altered light-colored biotite tuff-breccia and is cut off on the south by a near-vertical fault. A second mineralized zone occurs approximately 1,000 feet farther north at the north end of the Buckey claim. It consists of a fissure zone trending northwest in a gray fine-grained tuff-breccia. Iron occurs in volcanic rocks as minor veinlets, small replacement pods, and as hematite fragments from two to six inches in diameter. One small replacement pod measured three feet in length.

A magnetometer survey over the property encountered no favorably mineralized bodies. One small anomaly was found, too small for a commercial ore body. The property was developed by a series of bulldozer cuts, prospect pits, and one drill hole 216 feet deep. In 1955, the U. S. Steel Corporation drilled an exploratory hole on the mineralized zone in the south central part of the Buckey claim and encountered sporadic mineralization to 28 feet. The ore consisted of small pieces of hematite to one-half inch in size; it occurs along small fissure veins that cut volcanic rocks. The quantity of ore exposed and that determined from drilling is small. The ore potential for the Buckey group is estimated to be less than 1,500 tons. Chemical analyses of the higher-grade ores are given in table 1.

Cove Mountain deposits are located on the north slope of Cove Mountain in the Bull Valley district, in scattered outcrops in secs. 1, 2, 3, 10, 11, and 12, T. 39 S., R. 18 W., and in secs. 6 and 7, T. 39 S., R. 17 W. (figure 30). The property is accessible by a U. S. Forest Service road extending 14 miles northwest from Veyo to Wilson's Camp, thence two miles south over an unimproved road to the lower claims. The main mineralized zone occurs in parts of secs. 1, 2, 11, and 12, T. 39 S., R. 18 W., approximately 1,000 feet above Wilson's Camp. The property is held by assessment work by Jay R. Johnson of Salt Lake City who has seven claims known as the Iron Rod group, and other claims, including Gregerson claims, held by W. L. and V. H. Rasmussen of Veyo.

Iron occurrences are associated with the Rencher Formation which is about 500 feet thick on Cove Mountain and is composed of white to pinkish quartz latite tuff. The Upper Rencher Formation is partially mineralized and is capped by a siliceous hematite bed averaging 3½ feet thick; it can be traced in continuous outcrop for more than one mile. It is unconformably overlain by the Cove Mountain Formation. The basal Willow Spring member of the Cove Mountain Formation overlies the principal iron occurrence. It consists of about 50 feet of interbedded tuff, tuffaceous sandstone and latite tuff-breccia. These volcanic-derived sediments on Cove Mountain contain detrital pieces of siliceous hematite ore, demonstrating that the basal unit of the Cove Mountain Formation postdates iron mineralization. The overlying Racer Canyon member of the Cove Mountain Formation forms extensive outcrops north, northwest and south of the principal iron deposits. These volcanic and volcanic-sedimentary rocks strike easterly and dip 15° to 20° north. Several prominent northwest- and northeast-trending, steeply dipping faults occur in and near the ore deposits. The siliceous hematite bed is displaced approximately 50 feet by a steeply dipping fault.

The deposit on Cove Mountain consists of about eight feet of slight hematite mineralization at the top of the Rencher Formation and an overlying fine-grained, siliceous, hematite bed which averages 3½ feet in thickness. The siliceous hematite bed may

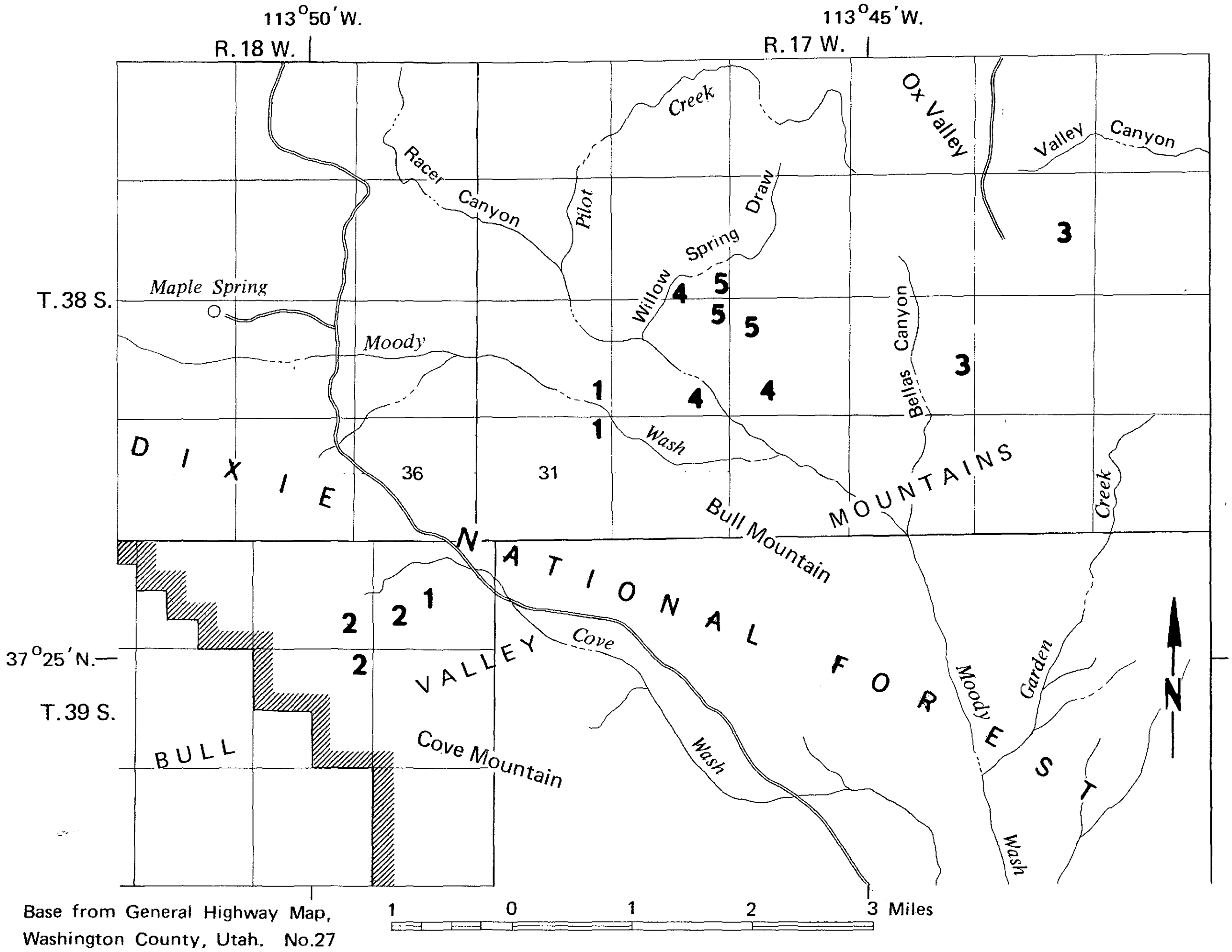


Figure 30. Bull Valley district iron occurrences, Washington County.

1. Buckey group prospects, Bull Valley Mountains
2. Cove Mountain deposits, Bull Valley Mountains
3. Farnsworth prospects, Bull Valley Mountains
4. Pilot deposits, Bull Valley Mountains
5. Soft Iron prospects, Bull Valley Mountains

possess some ore potential, and differs from the other iron occurrences in the district in that it is sedimentary in origin. Criteria favoring a sedimentary origin for the siliceous hematite bed are: the simple mineralogy consisting of fine-grained colloidal hematite and quartz, the banding or 'pseudo' banding of the deposit, the occurrence of the iron bed at the same stratigraphic horizon, the continuity of the bed for more than one mile, and the overlying bedded, waterlain tuffs and tuffaceous sands indicating sedimentary deposition in a shallow lake basin.

Iron mineralization at the top of the Rencher Formation is not intense and is noncommercial. It occurs as small veinlets, cavity fillings and replacements in the host rock. The writer considers the Cove Mountain siliceous hematite bed to have resulted from deposition of iron from thermal springs in a shallow lake basin. Partial mineralization of the upper few feet of the Rencher Formation was accomplished by seepage and leaching of iron downward from the siliceous hematite bed during and perhaps after its deposition.

A magnetic survey on Cove Mountain iron deposits gave negative results since the ore is nonmagnetic. The property was developed by a series of bulldozer cuts, trenching and drilling. In 1941, the U. S. Bureau of Mines carried on exploratory activities in which they dug 598 feet of trenches on the two most prominent iron outcroppings. In 1955, U. S. Steel drilled a hole 155 feet deep on the Iron Rod group of claims. The ore potential of the Cove Mountain deposits are based on the assumption that the siliceous hematite bed continues down-dip with an average thickness of 3½ feet. The ore potential of the Cove Mountain deposits is regarded as more than 1 million tons. A rather high stripping ratio would be required to remove large tonnages, and stripping may therefore be economically impractical. Both open pitting and underground mining would be required to obtain the estimated ore potential of this deposit.

The U. S. Bureau of Mines excavated 17 trenches on two prominent ore outcrops on Cove Mountain. The trenches revealed an average thickness of the siliceous hematite bed of 3.4 feet. A weighted average of chemical analyses showed 45.7 percent iron content for the siliceous hematite bed. Chemical analyses from a series of 20 chip samples taken from Cove Mountain deposits are given in table 1.

Farnsworth claims lie on the east and southeast sides of the Bull Valley intrusive, about 14 miles south of Enterprise. The property consists of three groups of unpatented claims, the Mastodon group of three claims at the south end of Ox Valley in sec. 23, the High Up group of five claims on the east side of Bellas Canyon in secs. 26 and 27, and the Low Down group of two claims on the west side of Bellas Canyon in secs. 24, 27 and 28. All claims are located in T. 38 S., R. 17 W. (figure 30). These 10 mining claims are held by assessment work by Clayton and Erwin Farnsworth of Las Vegas, Nevada and Delta, Utah.

The Farnsworth properties were developed by shallow pits, a shaft, an adit and bulldozer cuts near small iron ore outcrops. Three small magnetite veins are exposed on the Mastodon claims, cutting volcanic rocks of the Rencher Formation. A magnetometer survey of these outcrops indicated only small shallow ore veins. The High Up group contains a small replacement-type iron deposit which occurs along the contact zone of the Bull Valley stock and the Jurassic Carmel Formation. The Low Down claims are near the contact zone of the Carmel Formation and the Bull Valley stock. Ore is exposed in a shallow shaft and an adit in the Carmel Limestone. Hematite ore is found on the High Up and Low Down groups. No ore has been produced at the Farnsworth property, and iron ore potential probably does not exceed 1,000 tons. Chemical analyses of iron ores from the Farnsworth property are given in table 1.

Moody group of claims is included in one block because of their proximity to each other, their similar geologic setting and their location adjacent to the Pilot deposits. The Moody group includes five Moody claims in sec. 33, seven Iron Valley claims in sec. 28, five Iron Cross claims in sec. 29, and two Horseshoe claims in secs. 20 and 29, all in T. 38 S., R. 17 W. (figure 30). The property is accessible south from Enterprise by 15 miles of improved dirt road. The property is held by assessment work by Jay R. Johnson of Salt Lake City.

The Horseshoe, Iron Cross, and Iron Valley claims are staked entirely on the Bull Valley intrusion. The Moody claims lie on the intrusive Carmel Formation and a small portion of the Cretaceous Iron Springs Formation in fault contact with the Tertiary Quichapa Formation. No iron mineralization of any consequence occurs on any of the claims, located adjacent to the patented Pilot claims of the Milner Corporation.

A magnetometer survey did not find any magnetic anomalies suggestive of a commercial iron ore body. A small northwest-trending anomaly was outlined on the Iron Valley group. In 1955, U. S. Steel drilled a hole on this anomaly and cut only quartz monzonite porphyry from the surface to 305 feet.

Pilot claims lie in the Bull Valley district in secs. 20, 28 and 29, T. 38 S., R. 17 W. (figure 30). The topography of the area is rugged with a local relief of about 1,700 feet. The property is accessible over improved and unimproved dirt roads extending south from Enterprise about 16 miles. The property is owned by Milner Corporation of Salt Lake City and consists of 25 patented lode claims covering an area of 455 acres. Milner Corporation also has several unpatented Enterprise claims that are contiguous to and lie on the north and northeast sides of the Pilot claims. No iron ore outcrops on the Enterprise claims, but they may have some iron ore potential since the Pilot ore body dips north toward this property.

Ore occurrences on the Pilot property have been known since 1903, but there has been no iron ore production. The property was developed by many test pits, small adits, trenches, bulldozer cuts and drill holes. In September 1941, the U. S. Bureau of Mines established a development project on the Pilot claims. In one year they drilled three holes aggregating 1,000 feet, trenched 6,458 feet and completed 171 feet of underground workings. During the last half of 1955, U. S. Steel drilled six holes aggregating 3,579 feet.

The Pilot group is associated with the Bull Valley stock. Sedimentary, volcanic and intrusive igneous rocks are exposed. The most widely distributed rocks are lava flows, ignimbrites, tuffs, tuff breccias and sedimentary interbeds, which form the Needles Range, Isom, Quichapa and Rencher formations. These volcanic sequences surround much of the Bull Valley stock, except on the south side where concordant outcrops of sedimentary strata of the Carmel, Iron Springs, and Claron formations are exposed.

Iron mineralization on the Pilot property consists of hematite and magnetite ores. Fissure veins cut the Bull Valley quartz monzonite porphyry and the Rencher Formation; replacement deposits occur in xenolithic blocks and contact zones of the Isom and Quichapa formations. Outcrops of these latter formations consist of lava flows, ignimbrites, tuffs, tuff breccias and small interbeds of limestone, and occur in secs. 20, 28 and 29. They are completely surrounded by quartz monzonite porphyry or intrusive and vent phase quartz latite of the Rencher Formation. The largest outcrop lies in sec. 28 in Pilot claims Nos. 7 and 11 (figure 31).

The Bull Valley stock consists of quartz monzonite porphyry and an intrusive vent phase of the Rencher Formation. In the iron mineralized area of the Pilot claims, the intrusion stoped some xenolithic blocks along its margin; however, in the vicinity of the main Pilot ore body the Isom and Quichapa formations appear to have normal intrusive contact relationships. A major vent zone (Blank, 1959) through which Rencher magma erupted lies immediately south and west of the main Pilot ore body. Northeast of this ore body lies an extrusion of the Rencher that texturally is similar to the vent area and overlies the mineralized Isom and Quichapa formations.

Rocks of the principal Pilot ore body in sec. 28 generally strike eastward and dip 30° north. Bedded structures of the northmost mineralized ore body in sec. 20 have similar strikes and dips. At least two sets of faults occur within the Pilot property. The more prominent set trends northeast and dips generally northwest and has displacements up to several hundred feet. A second set of faults trends northwest and dips to the northeast. Joint sets, often mineralized, generally parallel these latter fault directions.

Iron mineralization on the Pilot property occurs as narrow magnetite fissure veins in the intrusive and vent phase of the Rencher Formation and as hematite-magnetite replacements in the Isom and Quichapa formations. The largest exposed fissure vein occurs on Pilot No. 11 claim in sec. 28, immediately north of the main Pilot replacement deposit and about 1,000 feet directly south of U. S. Mineral Monument No. 1. This fissure vein cuts the intrusive complex, strikes north 60° west and dips 45° to 55° northwest. It averages four feet in width and measures about 300 feet in length. The majority of the other fissures range to about two inches in width and several feet in length and strike northwest. The main iron mineral is magnetite, some of which has altered to hematite. Gangue minerals are mainly quartz and calcite.

Six outcrops of Isom and Quichapa rocks on the Pilot property lie within the Bull Valley intrusive complex. The smallest exposure measures about 50 by 150 feet; the largest, the Pilot ore block, measures 400 by 1,000 feet. Three of the six outcrops show contact metasomatic-hydrothermal replacements, but only the Pilot ore body contains potentially commercial ore. The Pilot block lies east-west, parallel to the strike of the tuffaceous beds; it dips 30° north and is exposed on Pilot Nos. 7 and 11 claims in sec. 28. Several zones of iron mineralization in this block irregularly follow bedding and flow structures of the volcanic rocks and thin interbeds of limestone. The Pilot block of Isom and Quichapa formations appears to be in normal contact relationship with Bull Valley quartz monzonite porphyry, with the volcanic sequence dipping north and overlain by extrusions of vent phase quartz latite of the Rencher Formation. The second largest mineralized area crops out at the north end of pilot No. 6 and the south end of Pilot No. 5 claims in sec. 20. A major fault zone bounds this block on the east side. A north-south trending replacement body of hematite-magnetite, approximately 40 by 150 feet, lies along its west boundary. A third mineralized block lies in the central part of Pilot No. 6 claim in sec. 29 and contains several small iron deposits associated with volcanics and interbeds of limestone.

Surface outcrops in the main Pilot ore block are lenticular to irregular in form. The largest exposure lies in the east part of this block and measures approximately 100 by 350 feet. A second mineralized zone in the central area averages about 25 by 400 feet. Other iron occurrences lie in the west half of the Pilot ore block but are less than 100 by 200 feet. In general, replacement bodies follow the original bedding in the Isom and Quichapa formations. Lower-grade iron mineralization surrounds

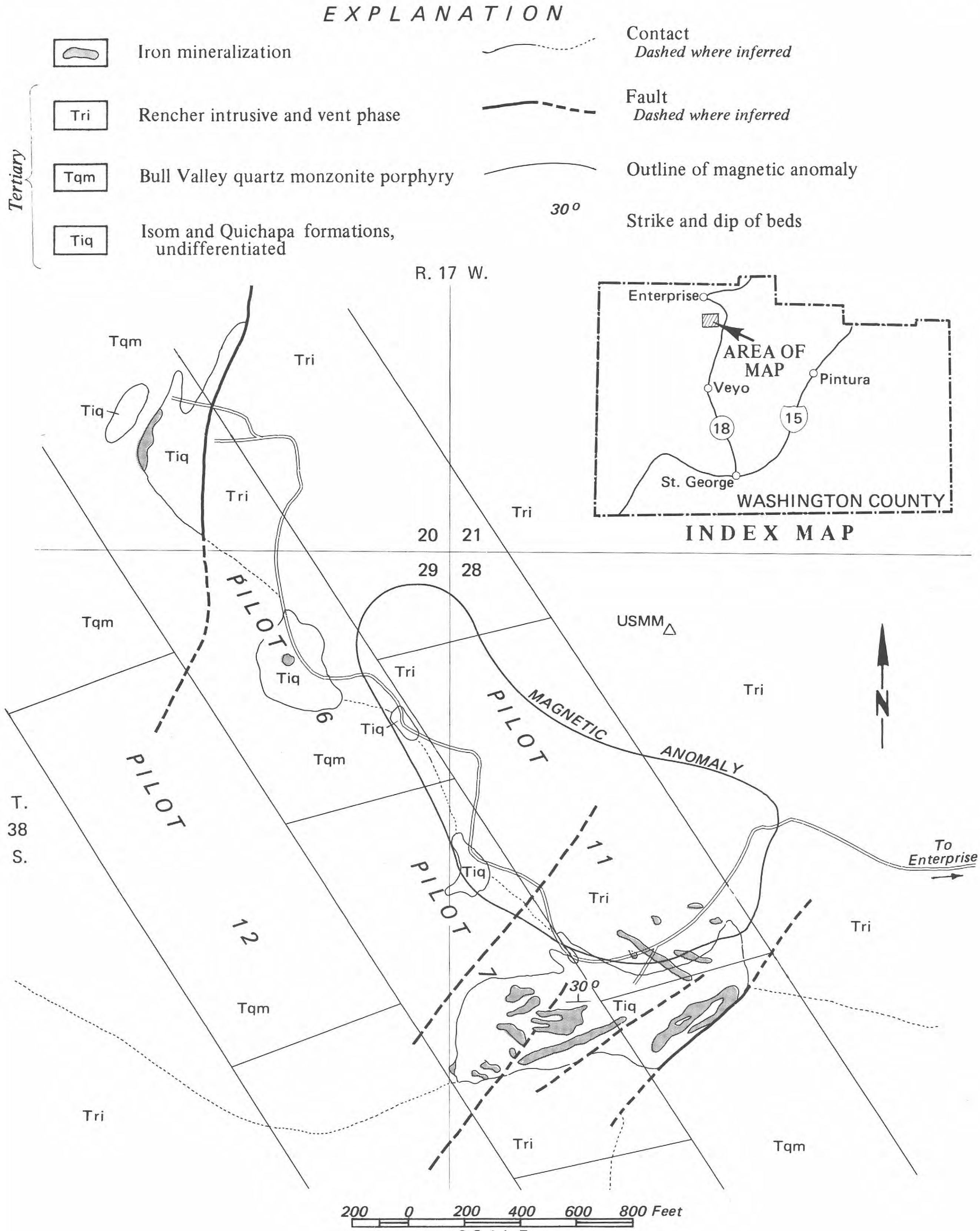


Figure 31. Pilot Iron deposits, Bull Valley district, Washington County.

the more intensely replaced zones. The chief iron-bearing mineral is hematite. Martite crystals and magnetite are also present. Gangue minerals are mainly quartz, calcite and apatite. In the lower-grade zones, iron occurs as disseminations of magnetite crystals and as small magnetite veinlets with some hematite.

Drilling operations on the main Pilot ore body have shown an extension of an irregularly shaped mineralized zone toward the north for 900 feet or more. The mineralized zone dips about 20° north with an average thickness of approximately 400 feet. Hematite and magnetite replacements of volcanic rocks, tuffaceous beds and interbeds of limestone range from slight mineralization to high-grade ore, containing from 10 to 60 percent iron. The variable character of the ore would make mining of this deposit difficult. The Pilot ore body is estimated to have a potential of 15 million to 20 million tons of ore with an overall weighted average of 31 percent iron content. From 2 million to 3 million tons could be classified as high-grade ore with a weighted average of 45 percent iron content. Several hundred ore samples were taken from the Pilot ore body. A summary of the chemical analyses of these samples made by several investigators is given in table 5.

Soft Iron group of nine claims is located between Cove Mountain and Moody Wash in sec. 5, T. 39 S., R. 17 W., in the Bull Valley district (figure 30). The claims are accessible by a U. S. Forest Service road extending northwest from Veyo for 13 miles, thence one mile over an unimproved dirt road. The property is held by assessment work by Jay R. Johnson of Salt Lake City.

Rocks exposed in the vicinity of the Soft Iron prospects consist of sedimentary and volcanic rocks in block-fault relationships. The oldest sedimentary rock exposed is the Tertiary Claron Formation which is overlain conformably by the volcanic Needles Range and Isom formations. The remaining rocks near the property belong to the Quichapa Formation. Mineralization is in association with an upthrown block of Claron sediments in fault contact with volcanic rocks of the Quichapa Formation. The Soft Iron fault block lies in the center of the claims and has been formed by a system of northwest-trending faults that dip steeply to vertical. The strata strike northwest and dip 25° to 30° southwest. Local folds and faults produce some reversal and steepening of dip of the beds.

Iron mineralization is weak and occurs as small fissure veins and as small replacement pods that occur in siltstone, limestone and tuff, and range from a few inches to five feet in thickness. These pods are sporadically distributed in a north-south direction in the Soft Iron fault block. Manganese oxides are present in some limestone outcrops. Fissure veins range from a few inches to two feet in width and to 50 feet in length. Faults have served as feeder channels for the iron mineralization.

The ore consists of red earthy hematite and some magnetite. In places hard nodules of granular hematite and magnetite are present. Gangue minerals are of minor importance. Hematite float is scattered over parts of the property, and the soil is stained red. A magnetometer survey over the property gave discouraging results. Two sharp magnetic anomalies were observed, but they were caused by a magnetic

Table 5. Analyses of Pilot deposits, Bull Valley district, Washington County.

Name of Deposit	Source of Samples	Number of Samples	Total Sample Length in ft.	Weighted Averages (percent) Fe	Insol.	SiO_2	S	P	Mn
Pilot ore body	Trenching	264	1,261	46.2	–	–	–	–	–
		24	120	–	17.2	–	0.011	0.24	0.08
Pilot ore body	Chipping outcrops	20	–	59.2	–	7.0	0.009	0.148	0.28
Pilot ore body	Upper adit	13	57	61.8	–	–	–	–	–
Pilot ore body	Lower adit	43	88	53.7	–	–	–	–	–
		2	2	–	11.25	–	0.002	0.198	0.07
Pilot ore body	Drilling	237	1,898	30.7	–	31.5	0.006	0.258	–
Northwest ore body	Trenching	22	109	52.2	–	–	–	–	–
		2	10	–	7.95	–	0.006	0.065	0.105

volcanic glass in the Bauers tuff member of the Quichapa Formation. Small anomalies in mineralized zones indicated small quantities of iron exposed at the surface.

The Soft Iron property was developed by a series of bulldozer cuts, prospect pits and three drill holes. In 1955, U. S. Steel drilled 961 feet on these claims prospecting for ore. Only surface and near-surface mineralization was encountered. One drill hole showed iron mineralization at five feet, another at 25 feet, and a third hole showed one foot of mineralization at 15 feet. The ore potential of this property is probably less than 1,000 tons and would be most useful as an iron pigment. Chemical analyses of the Soft Iron ores are given in table 1.

Mineral Mountain Deposits

Emma mine, on Mineral Mountain near the Utah-Nevada line, lies in sec. 4, T. 39 S., R. 19 W. (figure 29). The area is accessible from U. S. Highway 91 at the Shivwits Indian Reservation, eight miles west of Santa Clara. An improved dirt road extends northwest for 19 miles to Motoqua, thence eight miles north along Slaughter Creek to the property on the north side of Mineral Mountain. The mine consists of eight unpatented claims held by Mineral Mountain Mining Company of St. George.

Situated in a region of considerable relief, to an elevation of more than 7,000 feet with a variation of local relief of nearly 2,000 feet, Mineral Mountain is a small stock formed by granite porphyry intruding sedimentary rocks of Upper Paleozoic age. Extensive erosion left small roof pendants and flanking masses of sedimentary rocks. Tertiary volcanic rocks with an aggregate thickness of several thousand feet surround Mineral Mountain and probably covered it at one time in geologic history. The north half of Mineral Mountain is composed mostly of granite porphyry. Bipyramidal quartz crystals, occurring as large phenocrysts in the intrusive rock, give the rock its porphyritic texture. The intrusive is somewhat irregular in shape and measures more than two miles in diameter.

Two sedimentary formations outcrop on Mineral Mountain, but only part of each formation is exposed. These are Pennsylvanian Callville limestone and Permian Coconino sandstone. Callville limestone consists of fossiliferous limestone, chert that occurs as nodules and lenses, and dolomite. The formation is in contact with the intrusive and in general shows concordant relationships. The largest outcrops of Callville limestone occur on the south side of Mineral Mountain, where a south-plunging domal structure is exposed. A few scattered outcrops west and north of the intrusive dip away with variable inclinations. Some limestone outcrops form roof pendants. Along the contact the limestone is altered locally to fine- to coarse-grained dolomitic marble. Coconino sandstone outcrops on the extreme south end of Mineral Mountain near Potters Peak. It consists of massive, buff to brown cross-bedded sandstone.

Iron mineralization is restricted to the north side of Mineral Mountain, where it occurs as small fissure veins and replacements in a roof pendant of Callville limestone. One outcrop measures 10 by 50 feet and contains nearly vertical stringers of magnetite. The veinlets vary in width from less than one inch to several inches. A 150-foot adit crosscuts this zone of mineralization and exposes several stringers and a vein of magnetite two feet wide. Several prospect holes are excavated on the property. Small traces of copper occur as malachite, the most abundant copper mineral, and azurite and chrysocolla. All development work was directed to copper and gold exploration.

A magnetometer survey across the roof pendant revealed a small anomaly that suggested a shallow iron occurrence. From a study of the geology of the deposit, development work and geophysical data, it is estimated that the ore potential is less than 1,000 tons. Chemical analyses of Emma mine iron ores are given in table 1.

BIBLIOGRAPHY

Allsman, P. T., 1948, Investigation of iron ore reserves of Iron County, Utah: U. S. Bur. Mines, Rept. Inv. 4388, 3 p.

Anonymous, 1900, The Norway iron mines of Morgan County: Salt Lake Min. Rev., v. 2, May 30, p. 5.

Armstrong, R. L., 1963, Geochronology and geology of the eastern Great Basin: unpub. Ph. D. thesis, Yale Univ., 202 p.

——— 1966, K-Ar dating using neutron activation for Ar analyses–granitic plutons of the eastern Great Basin, Nevada, and Utah: Geochim. et Cosmochim., Acta, v. 30, p. 565-600.

Arrington, L. J., 1951, Iron manufacturing in southern Utah in the early 1880's, The Iron Manufacturing Company of Utah: Bull. Bus. Hist. Soc., v. 25 (3), p. 149-168.

——— 1958, Planning an iron industry for Utah, 1851-1858: Huntington Lib. Quart., v. 21 (3), p. 237-260.

Baer, J. L., 1962, Geology of the Star Range, Beaver County, Utah: Brigham Young Univ. Geol. Studies, v. 9, pt. 2, p. 29-52.

Bancroft, H. H., 1889, History of Utah, 1540-1886: The History Company, San Francisco, p. 735-737.

Barosh, P. J., 1960, Beaver Lake Mountains, Beaver County, Utah, their geology and ore deposits: Utah Geol. and Mineralog. Survey Bull. 68, 89 p.

Beeson, J. J., 1915, The disseminated copper ores at Bingham Canyon, Utah: Amer. Inst. Min. Eng. Bull. 107, p. 2191-2236.

——— 1916, The disseminated copper ores at Bingham Canyon, Utah: Amer. Inst. Min. Eng. Trans. 54, p. 356-401.

Bellum, D. P., and Lee Nugent, 1963, Iron mining, healthy Utah industry: Min. Eng., v. 15 (11), p. 34-38.

Blake, W. P., 1886, Iron ore deposits of southern Utah: Amer. Inst. Min. Met. Eng. Trans., v. 14, p. 809-811.

———— 1893, Association of apatite with beds of magnetite: Amer. Inst. Min. Met. Eng. Trans., v. 21, p. 159-160.

Blank, H. R., 1959, Geology of the Bull Valley district, Washington County, Utah: unpub. Ph.D. dissert., Univ. of Washington, 228 p.

Blank, H. R., and J. H. Mackin, 1967, Geologic interpretation of an aeromagnetic survey of the Iron Springs district, Utah: U. S. Geol. Survey Prof. Paper 516-B, 14 p.

Blue, D. M., 1960, Geology and ore deposits of the Lucin mining district, Box Elder County, Utah, and Elko County, Nevada: unpub. M.S. thesis, Univ. of Utah.

Boutwell, J. M., 1904, Iron ores in the Uinta Mountains, Utah: U. S. Geol. Survey Bull. 225, p. 221-228.

Boutwell, J. M., and others, 1905, Economic geology of the Bingham mining district, Utah: U. S. Geol. Survey Prof. Paper 38, 413 p.

Boutwell, J. M., and L. H. Woolsey, 1912, Geology and ore deposits of the Park City district, Utah: U. S. Geol. Survey Prof. Paper 77, 231 p.

Bradford, R. H., 1908, Some Utah mineral deposits and their metallurgical treatment: Salt Lake Min. Rev., 10, Dec. 30, p. 15-17.

———— 1909, Some Utah mineral deposits and their metallurgical treatment: Amer. Min. Cong. 11th Ann. Session, Papers and Addresses, p. 101-118.

Bullock, K. C., 1967, Minerals of Utah: Utah Geol. and Mineralog. Survey Bull. 76, 237 p.

Bullock, K.C., D. R. Smouse and G. B. Robinson, Jr., 1960, Minerals and mineral localities of Utah: privately pub., Brigham Young Univ. Press, 170 p.

Buranek, A. M., 1942, Report on the Mineral Point Copper mine, Cache County, Utah: Utah Dept. of Publicity and Industrial Dev. Circ. 4.

Bush, J. B., 1959, Ore deposits of the Eureka Standard, Apex Standard, and Iron King mines, *in* Geology of the East Tintic Mountains and ore deposits of the Tintic mining district: Utah Geol. and Mineralog. Survey Guidebook to the geology of Utah, No. 12, p. 122-123.

Butler, B. S., 1913, Geology and ore deposits of the San Francisco and adjacent districts, Utah: U. S. Geol. Survey Prof. Paper 80, 212 p.

Butler, B. S., G. F. Loughlin, V. C. Heikes and others, 1920, The ore deposits of Utah: U. S. Geol. Survey Prof. Paper 111, 672 p.

Calkins, F. C., and B. S. Butler, 1943, Geology and ore deposits of the Cottonwood-American Fork area, Utah: U. S. Geol. Survey Prof. Paper 201, p. 92, 113-114.

Callaghan, Eugene, 1939, Volcanic sequence in the Marysvale region, southwest-central Utah: Amer. Geophys. Union Trans. 1939, p. 438-452.

Carr, M. S., and C. E. Dutton, 1959, Iron ore resources of the United States including Alaska and Puerto Rico, 1955: U. S. Geol. Survey Bull. 1082-C, p. 61-134.

Chorney, Raymond, 1943, Scheelite and the mineral association at the Reaper mine, Gold Hill, Utah: unpub. M.S. thesis, Univ. of Utah.

Christiansen, F. W., 1952, Structure and stratigraphy of the Canyon Range, central Utah: Geol. Soc. Amer. Bull., v. 63, p. 727.

Christman, R. A., 1951, Petrology of the Swett Hills volcanics, Iron Springs district, Utah: unpub. U. S. Geol. Survey Rept., 105 p.

Coffman, W. E., 1932, A progress report of metals in Utah: unpub. M.S. thesis, Brigham Young Univ.

Cohenour, R. E., 1959, Sheeprock Mountains, Precambrian and Paleozoic stratigraphy, igneous rocks, structure, geomorphology, and economic geology: Utah Geol. and Mineralog. Survey Bull. 63, 201 p.

Cook, E. F., 1957, Geology of the Pine Valley Mountains, Washington County, Utah: Utah Geol. and Mineralog. Survey Bull. 58, 111 p.

———— 1960a, Geologic atlas of Utah, Washington County: Utah Geol. and Mineralog. Survey Bull. 70, 119 p.

———— 1960b, Great Basin ignimbrites, *in* Geology of east central Nevada, p. 134-141: Intermountain Assoc. Petrol. Geol. Guidebook, 11th Ann. Field Conf., 278 p.

Cook, K. L., 1948, Magnetic surveys in the Iron Springs district, Iron County, Utah (abst.): Geophysics, 13, p. 503.

———— 1950, Magnetic surveys in the Iron Springs district, Iron County, Utah: U. S. Bur. Mines, Rept. Inv. 4586, 78 p.

Cook, K. L., and Elwood Hardman, 1967a, Regional survey of the Hurricane fault area and Iron Springs district, Utah, *in* Geol. Soc. Amer. Abst. for 1966: Geol. Soc. Amer. Special Paper 101.

———— 1967b, Regional gravity survey of the Hurricane fault area and Iron Springs district, Utah: Geol. Soc. Amer. Bull. 78, p. 1063-1076.

Crawford, A. L., 1941, Bull Valley iron reserves: Utah Dept. of Publicity and Industrial Dev. Circ. 6.

———— 1942, Strategic minerals of Utah: Univ. of Utah Bull. 18, v. 33 (2), 19 p.

Crawford, A. L., and A. M. Buranek, 1943, Utah iron deposits other than those of Iron and Washington counties, Utah: Utah Geol. and Mineralog. Survey Circ. 24, 17 p.

———— 1944a, The martite deposits at Twin Peaks, Millard County, Utah: Utah Dept. of Publicity and Industrial Dev. Circ. 30.

——— 1944b, The martite iron deposits at Twin Peaks, Millard County, Utah: Utah Acad. Sci. Proc., v. 19-20, p. 139-141.

——— 1945, Tungsten deposits of Mineral Range, Beaver County, Utah: Univ. of Utah Bull., v. 34 (15).

——— 1948, A reconnaissance of the geology and mineral deposits of the Lake Mountains, Utah County, Utah: Utah Dept. of Publicity and Industrial Dev. Circ. 35.

Crawford, A. L., and R. Chorney, 1941a, Iron ore from Iron Peak, east of Paragonah, Utah: Utah Dept. of Publicity and Industrial Dev. Circ. 8.

——— 1941b, Iron ore from Iron Peak, east of Paragonah, Utah: Utah Acad. Sci. Proc., v. 19-20, p. 129-133.

Crittenden, M. D., Jr., J. A. Straczek and R. J. Roberts, 1961, Manganese deposits in the Drum Mountains, Juab and Millard counties, Utah: U. S. Geol. Survey Bull. 1082-H, p. 496-497.

Crittenden, M. D., Jr., and C. A. Wallace, 1967, Mineral resources of the high Uintas primitive area, Utah: U. S. Geol. Survey Bull. 1230-I, 27 p.

Crosby, G. W., 1959, Geology of the south Pavant Range, Millard and Sevier counties, Utah: Brigham Young Univ. Research Studies, Geology series, v. 6 (3).

Dahl, C. L., 1959, Trace ferrides in iron ores from the Iron Springs district, Cedar City, Utah: unpub. M.S. thesis, Univ. of Utah, 62 p.

Dean, R. S., and others, 1934, Studies in direct production of iron and steel from ore: U. S. Bur. Mines, Rept. Inv. 3229, p. 13-15.

Dempsey, W. J., 1951, Preliminary aeromagnetic map of the Iron Springs district, Utah: U. S. Geol. Survey open-file map.

Derick, Nick, and J. P. Riott, 1961, Experimental smelting of Utah and Wyoming iron ores: U. S. Bur. Mines, Rept. Inv. 5817.

Dern, John, 1907a, The mining and mineral resources of Utah: Amer. Min. Cong. Proc., 9th Ann. Sessions, p. 167-177.

——— 1907b, The mining and mineral resources of Utah: Mines and Min., v. 27, p. 250-252.

Dutton, C. E., 1880, Report on the geology of the high plateaus of Utah: U. S. Geog. and Geol. Survey, Rocky Mountain Region, 307 p.

——— 1882, Report on work in the high plateau region: U. S. Geol. Survey 2nd Ann. Rept. 2, p. 5-10.

Dutton, C. E., Jr., and M. S. Carr, 1947, Iron ore deposits of the western United States: U. S. Geol. Survey, Strat. Min. Inv. Prelim. Map 3-212.

Earll, F. N., 1957, Geology of the central Mineral Range, Beaver County, Utah: unpub. Ph.D. dissert., Univ. of Utah.

Eckel, E. C., 1914, Iron ores; their occurrence, valuation, and control: New York, McGraw-Hill Book Co., 430 p.

Einecke, Gustav, 1950, Die Eisenerzvorrate der Welt: Düsseldorf, Verlag Stahleisen, 418 p.

Emmons, W. H., 1940, Iron, Iron Springs, Utah, *in* Principles of economic geology: McGraw-Hill Book Co., New York, p. 269-270.

Englemann, Henry, 1876, Report on the geology of the country between Fort Leavenworth, Kansas Territory and the Sierra Nevada: *in* J. H. Simpson, Report of explorations across the Great Basin of the Territory of Utah in 1859, p. 243-336.

Erickson, M. P., 1966, Igneous complex at Wah Wah Pass, Beaver County, Utah; Utah Geol. and Mineralog. Survey Special Studies 17, 14 p.

Erspamer, E. R., 1964, Magnetic beneficiation of southern Utah iron ores: open-file report, Utah Construction and Mining Company (paper given at Wyoming Mining Assoc. Conv., Jackson Lake Lodge, Moran, Wyo., June).

Everett, A. G., 1967, Petrology and trace element chemistry of the Carmel Formation (Jurassic), Iron Springs district, Utah: unpub. Ph.D. dissert., Univ. of Texas.

Froiseth, B. A. M., 1874, Iron mines of Utah: Utah Min. Gazette 1, p. 189, 196, 205, 209, 221 and 225.

Gardner, E. D., and M. Mosier, 1941, Open-cut metal mining: U. S. Bur. Mines Bull. 433, p. 92-94.

Gilbert, G. K., 1875, Report on the geology of portions of Nevada, Utah, California, and Arizona examined in the years 1871 and 1872: U. S. Geog. and Geol. Survey, West 100th Mer., v. 3 (1), Geology, p. 17-187.

Gilluly, James, 1932, Geology and ore deposits of the Stockton and Fairfield quadrangles, Utah: U. S. Geol. Survey Prof. Paper 173, 171 p.

Granger, A. E., 1963, The iron province of southwestern Utah, *in* Guidebook to the geology of southwestern Utah, p. 146-150: Intermountain Assoc. Petrol. Geol., 12th Ann. Field Conf. Guidebook.

Gregory, H. E., 1950, Geology of eastern Iron County, Utah: Utah Geol. and Mineralog. Survey Bull. 37, 153 p.

Groff, S. L., 1959, Geology of the West Tintic Range: unpub. Ph.D. dissert., Univ. of Utah.

Hansen, G. H., 1941, A brief reconnaissance of the iron deposits of the Wah Wah Range, Iron Peak, Three Peaks, Cove Mountain, and Iron Mountain in southern Utah: Utah Dept. Publicity and Industrial Dev. Circ. 7.

——— 1948, Utah's mineral resources: Utah Acad. Sci. Proc. 25, p. 33-34.

Hardy, C. T., and J. S. Williams, 1953, Guide to the geology of northern Utah and southeastern Idaho: Intermountain Assoc. Petrol. Geol., 4th Ann. Field Conf. Guidebook.

Hayes, C. W., 1909, Iron ores of the United States: U. S. Geol. Survey Bull. 394, p. 70-113.

Head, R. E., 1925, The mineral resources of Utah: Mining and Metallurgy, v. 6(224), p. 389-391.

Hewett, D. R., and others, 1936, Mineral resources of the region around Boulder Dam: U. S. Geol. Survey Bull. 871, 197 p.

Hewett, G. C., 1902, Notes on southwestern Utah and its iron ores: Colo. Sci. Soc. Proc., v. 7, p. 55-66.

Hobbs, S. W., 1945, Tungsten deposits in Beaver County, Utah: U. S. Geol. Survey Bull. 945, p. 81-111.

Howell, E. E., 1875, Report on the geology of portions of California, Nevada, Utah, Colorado, New Mexico, and Arizona, examined in the years 1871, 1872, 1873: U. S. Geog. and Geol. Survey, West 100th Mer., v. 3, pt. 3, Geology, p. 227-301.

Huddle, J. W., and F. T. McCann, 1947, Pre-Tertiary geology of the Duchesne River area, Duchesne and Wasatch counties: U. S. Geol. Survey Oil and Gas Inv. Prelim. Map 75.

Huddle, J. W., W. J. Mapel and F. T. McCann, 1951, Geology of the Moon Lake area, Duchesne County, Utah: U. S. Geol. Survey Oil and Gas Inv. Map OM 115.

Hunt, C. B., 1958, Structural and igneous geology of the La Sal Mountains, Utah: U. S. Geol. Survey Prof. Paper 294-I, p. 305-364.

Huntley, D. B., 1885, The mining industries of Utah: U. S. 10th Census 13, p. 405-489.

Ingerson, Earl, and J. H. Mackin, 1961, Derivation of ore-forming fluids in the Iron Springs district, Utah: *in* Physico-chemical problems in the formation of rocks and ores, p. 138-148, (Korzhinsky Symposium), Inst. for Geol., Petrol., Mineral., and Geochem. for Ore Deposits, Adad. Nauk., U. S. S. R. (Russian).

Jaffe, H. W., and others, 1959, Lead-alpha age determinations of accessory minerals of igneous rocks: U. S. Geol. Survey Bull. 1097-B, p. 65-148.

James, H. L., 1954, Sedimentary facies of iron-formation: Econ. Geol., v. 49, p. 235-293.

Jennings, E. P., 1904, Origin of the magnetic iron-ores of Iron County, Utah: Salt Lake Min. Rev., 6, Apr. 30, p. 16-17.

____________ 1905, Origin of the magnetic iron-ores of Iron County, Utah: Amer. Inst. Min. Met. Eng. Trans., v. 35, p. 338-342.

Jensen, Joseph, 1908, Some salient features of the geology of Newhouse, Utah, and vicinity: unpub. M. S. thesis, Univ. of Utah.

Jones, M. E., 1900a, the geology of Marysvale: Salt Lake Min. Rev., 2, Sept. 15, p. 10-11.

____________ 1900b, Coal fields and iron deposits of Utah: Salt Lake Min. Rev., 2, Dec. 30, p. 23-26.

Julihn, C. E., and L. B. Moon, 1935, Summary of Bureau of Mines exploration projects on deposits of raw material resources for steel production: U. S. Bur. Mines Rept. Inv. 3801.

Juvelin, C. R., 1965, How Utah Construction recoveres iron ore from alluvial deposits: World Mining, August, p. 47-49.

____________ 1967, Recovery of iron from low-grade alluvial deposits: open-file report, Utah Construction and Mining Company.

Juvelin, C. R., and C. K. McArthur, 1967, Mobile magnetic iron ore concentrator: open-file report, Utah Construction and Mining Company (paper given at Pacific Southwest Mineral Industry Conf., Asilomar, Monterey Peninsula, California, May).

Keller, K. F., 1942, Contact metamorphism near Alta, Utah: unpub. M. S. thesis, Univ. of Utah.

Kemp, J. F., 1909, The iron ores of the Iron Springs district in southern Utah: (review) Econ. Geol. v. 4, p. 782-791.

Kildale, M. B., and R. C. Thomas, 1957, Geology of the halloysite deposit at the Dragon mine, *in* Geology of the East Tintic Mountains and ore deposits in the Tintic mining district: Utah Geol. and Mineralog. Survey Guidebook to the geology of Utah, No. 12, p. 94-96.

Kinney, D. M., 1955, Geology of the Uinta River-Brush Creek area, Duchesne and Uintah counties, Utah: U. S. Geol. Survey Bull. 1007, p. 161-162.

Knopf, Adolph, 1933, Pyrometasomatic deposits *in* Ore deposits of the western United States (Lindgren volume): New York, Amer. Inst. Min. Met. Eng., p. 540-541.

____________ 1942, Ore deposition in the pyrometasomatic deposits, *in* Ore deposits as related to structural features: Princeton Univ. Press, p. 63-72.

Larson, G. O., 1953, Where Mormons found a mountain of iron: Desert Magazine, May, p. 11-14.

____________ 1963, Bulwark of the kingdom, Utah's iron and steel industry: Utah Hist. Quart., v. 31, p. 248-261.

Leith, C. K., 1904, Iron ores in southern Utah: U. S. Geol. Survey Bull. 225, p. 229-237.

____________ 1906, Iron ores of the western United States and British Columbia: U. S. Geol. Survey Bull. 285, p. 194-200.

____________ 1910, Iron ores of Iron Springs, Utah, (reply): Econ. Geol. v. 5, p. 188-192.

Leith, C. K., and E. C. Harder, 1908, Iron ores of the Iron Springs district, southern Utah: U. S. Geol. Survey Bull. 338, 102 p.

Lerch, F., 1904, The iron-ore deposits in southern Utah: Iron Trade Review, May 19, p. 49-50.

Lewis, A. E., 1958, Geology and mineralization connected with the intrusion of a quartz monzonite porphyry, Iron Mountain, Iron Springs district, Utah: unpub. Ph.D. Dissert, California Inst. Tech., 75 p.

Lewis, R. S., and Thomas Varley, 1919a, The mineral industry of Utah: Univ. of Utah Bull. 10 (11).

__________ 1919b, The mineral industry of Utah: Utah Eng. Sta. Dept. Met. Research Bull. 12.

Lindgren, Waldemar, 1925, Metasomatism: Geol. Soc. Amer. Bull., v. 36, p. 247-261.

__________ 1933, Pyrometasomatic deposits, Iron Springs, Utah, *in* Mineral deposits: McGraw-Hill Book Co., New York, p. 715.

Lindgren, Waldemar, and G. F. Loughlin, 1919, Geology and ore deposits of the Tintic mining district, Utah: U. S. Geol. Survey Prof. Paper 107, p. 258-265.

Loer, R. F., 1956, Iron ore mining in southwestern Utah: unpub. paper, open-file report U. S. Steel Corporation (paper presented at A. I. M. E. Rocky Mountain Minerals Conf., Salt Lake City, Sept.).

Longwell, C. R., 1940, Structure of the northern Muddy Mountains area, Nevada: Geol. Soc. Amer. Bull., v. 60, p. 923-968.

Lovering, T. G., and E. P. Beroni, 1959, Preliminary study of radioactive limonite in Colorado, Utah, and Wyoming: U. S. Geol. Survey Bull. 1046-N, p. 339-384.

Mabey, D. R., and others, 1964, Aeromagnetic and generalized geologic map of part of north-central Utah: U. S. Geol. Survey Geophys. Inv. Map GP-422.

Mackin, J. H., 1946, Structural control of mineralization in the Iron Springs district, southwestern Utah: (abst.) Geol. Soc. Amer. Bull., v. 57, p. 1255.

__________ 1947a, Joint patterns in the Three Peaks laccolith, Iron Springs district, Utah: (abst.) Geol. Soc. Amer. Bull., v. 58, p. 1255.

__________ 1947b, Some structural features of the intrusions in the Iron Springs district, Utah: Utah Geol. Soc. Guidebook to the geology of Utah, No. 2, 62 p.

__________ 1952a, Hematite veinlets in an ignimbrite in the Iron Springs district, southwestern Utah: (abst.) Geol. Soc. Amer. Bull., v. 63, p. 1337-1338.

__________ 1952b, Correspondence between composition of replacement iron ore and limestone in the Iron Springs district, southwestern Utah: (abst.) Econ. Geol., v. 47, p. 124.

__________ 1954, Geology and iron ore deposits of the Granite Mountain area, Iron County, Utah: U. S. Geol. Survey Min. Inv., Field Studies Map MF 14.

__________ 1955, Exploration for replacement deposits of iron ore in the Iron Springs district, Utah: (abst.) A. I. M. E., Ann. Mtg., Min. Geol. and Geophys. Div., p. 38-39.

__________ 1960, Structural significance of Tertiary volcanic rocks in southwestern Utah: Amer. Jour. Sci., 258, p. 81-131.

__________ 1963, Reconnaissance stratigraphy of the Needles Range Formation in southwestern Utah, *in* Guidebook to the geology of southwestern Utah: Intermountain Assoc. Petrol. Geol., 12th Ann. Field Conf. Guidebook, p. 71-78.

__________ 1968, Iron ore deposits of the Iron Springs district, southwestern Utah: *in* Ore deposits in the United States, 1933-1967, two vols., A. I. M. E., p. 992-1019.

Mackin, J. H., and George Switzer, 1948, Origin of mineralizing emanations in the Iron Springs district, southwestern Utah (abst.): Geol. Soc. Amer. Bull., v. 59, p. 1339.

Mackin, J. H., and W. H. Nelson, 1950, Early Tertiary welded tuffs in the Iron Springs district, Utah: (abst.) Geol. Soc. Amer. Bull., v. 61, p. 1528.

Mackin, J. H., and E. Ingerson, 1960, An hypothesis for the origin of ore-forming fluids: U. S. Geol. Survey Prof. Paper 400-B, p.B1, B2.

Mackin, J. H., and B. McKee, 1962, Gains in SiO_2, Al_2O_3, and MgO in replacement of limestone by iron ore in the Iron Springs district, Utah: (abst.) Geol. Soc. Amer. Special Paper 73, p. 49.

MacVichie, Duncan, 1925, Iron fields of the Iron Springs and Pinto mining districts, Iron County, Utah: (abst.) Min. and Met. 6, p. 441.

__________ 1926, Iron fields of the Iron Springs and Pinto mining districts, Iron County, Utah: Amer. Inst. Min. Eng. Trans., 74, p. 163-173.

Maguire, Don, 1905, Iron ores of Utah: Salt Lake Min. Rev., 6, Mar. 30, p. 21-22.

Marvine, A. R., 1875, Report on the geology of a route from St. George, Utah, to the Gila River, Arizona: U. S. Geog. and Geol. Survey, West 100th Mer., v. 3, Geology, pt. 2, p. 189-225.

Maxey, G. B., 1946, Geology of part of the Pavant Range, Millard County, Utah: Amer. Jour. Sci., 244, p. 324-356.

McArthur, C. K., and R. P. Porath, 1965, Concentrating iron ore in a mobile plant: Min. Cong. Jour., v. 51 (10), p. 28-33.

McGannon, H. C., 1964, Iron ores--Iron Springs district: *in* The making, shaping, and treating of steel, 8th ed., U. S. Steel Corp., p. 168.

Mikami, H. M., 1944, World iron-ore map: Econ. Geol., v. 39 (1), p. 1-24.

Miller, G. M., 1959, The Pre-Tertiary structure and stratigraphy of the southern portion of the Wah Wah Mountains, southwest Utah: unpub. Ph. D. dissert., Univ. of Washington.

__________ 1966, Structure and stratigraphy of the southern part of the Wah Wah Mountains, southwest Utah: Amer. Assoc. Petrol. Geol. Bull., v. 50, p. 858-900.

Newberry, J. S., 1880, The genesis of the ores of iron: Columbia Univ. School of Mines Quart., v. 1, p. 9-12.

__________ 1881a, The genesis of our iron ores: Eng. and Min. Jour., v. 31, p. 286-287, 298-300.

———— 1881b, The iron ores of southern Utah: Amer. Naturalist, v. 15, p. 410-412.

———— 1882, Origin of crystalline iron ores: New York Acad. Sci. Trans., v. 2, p. 13-15.

Nolan, T. B., 1935, The Gold Hill mining district, Utah: U. S. Geol. Survey Prof. Paper 177, 172 p.

O'Carroll, H. J., 1967, The concentration potential of the ores at Iron Mountain, Utah: unpub. Ph. D. dissert., Stanford Univ.

Ochsenius, Carl, 1882, Geologisches und montanistisches aus Utah: Deutsche Geologische Gesellschaft, Zeitschrift 34, p. 288-372.

O'Connor, E. S., 1937, Utah's iron industry: The Utah Mag., v. 2 (11), p. 25, 28.

Palmer, W. R., 1933, Graphic story of pioneer iron works: Iron County Record, Cedar City, Sept. 7.

Park, C. F., Jr., and R. A. MacDiarmid, 1964, Igneous metamorphic deposits, Iron Springs, Utah, *in* Ore deposits, W. H. Freeman and Company, San Francisco, p. 259-266.

Peterson, V. E., 1941, A study of the geology and ore deposits of the Ashbrook silver mining district, Utah: unpub. M. S. thesis, Univ. of Utah.

———— 1942, A study of the geology and ore deposits of the Ashbrook silver mining district, Utah: Econ. Geol., v. 37, p. 466-502.

Powell, J. D., 1875, Exploration of the Colorado River of the West and its tributaries: U. S. Geog. and Geol. Survey, Rocky Mountain Region, 291 p.

———— 1878, Report on the lands of the arid region of the United States with a more detailed account of the lands of Utah: U. S. 45th Cong. 2nd Session House Ex. Doc. 73, 2nd Ed., 1879, 195 p.

Pratt, P. P., 1849, Journal of History, Church of Jesus Christ of Latter-day Saints, Historical Library, Dec. 28-29.

Putnam, B. T., 1880, Iron ore in Utah, *in* Notes on the samples of iron ore collected west of the 100th Meridian: U. S. Bureau of Census, 10th Census of United States, v. 15, p. 486-492. Also see: Appendix I, Mining Industries of Utah, p. 476-477.

Ratte, C. A., 1963, Rock alteration and ore genesis in the Iron Springs-Pinto mining district, Iron County, Utah: unpub. Ph. D. dissert., Univ. of Arizona, 149 p.

Reeves, R. G., 1964, Iron, *in* Mineral and water resources of Utah: Utah Geol. and Mineralog. Survey Bull. 73, p. 89-96.

Richardson, G. B., 1941, Geology and mineral resources of the Randolph quadrangle: U. S. Geol. Survey Bull. 923, 54 p.

Riddle, A. M., and others, 1953, Colorado Fuel and Iron Corp., now a nationwide network of 14 modern industrial plants: Min. Eng., v. 5 (11), p. 1084-1098.

Rigby, J. K., 1958, Geology of the Stansbury Mountains, Tooele County, Utah: Utah Geol. Soc. Guidebook to the geology of Utah, No. 13, p. 126.

Ritzma, H. R., 1959, Geologic atlas of Utah, Daggett County: Utah Geol. and Mineralog. Survey Bull. 66, 107 p.

Rohlfing, D. P., 1923, Iron ore deposits of southern Utah: Eng. and Min. Jour. Press 115, p. 716-719.

Ryan, G. H., 1914, Geology and ore deposits in the Lucin mining district: Salt Lake Min. Rev., 16, Apr. 30, p. 20-22.

Sanford, Samuel, and R. W. Stone, 1914, Useful minerals of the United States: U. S. Geol. Survey Bull. 585, p. 184-188.

Schick, R. B., 1955, Geology of the Morgan-Henefer area, Morgan and Summit counties, Utah: unpub. M. S. thesis, Univ. of Utah.

Schrader, F.C., and others, 1917, Useful minerals of the United States: U. S. Geol. Survey Bull. 624, p. 298-309.

Skillings Mining Review, 1922-1969, David N. Skillings, publisher, 210 Sellwood Bldg., Duluth, Minn., v. 12-58.

Slawson, W. F., 1958, Lead in potassium feldspars from Basin and Range quartz monzonites: unpub. Ph. D. dissert., Univ. of Utah.

Smith, G. O., and others, 1900, Descriptions of the Tintic special district, Utah: U. S. Geol. Survey Geol. Atlas 65, 8 p.

Stokes, H. N., 1901, On pyrite and marcasite: U. S. Geol. Survey Bull. 186, 50 p.

Stringham, B. F., 1942, Mineralization in the West Tintic mining district, Utah: Geol. Soc. Amer. Bull., v. 53, p. 267-290.

———— 1958, Relationship of ore to porphyry in the Basin and Range Province, U. S. A.: Econ. Geol., v. 53, p. 806-822.

Tarr, W. A., 1938, Iron, the deposits near Iron Springs, Utah, *in* Introductory economic geology: McGraw-Hill Book Co., New York, p. 106.

Thomas, H. E., and G. H. Taylor, 1946, Geology and ground-water resources of Cedar City and Parowan valleys, Iron County, Utah: U. S. Geol. Survey Water-Supply Paper 993, 210 p.

Threet, R. L., 1952, Geology of the Red Hills area, Iron County, Utah: unpub. Ph. D. dissert., Univ. of Washington, 107 p.

———— 1963, Geology of the Parowan Gap area, Iron County, Utah, *in* Guidebook to the geology of southwestern Utah: Intermountain Assoc. Petrol. Geol., 12th Ann. Field Conf. Guidebook, p. 136-146.

Tower, G. W., Jr., and G. O. Smith, 1898, Geology and mining industry of the Tintic district, Utah: U. S. Geol. Survey 19th Ann. Rept., pt. 3, p. 601-767.

Warwick, A. W., 1904, The iron ores of the Uinta Mountains: Min. Reporter, 50, p. 166-167.

Wegg, D. S., Jr., 1915, Bingham mining district, Utah: unpub. M. S. thesis, Univ. of Utah.

Wells, F. G., 1937, The origin of the Bull Valley, Utah, iron ore deposits: Econ. Geol., v. 32 (2), p. 192-193.

———— 1938, The origin of the iron ore deposits of the Bull Valley and Iron Springs districts, Utah: Econ. Geol., v. 33 (5), p. 477-507.

———— 1941, Iron ore deposits of the Bull Valley district, Washington County, Utah: U. S. Geol. Survey Prelim. Rept., Press Notice 152284.

Whelan, J. A., 1965, Hydrothermal alteration and mineralization, Staats mine and Blawn Mountain areas, central Wah Wah Range, Beaver County, Utah: Utah Geol. and Mineralog. Survey Special Studies 12, 31 p.

Wile, W. H., Jr., 1905, The Escalante Desert: Irrigation Age, v. 21 (1), p. 17-20.

Williams, P. L., 1960, A stained slice method for rapid determination of phenocryst composition of volcanic rocks: Amer. Jour. Sci., v. 258, p. 148-152.

Wilson, S. R., 1943, Mineral Point iron mine, Cache County, Utah: U. S. Bur. Mines open-file report.

———— 1960, Iron deposits of Utah: U. S. Bur. Mines open-file report.

Young, W. E., 1947, Iron deposits, Iron County, Utah: U. S. Bur. Mines Rept. Inv. 4076, 102 p.

Young, W. E., and H. R. Thurber, 1950, Tecoma lead-zinc mine, Box Elder County, Utah, and Elko County, Nevada: U. S. Bur. Mines open-file report.

Zoldock, S. W., and S. R. Wilson, 1953, Bull Valley iron ore deposits, Washington County, Utah: U. S. Bur. Mines Rept. Inv. 4948, 17 p.

EXPLANATION

CENOZOIC

Quaternary

- Qal — Superficial Deposits

Tertiary

- Tr — Rencher and Page Ranch Formations
- Iron Deposits (diagrammatic) Veins and Replacement Bodies
- Ti — Quartz Monzonite Porphyry Intrusions
- Tq — Quichapa Formations
- Tin — Needles Ranch and Isom Formations
- Tc — Claron Formation

MESOZIOC

Cretaceous

- Kis — Iron Springs Formation

Jurassic Cretaceous?

- JKm — Marshall Creek Breccia

Jurassic

- Je — Entrada Formation
- Jc — Carmel Formation

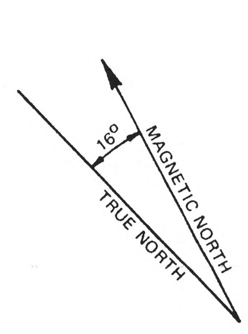
SYMBOLS

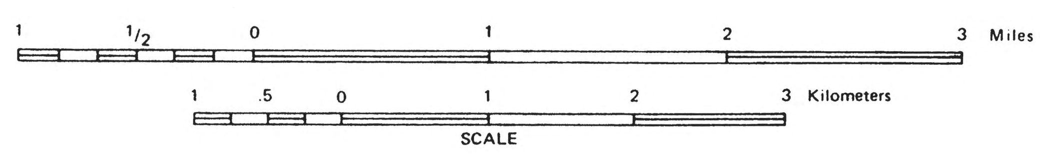
Fault
Dashed where approximately located, dotted where concealed.

Contact

Strike and Dip of Beds

- 25 Normal
- 70 Overturned
- 90 Vertical





Base map from USGS 7.5 minute topographic series: Page Ranch 1950, Stoddard Mountain 1950, Silver Peak 1950, Desert Mound 1950, Cedar City NW 1949 and The Three Peaks 1950; 1:24,000.

Geology adapted and modified from Mackin (1947, 1954, 1967).

Map drafted by R. Howard and J. Dean

GEOLOGY AND IRON ORE DEPOSITS OF THE IRON SPRINGS DISTRICT, IRON COUNTY, UTAH

PUBLISHED AND SOLD BY THE
UTAH GEOLOGICAL AND MINERALOGICAL SURVEY
W. P. HEWITT, DIRECTOR
103 UTAH GEOLOGICAL SURVEY BUILDING
UNIVERSITY OF UTAH
SALT LAKE CITY, UTAH, 84112