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PART A

Iron-Ore Deposits in the Eastern Part of the Eagle Mountains Riverside County, California

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IRON ORE DEPOSITS IN THE EASTERN PART OF THE EAGLE MOUNTAINS, RIVERSIDE COUNTY, CALIFORNIA *

By Jarvis B. Hadley * *

United States Department of the Interior, Geological Survey and Bureau of Mines (Project 902)

OUTLINE OF REPORT

ABSTRACT

In 1941-42 iron-ore deposits in the northeast part of the Eagle Mountains, Riverside County, California, were examined and mapped in detail by the Geological Survey and explored by the Bureau of Mines, both of the United States Department of the Interior, as part of a general investigation of raw material resources for western steel production.

The iron ore is associated with dolomite, quartzite, and lime-silicate rocks of igneous-metamorphic origin, which have been invaded by quartz monzonite. Two beds, one 80 feet thick, the other 30 to 300 feet thick, are ore-bearing for more than 8,000 feet along their strike. The stratified rocks dip 20° to 60° and are broken by normal faults.

Magnetite and hard red hematite mixed with various amounts of tremolite, serpentine, talc, and micas constitute the ore. Its specific gravity ranges from 3.5 for granular ore estimated to contain 50 percent iron oxide to 4.5 for massive hematite and to nearly 5.0 for magnetite. Pyrite is widely disseminated in fresh ore in the lower part of the deposits, where it averages about 3 percent, equivalent to 1.5 percent sulfur. It has generally been removed by oxidation within 150 or 250 feet of the surface. One-half to three percent gypsum, equivalent to 0.1 to 0.6 percent sulfur, is generally found in ore in the oxidized zone.

The iron content of the ore ranges from 30 percent to 65 percent. The average ore contains 50 percent iron, 11 percent silica, 5 percent magnesia, 2.5 percent lime, 2.5 percent alumina, and 0.085 percent phosphorus. Sulfur generally averages less than 0.2 percent in oxidized ore (0.4 percent in one deposit) and 1.5 percent in fresh ore. Phosphorus, presumably in apatite, is associated with gangue minerals rather than with ore minerals.

Five major orebodies containing 2 to 16 million tons each and one smaller body have been sampled by trenching and diamond drilling. They are 600 to 1500 feet long, 70 to 300 feet thick, and extend 200 to 750 feet down dip. Measurable ore in these bodies totals 28 million long tons containing more than 30 percent iron, with an average grade of 50 percent iron and 0.4 percent sulfur. In addition about 15 million tons of inferred ore estimated to contain 45 to 55 percent iron is believed to exist in smaller or less accessible bodies within the area investigated.

About 75 percent, or 20 million tons, of the measurable ore could probably be mined from surface pits, and about 30 percent of this amount, or 7 million tons, is estimated to be shipping ore containing more than 50 percent iron and less than 0.2 percent sulfur.

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INTRODUCTION

Iron-ore deposits in a district 6 miles long and 1½ to 2 miles wide in the northeast part of the Eagle Mountains, Riverside County, California, were described by E. C. Harder (12). The deposits are covered by more than 100 patented claims, most of which are now held by the Southern Pacific Company of San Francisco and the remainder by the Iron Queen Mining Company of Los Angeles. The present geologic investigation of a part of this district was conducted in the fall of 1941 and the spring of 1942 by the Geological Survey, United States Department of the Interior, in cooperation with an extensive program of trenching and diamond drilling by the Bureau of Mines of the Department of the Interior, as part of an investigation of raw material resources for the production of iron and steel in the Western States. (Bureau of Mines Project No. 902.)

The area investigated covers 1½ miles by half a mile at the east end of the iron-ore district, in secs. 34, 35, and 36, T. 3 S., R. 14 E., San Bernardino base and meridian (see fig. 2). The area is 15 miles by paved road from Desert Center, California, a town on U. S. Highway No. 70. The nearest railroad points are Mecca, California, 43 miles distant, on the Union Pacific Railroad, and Rice, California, 52 miles distant, on the Santa Fe Railroad. Blythe and Indio, the nearest sources of most supplies, are each about 60 miles by paved roads from the deposits. The Colorado River aqueduct of the Metropolitan Water District of Southern California passes within 2 miles of the deposits, and the settlement and pump-lift station of Eagle Mountain are 5 miles away.

No commercial production of iron ore has been made from the district, although several hundred prospect shafts and adits have been dug. Gold was formerly mined at the Iron Chief mine in the western part, and lead and zinc were mined at the Black Eagle, or Scott mine, which was abandoned in 1941.

Robert T. Littleton of the Geological Survey, United States Department of the Interior, ably assisted throughout the field work. The writer also wishes to acknowledge with thanks the hospitality of the staff of the Metropolitan Water District at Eagle Mountain, and the cooperation of W. D. McMillan and F. A. Rutledge, engineers in charge for the Bureau of Mines, Interior Department. All assay data used in this report were furnished by the Bureau of Mines.

GEOLOGY

The iron-ore deposits are in contact-metamorphosed sedimentary rocks which have been folded, faulted, invaded by irregular, sill-like bodies of quartz monzonite, and cut by dikes of fine-grained igneous rocks. These rocks are summarized in Table 1 and their distribution is shown on Plate I.

Rocks

Vitreous quartzite and feldspathic quartzite constitute the "vitreous quartzite series" of Harder (12, pp. 30-35). Vitreous quartzite is among the most resistant rocks in the region and forms bluffs of brownish white outcrops. Its maximum exposed thickness is 150 feet, although the base is generally cut out by quartz monzonite. Schistose, feldspathic quartzite is one of the least resistant rocks and forms smooth slopes and

Table 1—Rock units in the eastern part of the Eagle Mountains iron district.

Rock units in order of age	*Lithology*	*Approximate thickness, feet*
Slope wash and alluvium	Coarse sand and gravel, commonly cemented by caliche. Locally contains abundant boulders of iron ore.	0 to 100+
Dike rocks	Syenite porphyry, diabase, granite.	
Quartz monzonite	Coarse-grained and porphyritic quartz monzonite with biotite and hornblende.	
Conglomerate	Metamorphosed limestone conglomerate.	400+
Lime-silicate rocks	Contact-metamorphic rocks composed of mica, actinolite, diopside, feldspar, and quartz.	100
Upper ore bed	Iron ore with lenses composed dominantly of lime-magnesia silicates.	30 to 300
Quartzite	White to dark-gray glassy quartzite; sporadic bodies of iron ore.	200 to 300
Lower ore bed	Iron ore with lenses composed dominantly of lime-magnesia silicates.	40 to 140
Feldspathic quartzite	Coarse- to fine-grained feldspathic quartzite and schist.	50 to 150
Vitreous quartzite	Pure, coarsely recrystallized quartzite.	150+
	Total average thickness of metamorphic rocks	1250

saddles. It is most easily recognized by its tendency to break parallel to bedding into small angular slabs, and by red, yellow, and gray colors in some weathered outcrops. Beds of relatively pure quartzite several feet thick appear locally within the schistose quartzite, and a zone of mica schist or pale-green quartz-feldspar rock a few tens of feet thick commonly lies at the top.

The lower ore bed conformably overlies the feldspathic quartzite and consists of iron ore and related lime-silicate rocks, although to the west it passes into coarsely crystalline dolomite with sporadic iron ore. The ore bed is 50 to 90 feet thick in the eastern part of the area and is as much as 140 feet thick in the western part. The variation in thickness is due in part to interfingering with the overlying beds, a feature especially noticeable northwest of Briest Hill.

The rock immediately above the lower ore bed is dominantly quartzite, which contains more quartz and is less schistose than the feldspathic quartzite and finer-grained than the vitreous quartzite. On Briest Hill the lower part of the quartzite that overlies the lower ore bed is dark gray and distinctively banded with closely-spaced discontinuous layers a half inch or less wide containing disseminated iron oxides and lime-silicate minerals. The upper part is generally white, has a sugary texture, and is closely fractured. West of Bald Eagle Canyon, the quartzite is more massive than elsewhere and much of it resembles the vitreous quartzite. It also contains much light-colored granite and dioritic rock in irregular bodies which have obscure boundaries. Similar vitreous quartzite beds and granitic bodies occur near the top of the quartzite on North Hill. Lenses rich in diopside or tremolite are present locally in the quartzite, and several small bodies of iron ore occur in it.

The upper ore bed, like the lower one, is composed of iron ore and silicates and passes westward into dolomite. The base of the ore bed is commonly marked by a zone 10 or more feet wide consisting of serpentine and tremolite, or alternating layers of iron ore and greenish feldspathic quartzite.

Stratigraphically above the upper ore bed in the vicinity of North Hill are well-bedded rocks composed of quartz, feldspar, mica, actinolite, and diopside in various proportions. They are so severely folded that an accurate determination of thickness is not possible.

Metamorphosed conglomerate composed of quartz, feldspar, tremolite, and diopside forms the upper parts of the hills north of the orebodies and is the highest known stratigraphic unit, although it is everywhere separated from the lower beds by quartz monzonite.

The metamorphic rocks are cut by quartz monzonite and associated aplite, granite, syenite, and diorite, to which the metamorphism and mineralization are probably related. Coarse-grained and commonly porphyritic quartz monzonite forms interconnected elongate bodies ranging from 100 to more than 1,000 feet in width and from half a mile to several miles in length. At the margins of these bodies many smaller sills and tongues have penetrated the metamorphosed rocks and contain many inclusions of them. The quartz monzonite is partly in contact with ore, but is more commonly separated from it by an irregular zone of lime-silicate rocks. The marginal part of the quartz monzonite commonly differs considerably from the normal rock; such marginal rocks, as seen at the surface and in drill cores, are recognized by coarseness of grain and absence of dark minerals and quartz, or by abundance of biotite or hornblende or both, with or without quartz.

A fine-grained pale-green rock marked by small feldspar phenocrysts and identified in the field as syenite, appears in dikes 1 to 50 feet wide, which are especially abundant in the eastern part of the upper ore bed. One such dike extends more than 3,000 feet from east to west and was found in drill holes as much as 450 feet below the surface. The dikes follow two sets of fractures, one at considerable angles to the bedding and the other nearly parallel to it, giving the dikes irregular and disjointed shapes. The dikes are not mineralized, but locally contain inclusions of ore. Other dikes, largely confined to the Bald Eagle deposits, are dark greenish-gray diabase and are 1 to 20 feet wide. They commonly lie along southwest-dipping faults and are younger than the ore.

Structure

The stratified rocks are on the north limb of a broad anticline which trends west-northwest. They have been further deformed by local folding so that at some places their strike departs widely from the regional trend. The dip generally ranges from 20° N. to nearly vertical but near the quartz monzonite on North Hill the well-bedded rocks above the upper ore bed have been compressed into a series of small folds a few feet across, so that reverse (southward) dips are common. On the west end of North Hill, the upper ore bed is involved in a syncline which plunges 35° to 45° NE. Quartz monzonite, in the trough of this syncline, has deeply embayed the ore bed. (See section B-B′, on Pl. II.)

High-angle normal faults with vertical separations which range from a few feet to more than 300 feet displace the ore beds at many places. They trend north to northwest and dip generally southwestward, though a few are vertical or dip steeply to the east.

Although the larger quartz monzonite bodies follow the strike of the stratified rocks for several miles to the west of the area, they cut across the beds in many places and are believed to be more or less discordant downward. Drilling in the upper ore bed on North Hill has shown that the quartz monzonite that limits the bed on the north has a steep cross-cutting contact with many offshoots into the bed and the adjacent metamorphic rocks. (See section A-A′, Pl. II.)

ORE DEPOSITS

Origin of the Ore

The great quantity of iron in these deposits is believed to have resulted from the action of the quartz-monzonite magma on calcareous beds in the invaded rocks. The stages in the metamorphism and associated deposition of iron oxides can be indicated here only generally and tentatively pending further mineralogical and chemical study. An earlier thermal phase of metamorphism seems to have formed diopside, actinolite, grossularite, wollastonite, scapolite, and labradorite in impure calcareous rocks containing sufficient silica and alumina, but did not materially change the purer dolomite beds. In a somewhat later hydrothermal phase dolomite was extensively altered, first to tremolite, then to serpentine. Magnetite and pyrite were deposited along with these minerals, not only in the dolomite beds, but also in veins in the adjacent quartzite. Elsewhere the quartzose and feldspathic rocks were sericitized. Sometime after the magnetite was deposited, much of it was altered to pseudomorphous hematite, but it is not known to what extent this alteration resulted from supergene processes.

The possibility has been considered that the magnetite was formed by metamorphism of beds of sedimentary iron. This is believed to be not true for the following reasons: (1) no evidence of iron-bearing beds of sedimentary origin is found in the unaltered dolomite or in other beds of the metamorphosed sediments; (2) the magnetite bodies generally do not occur as beds in the dolomite, nor is stratification well preserved in the iron deposits; (3) metamorphism of iron deposits known to be of sedimentary origin tends to produce hematite rather than magnetite; all of the hematite seen in the Eagle Mountains deposits is pseudomorphous after magnetite or pyrite; (4) the constant association of pyrite with the ore suggests a hypogene origin for the iron.

Character and Grade of Ore

The highest-grade ore is hematite or magnetite with less than 5 percent impurities and contains as much as 65 percent iron. The hematite is generally more abundant than the magnetite but a large part of the ore contains both. Bodies composed wholly or largely of magnetite are lenticular and have a maximum known width of about 40 feet. Their downward extent is illustrated by figure 4. The magnetite occurs in tightly interlocking grains one-fourth inch or less across and at some places has moderate polarity. The hematite is red, hard, and dense. It has resulted from alteration of magnetite and generally contains pseudomorphs and unreplaced remnants of magnetite. The hard hematite ore has a specific gravity of about 4.5, which with increasing amounts of magnetite, approaches 5.0.

Some of the ore is a mixture of granular hematite or magnetite with tremolite, serpentine, talc, mica or chlorite, in which the proportion of gangue ranges from 5 to 50 percent. The size of the mineral grains ranges from 0.1 millimeter to 2 millimeters, and averages somewhat less than 1 millimeter. Other ore contains gangue minerals in irregular bunches with dimensions ranging from a few inches to a foot. Part of the ore is tremolite and serpentine with minor amounts of irregularly disseminated magnetite or less commonly hematite. The iron content of this ore is generally less than 40 percent; the specific gravity ranges between 3.0 and 3.5.

Veins of silicified magnesite or sepiolite, a few inches to 2 feet wide, commonly follow the bedding and fracture planes in the ore. Seams of oxidized copper minerals are similarly distributed at several places, and suggest the presence of chalcopyrite in the fresh ore.

Bedding has generally been obliterated in the ore deposits, except near the base of the ore beds, but locally bands of granular ore in more massive ore indicate original bedding; large lenses of lime silicates also tend to lie parallel to the bedding in the better ore. At some places ore appears to follow fractures at considerable angles to the bedding.

The ore is jointed and tends to break into irregular blocks ranging from an inch to 3 feet across. There is little tendency for the ore to break in any consistent direction, except at the base of the beds, where it tends to break parallel to the bedding. Much of the ore is cavernous; open spaces several feet long were found in tunnels in the upper ore bed.

Pyrite, the only sulfide observed in the ore, is present chiefly in fresh ore in the lower parts of the deposits. It is unevenly distributed and may amount to as much as 10 percent in a few samples. Exploration has not been sufficient to determine the shape or extent of individual pyritiferous bodies, but the average amount of pyrite in fresh pyritiferous ore ranges from about 3 to 4 percent, equivalent to 1.5 or 2 percent of sulfur. Pyrite occurs in irregular grains 5 millimeters to less than 0.1 millimeter across, in thin tablets 0.5 millimeter by 5 millimeters or less, and in veinlets less than 0.5 millimeter wide and as much as several centimeters long.

According to Bureau of Mines assays, average ore above a 30 percent cut-off contains 50 percent iron, 11 percent silica, 5 percent magnesia, 2.5 percent lime, 2.5 percent alumina, 0.085 percent phosphorus, and 0.4 percent sulfur. Average amounts of silica, magnesia, and lime as determined in composite sludge samples, each representing 40 to 80 feet of drill hole, are shown plotted against iron content in figure 5. Alumina, determined in relatively few samples, ranges between 2.0 and 3.5 percent. The curves for silica, magnesia, and lime are nearly parallel in the range below 50 percent iron and represent approximately the same proportion of these oxides that is found in tremolite. The tendency for the CaO curve to become level at about 2 percent in ore containing 50 percent or more iron is probably due to the presence of gypsum and calcium carbonate.

The amount of phosphorus determined from composite sludge samples ranges from 0.02 percent to 0.20 percent with the exception of two samples with 0.26 and 0.46 percent; equivalent core assays of phosphorus were not made. Assays made for phosphorus on cores from drill holes 1 and 2 (sludges not sampled) yielded an average of about 0.1 percent; but individual 4-foot samples carried as high as 1.1 percent. Phosphorus appears to be associated more abundantly with the gangue minerals than with the iron oxides, for cores low in iron are proportionally high in phosphorus. Sink-and-float tests made by the Bureau of Mines verify this conclusion. Phosphorus is more abundant in the North orebody than elsewhere, probably because of the proximity of the quartz monzonite.

Other minor substances in the ore, determined from composite sludge samples, include 0.7 percent manganese, 0.12 percent titanium dioxide, TiO_2, 0.10 percent copper, and traces of arsenic, chromium, and nickel. Assays for TiO_2 were obtained from only two sludge samples from the South orebody and the amount is probably higher in the North orebody, because of the proximity of igneous rocks containing considerable sphene.

Changes Due to Oxidation and Weathering

Pyrite has been largely removed by oxidation at most places within 200 feet of the surface, and locally to greater depths, although pyrite was encountered in the oxidized zone in several drill holes and at one place on the surface.

The gangue in the oxidized ore is generally altered to soft, claylike minerals; thus, oxidized granular ore is soft, crumbly, and stained with limonite. At the surface such soft ore may be hardened again by deposition of opaline silica.

Gypsum is irregularly distributed but generally present in the oxidized zone and extends to the lowest depth explored. It fills seams ranging from one-fiftieth of an inch to 1 inch in width, lines cavities, and is disseminated in the ore. The average amount in the oxidized zone varies with different orebodies and ranges from less than 0.5 percent to 3 percent, equivalent to 0.1 to 0.6 percent sulfur.

Abnormally large amounts of gypsum, concentrated in bodies of decomposed gangue minerals, were encountered in some of the trenches. This gypsiferous soil fills cracks in the ore as much as 10 feet below the surface and contaminates the ore with much sulfur. Samples from these trenches contain as much as 5 percent sulfur, equivalent to 26 percent of gypsum.

Figure 6 illustrates changes, with increasing depth, in the iron and sulfur content of ore above 40 percent iron. Ore at or near the surface has been enriched by as much as 5 percent iron as a result of removal of pyrite and leaching of gangue minerals. The sulfur content also abruptly increases at about 250 feet depth, as the deeper holes are chiefly in the unoxidized zone.

Orebodies

Six orebodies were sampled by trenching and drilling. These are the North deposit, the South deposit, which includes three distinct bodies separated by faults, and the Bald Eagle deposit in which two orebodies are separated by a fault. Two-thirds of the ore in the area is in these bodies. Several other bodies, mapped but not sampled, are parts of the upper and lower ore beds which are separated from the principal deposits by faults or by intervening areas of essentially barren material.

North Deposit. The North deposit has been trenched and drilled over a strike-length of 1400 feet. (See Pl. II.) In this distance the orebody is 200 to 300 feet thick and extends down dip more than 350 feet at the west end and more than 500 feet at the east end. It is probably cut off by quartz monzonite 400 to 850 feet down dip from the outcrop. (See section A-A′, Pl. II.)

The footwall is fairly uniform, though somewhat warped so that its dip ranges from 30° to 65° N. The hanging wall on the contrary is much complicated by folding and by tongues of quartz monzonite partly enveloped by haloes of lime-silicate rock. A mass of such tongues forms a considerable embayment in the hanging wall in the vicinity of trench C, and in successive sections eastward from trench C the upper part of this embayment appears in drill holes at lower levels as far as trench A. West of trench C the embayment appears to occupy a synclinal trough in the upper part of the ore bed almost as far as trench D. The hanging wall is further complicated, in the west end of the orebody, by tongues of ore projecting into the overlying lime-silicate rocks.

Lenses of gangue, some of them 30 to 40 feet wide and 200 to 300 feet long, occupy a considerable part of the ore bed. (See Pl. II.) The amount of these lenses in different explored sections of the orebody ranges from less than 10 percent in a section along trench D to 40 percent along trench C, the proportion increasing generally down dip and toward the ends of the orebody. The larger lenses could probably be avoided in mining, but it might be difficult to segregate many of the smaller ones. The amount of the smaller lenses in the drilled part of the North deposit is believed to be about 1,000,000 tons.

No key beds were found in the North deposit that would permit correlation from hole to hole or from section to section. The internal structure of the ore was interpreted from the attitude of the base of the ore bed as determined by drilling, from meager observations of poorly preserved bedding at the surface, and on the basis of the lithologic character of the cores modified by assay data. This tends to exaggerate somewhat the continuity of low-grade bodies, but it is the best that could be done under the circumstances.

In the North deposit, the zone of oxidation extends to an average depth of about 200 feet, but tongues of oxidized ore are found at lower levels and pyrite is found locally at higher levels. About 65 percent of the orebody is believed to lie within the oxidized zone. Six or eight percent of the ore in the oxidized zone is estimated to be pyritiferous, and the average sulfur content of all ore in the zone is about 0.4 percent. The distribution of sulfur and pyrite in the oxidized and unoxidized zones is illustrated by figure 8.

South Deposit. The South deposit (Pl. II) has been explored over a strike-length of 2,200 feet. The ore bed is 25 to 90 feet thick and extends in places at least 650 feet down dip from the outcrop. The bed dips northward or northeastward 25° to 30° in the western part and northward 40° to 50° in the eastern part. About 10 percent of the explored part of the deposit consists of lenses of lime-silicate rock and serpentine.

At the east end of the South deposit, the lower ore bed is buried under 70 feet of alluvium. For 500 feet west of the explored area the ore bed, which is 70 to 100 feet thick, is poorly exposed and contains a large proportion of low-grade or barren material. The downward limit of the ore bed in the South deposit is not known. The bed is 40 to 80 feet thick in the lowest drill holes and lies 210 feet stratigraphically below the base of the upper ore bed at the south end of trench A (Pl. II). The bed probably extends several hundred feet below the drill holes, and possibly 1,000 feet if it is cut off by the same body of quartz monzonite that forms the lower limit of the North deposit.

About 90 percent of the measurable ore in the South deposit lies in the oxidized zone and is essentially free from sulfides. Sulfur in this ore averages 0.13 percent. Pyrite appears only in the lower parts of the deposit, more than 100 feet below the surface and the sulfur content of the unoxidized ore is about 1.4 percent.

The South deposit is broken by two faults into three separate orebodies. The western orebody, about 600 feet by 800 feet, 70 feet thick, contains half of the measurable ore in the deposit. About two-fifths of this ore is covered by quartzite with an average thickness of 70 feet and a maximum thickness of 100 feet. The eastern block contains about 40 percent of the deposit in a tabular body about 1200 by 300 by 60 feet, most of which is covered by 100 feet or more of quartzite and alluvium. The central block, containing less than 10 percent of the deposit, is a wedge-shaped body about 450 by 200 by 60 feet exposed on a dip slope and is partly covered by a remnant of quartzite not more than 10 feet thick.

Bald Eagle Deposit. The Bald Eagle deposit (Pl. III) occupies the same stratigraphic position as the South deposit. It consists of two principal orebodies and several smaller bodies, separated from each other by high-angle faults. The principal fault trends northwest, midway through the deposit, dips 85° SW., and has a maximum throw of about 300 feet.

The ore bed has been explored for 600 feet northwest of this fault, and 1,000 feet to the southeast. The western part is 80 to 140 feet thick and extends down dip at least 600 feet. The well-defined footwall dips about 35° near the surface but steepens down dip to 55°. The hanging wall is irregular and the quartzite in it is erratically folded. One aspect of this irregularity is seen in the prong of ore that extends into the overlying quartzite between trench V and trench W where the ore seems to have followed a set of fractures trending northeast. The ore bed itself has apparently been displaced along similar fractures near the east end of trench U.

The eastern block extends at least 150 to 250 feet down dip. The thickness decreases downward and eastward from 80 to 45 feet, and the average dip decreases eastward from 55° to 40°. At a depth of 170 feet, the eastern block is cut in the vicinity of trenches R and S by diabase dikes and small bodies of diorite, most of which are not exposed at the surface.

Lenses of low-grade or barren rock are erratically distributed, principally in the western block, where they amount to about 15 percent of the orebody. Pyrite is present only in the deeper parts of the western block, most of it more than 200 feet below the surface. About 80 percent of the measurable ore in the deposit is believed to lie in the oxidized zone, and to contain 0.08 percent sulfur. Ore below the oxidized zone contains about 1.5 percent sulfur.

East of the explored area, the ore bed is deeply covered by alluvium; to the west, both grade and accessibility of the ore bed diminish. The downward limit of the ore bed in the Bald Eagle area is not known. The deepest drill holes everywhere indicate a markedly

Table 2—Iron-ore reserves, east end, Eagle Mountains district

Based on sample data obtained by U. S. Bureau of Mines

MEASURABLE ORE

	Maximum depth inferred, in feet		Ore containing								Total ore having an Fe content of 30 percent and over							
			30 percent or less Fe		30 to 40 percent Fe		40 to 50 percent Fe		Over 50 percent Fe			Fe	S	P[1]	SiO_2[1]	MgO[1]	CaO[1]	Al_2O_3[1]
	Below surface	Down dip	Millions of long tons	Average percent Fe	Millions of long tons	Average percent Fe	Millions of long tons	Average percent Fe	Millions of long tons	Average percent Fe	Millions of long tons	Average percent						
North deposit	600	600	2.0	23	2.0	34	7.0	46	7.0	56	16	49	[4]0.7	0.124	12.3	4.5	2.5	------
South deposit	300	750	0.1	22	0.5	36	1.6	45	4.8	55	6.9	51	[5]0.20	0.027	11.0	4.5	2.1	2.8
Bald Eagle deposit	450	650	0.1	16	0.2	36	1.6	45	3.3	55	5.1	51	[6]0.36	0.056	12.0	5.8	2.7	2.6
Total measurable ore	600	750	2.2	23	2.7	35	10.2	46	15.1	55	28.0	50	0.40	0.085	[2]12.	[2]4.8	[2]2.5	------

INFERRED ORE[3]

	Below surface	Down dip									Millions of long tons	Fe	S
Class A:													
West extension, North deposit	150	150									1.0	52	0.15
East extension, North deposit	300	200									2.5	50	0.20
Bald Eagle deposit	100	100									0.5	52	0.10
Total Class A ore											4.0	51	0.2

Class B:						
West extension, South deposit	550	400		2.0	45-50	0.5
West extension, Bald Eagle deposit	350	250		1.5	45-55	0.5
East side Bald Eagle Canyon	250	250		0.5	50-55	0.3
Total Class B ore				4.0	47	0.5
Class C:						
North deposit	750	850		2	45	1.5
South deposit	400	1000		3	45-50	1.5
Bald Eagle deposit	650	1000		2	45-50	1.5
Total Class C ore				7	45-50	1.5
Total inferred ore				15	45-50	
Total reserves				43	49	

1 From assays of composite sludge samples.
2 Assays from one hole only.
3 Grades of iron and sulfur estimated.
4 11,000,000 tons oxidized, 0.4 percent S; 5,000,000 tons unoxidized 1.3 percent S.
5 6,500,000 tons oxidized, 0.13 percent S; 400,000 tons unoxidized 1.1 percent S.
6 4,000,000 tons oxidized, 0.08 percent S; 1,000,000 tons unoxidized 1.5 percent S.

reduced thickness of the ore bed, or an increase in the amount of waste material in it. The nearest quartz-monzonite outcrops in the direction of the dip are 1,000 feet distant; thus the bed may extend several hundred feet below drill holes.

RESERVES

About 43 million long tons of iron ore, containing 30 percent or more of iron, are estimated to be present in the area investigated. Of this 28 million tons contain more than 30 percent of iron in sampled bodies and can be said to be measurable ore; the rest, amounting to 15 million tons, is inferred ore in bodies of various sizes and degrees of accessibility.

Measurable ore is largely within blocks bounded by trenches and drill holes. At some places, ore that extends 20 to 100 feet beyond trenches and drill holes is included where geologic factors indicate there is a small margin of error relative to the accuracy of sampling within the explored blocks. Inferred ore includes ore below drill holes and ore that has not been sampled either by trenching or drilling. It has been divided into three classes depending upon accessibility and the extent of information available:

Class A—Well-exposed with good geologic control; grade judged to be similar to measurable ore but margin of error greater, principally because of lack of precise information as to downward extent.

Class B—Poorly exposed and geologic information less complete than for class A; over-all grade probably less than for measurable ore.

Class C—Below explored orebodies; estimates of grade and quantity subject to considerable error.

Classification of ore according to iron content was made as follows: assays from trenches and drill holes were divided into sections 15 or more feet long, each considered to represent a minable unit with an average iron content falling within one of four classes: below 30 percent, 30 to 40 percent, 40 to 50 percent, and above 50 percent. A very small part of the reserves contain more than 60 percent iron. Most of the assays in each unit fall within the appropriate grade limits, but the iron content of the ore is so variable that some individual assays of 5-foot samples are lower or higher than the average of the unit by as much as 15 percent. The proportions of the different classes of ore as represented in drill holes and trenches were computed by sections in each orebody, the sections then weighted according to their areas and combined to give the grade-percent curves shown in figure 7. The total tonnage of measurable ore in the North, South, and Bald Eagle deposits was calculated separately, at 8.5 cubic feet per long ton. Tonnages of classified ore (table 2) represent the total tonnage multiplied by the proportions of different classes of ore for each orebody.

The amount of sulfur in the measurable ore in the oxidized and unoxidized zones was calculated statistically for each orebody, and the overall averages as computed were increased slightly in some instances to allow for the inclusion of unoxidized, high-sulfur ore below drill holes.

Owing to the widely spaced sampling and the difficulty of making adequate correlations between sections, the accuracy with which ore can be classified according to blocks does not seem to support much refinement of reserve figures. It also appears unlikely that accurate detailed correlations between sulfur and iron content can be made at this stage of exploration.

About 30 percent of the reserves of measurable ore of all grades is estimated to contain more than 50 percent iron and less than 0.2 percent sulfur and thus could be shipped directly to blast furnaces without beneficiation. About half of this shipping ore is in the South deposit, as shown in table 3.

Table 3—Estimated proportions of direct shipping ore and mill ore

Deposit	*Direct-shipping ore*		*Mill ore*	
	Millions of long tons	*Percent of deposit*	*Millions of long tons*	*Percent of deposit*
North deposit	2.5	15	13.5	85
South deposit	4.2	65	2.5	35
Bald Eagle deposit	2.0	40	3.0	60
Totals	8.7	31	19.0	69

Mill ore as estimated in the above table would have to be treated to remove sulfur, or to increase the iron content, or both. Sink-and-float tests conducted by the metallurgical division of the Bureau of Mines, United States Department of the Interior, on oxidized middle-grade ore from the Eagle Mountains produced an efficient concentration of iron and a marked reduction in sulfur and phosphorous content.

Should mining be done in open pits with walls becoming ultimately as steep as 45 degrees, it is estimated that about 30 percent of measurable reserves, or about 8 million tons, could be mined without removal of any overburden, and about 75 percent, or 20 million tons, could be mined before the ratio of overburden to ore reached 2 to 1. Under the same assumptions, 3 to 4 million tons of inferred ore might be mined from open pits.

Reserve figures obtained by the Bureau of Mines, United States Department of the Interior, agree on the whole with those given in table 2. Bureau estimates as of July 1, 1942, give 21.6 million tons of ore above drill holes and between trenches, and 13 million tons of "geologic" (inferred) ore as compared with 28 million tons of measurable ore and 15 million tons of inferred ore in this report. The chief points of difference are explained as follows:

(1) Bureau estimates of ore indicated by trenching and drilling exclude 2.7 million tons of ore between 30 percent and 40 percent iron and about 3.5 million tons of ore of all grades below drill holes and beyond trenches. The writer has included this ore, amounting to 6.2 million tons, in his estimates of measurable ore.

(2) Because ore of lower grade is included, the average iron content of the principal deposits given in this report is lower than that of the Bureau by 1 or 2 percent Fe.

(3) "Geologic" ore estimated by the Bureau includes the 3.5 million tons below and beyond drill holes and trenches mentioned under (1) as well as most of classes A and B of inferred ore in table 2, altogether about 11 million tons.

(4) Most of the 7 million tons of inferred ore, class C, was not included in Bureau estimates.

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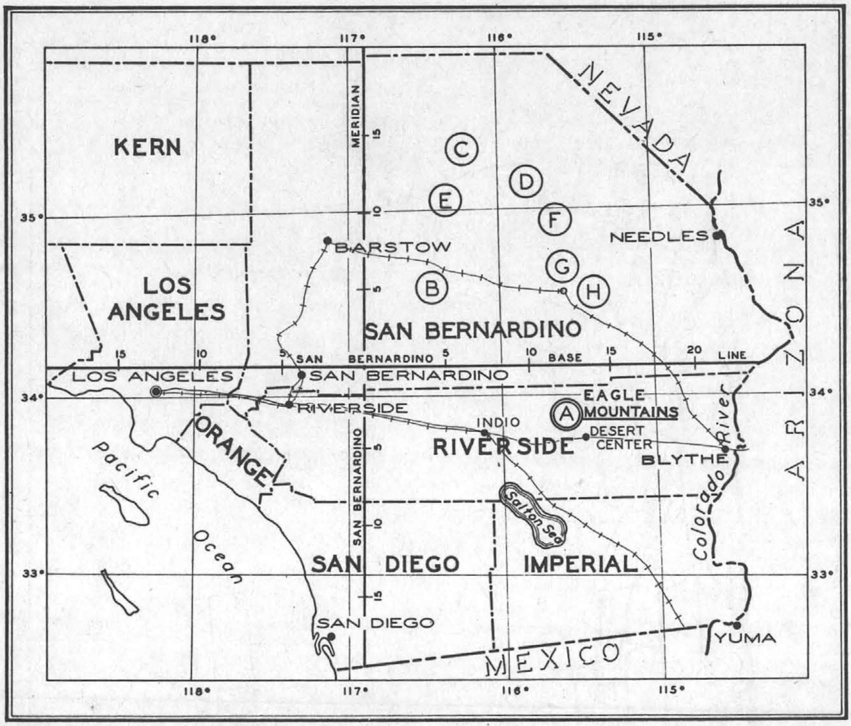

FIG. 1. Index map of southern California iron-ore deposits showing (A) EAGLE MOUNTAINS (described in this report); (B) Iron Mountain (Lava Bed); (C) Iron Mountain (Silver Lake); (D) Old Dad Mountain; (E) Cave Canyon; (F) Vulcan; (G) Iron Hat; (H) Ship Mountains.

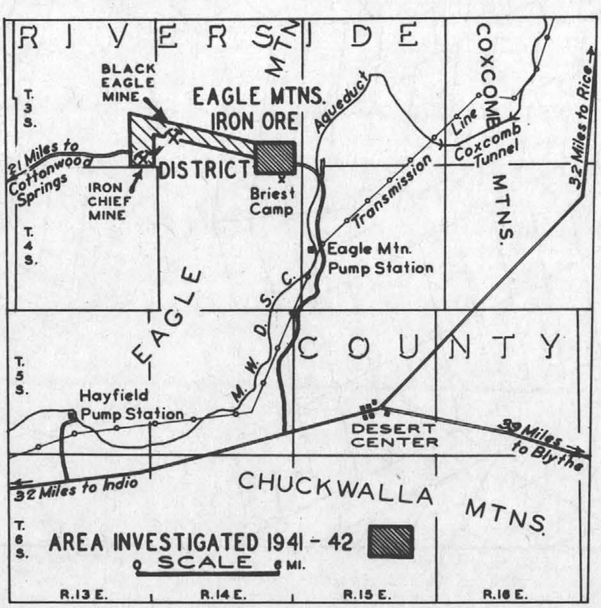

FIG. 2. Index map of a part of Riverside County showing location of Eagle Mountains iron-ore district.

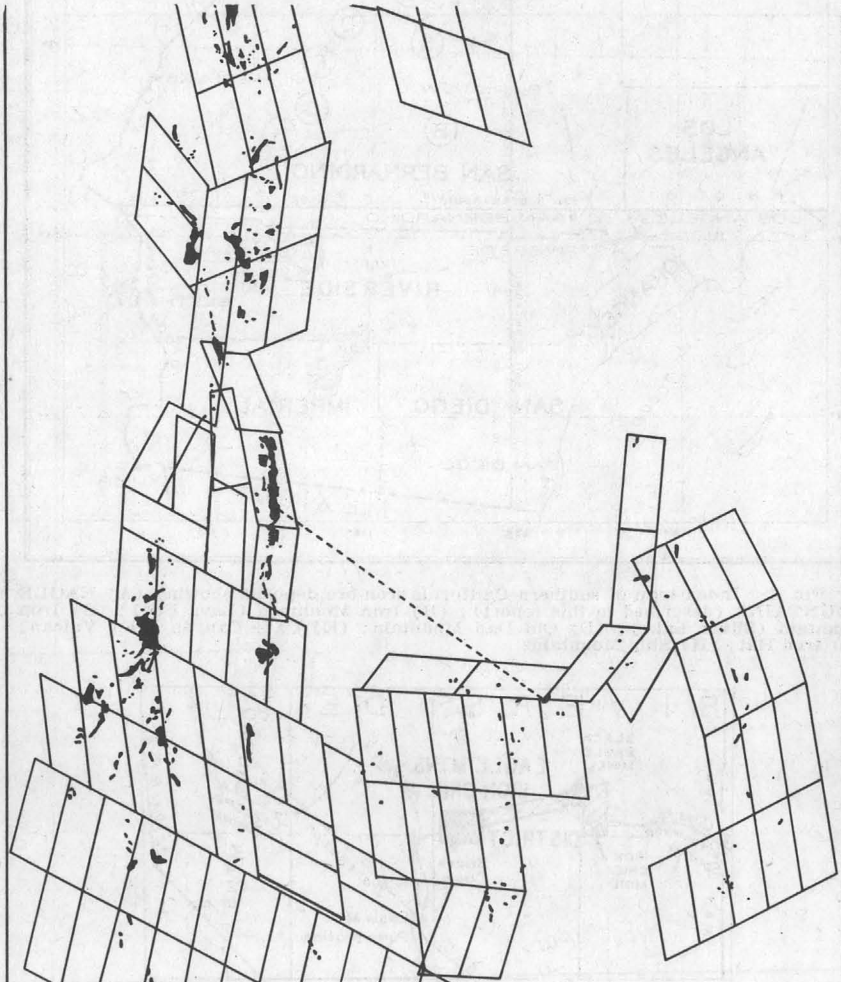

Illustration continued on page 19. Read from left to right.

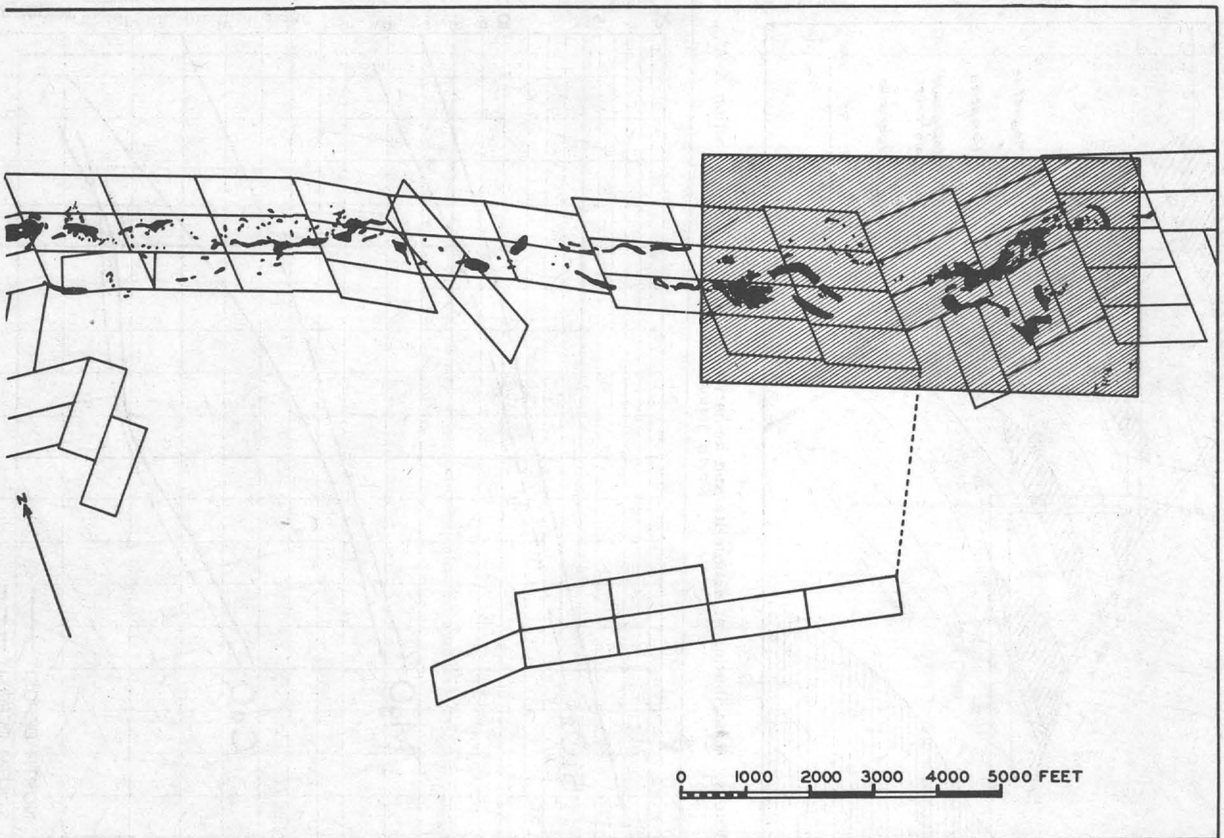

FIG. 3. Map showing the distribution of iron-ore deposits on mining claims of the Eagle Mountain district, by E. C. Harder and J. L. Rich (U. S. Geol. Survey Bull. 503, Pl. 8), 1912. (The eastern 25 claims, which occupy about one-fifth of the length of the entire range, comprise the area described in the present report.)

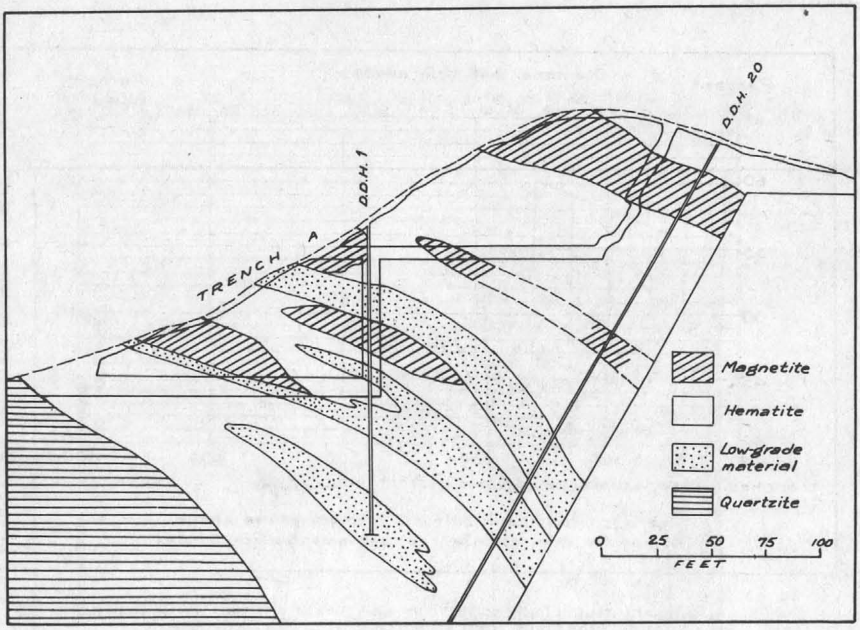

FIG. 4. Distribution of magnetite and hematite in part of structure section A-A', North deposit.

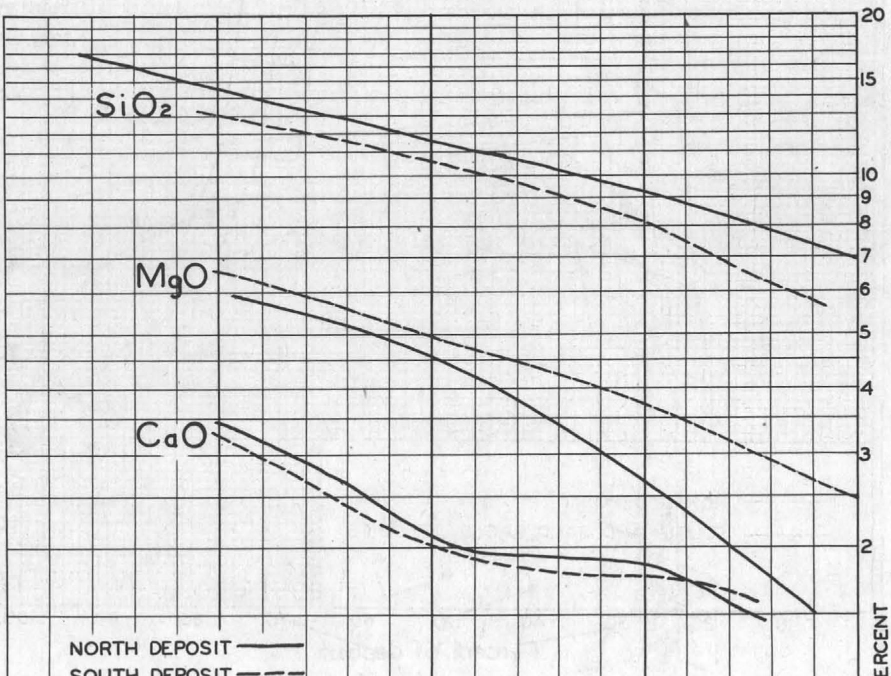

FIG. 5. Graph showing silica, magnesia, and lime in Eagle Mountains iron-ore deposits, based on 19 composite sludge samples from North deposit, 11 from South deposit, in relation to percentage of iron.

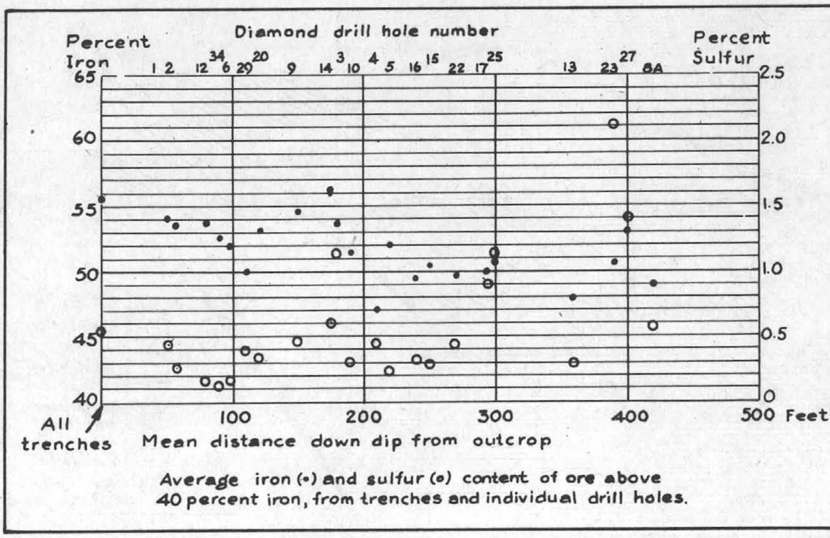

FIG. 6. Graph showing changes in iron and sulfur content with depth, in ore containing more than 40 percent iron, North deposit.

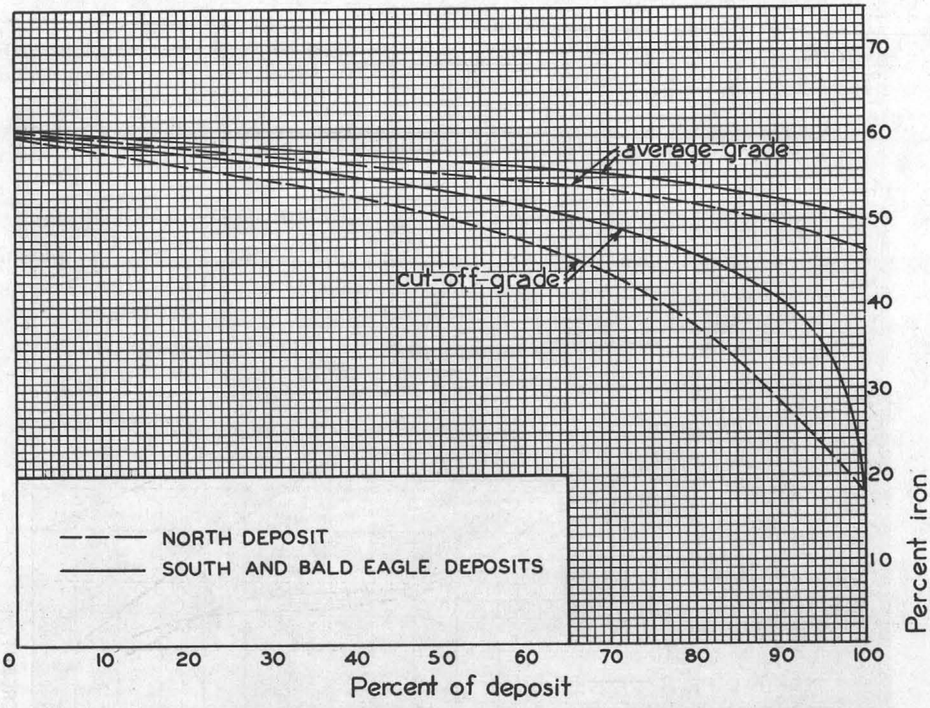

FIG. 7. Graph showing relation of reserves to average grades and cut-off grades of iron in Eagle Mountains deposits. For example: Ore containing more than 45 percent iron constitutes 67 percent of the North deposit and averages 50 percent iron; ore containing more than 45 percent iron constitutes 82 percent of the South and Bald Eagle deposits and averages 54 percent iron.

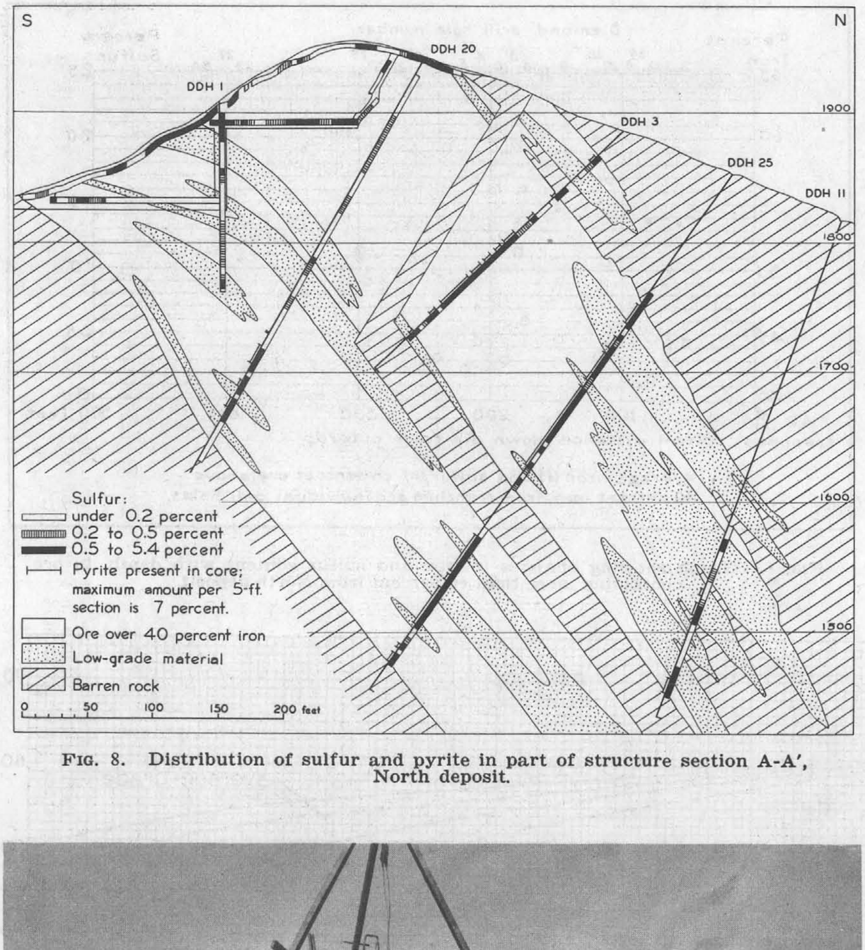

Fig. 8. Distribution of sulfur and pyrite in part of structure section A-A', North deposit.

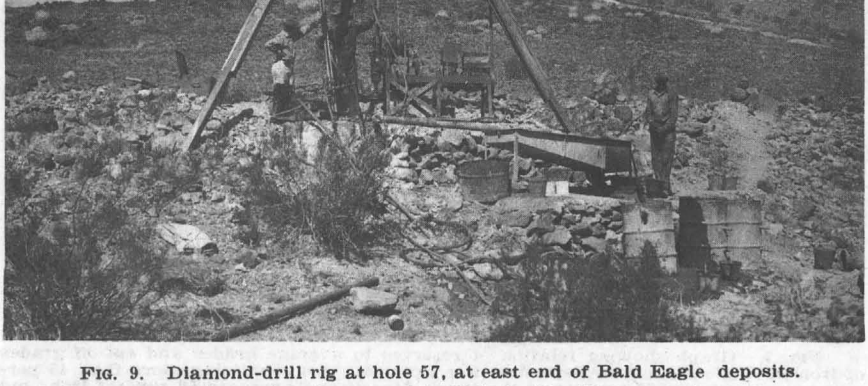

Fig. 9. Diamond-drill rig at hole 57, at east end of Bald Eagle deposits. The ore here is covered by 27 feet of bouldery gravel.

FIG. 10. Bald Eagle deposits seen from the east. Short white lines are trenches—lower group, left to right: P, Q, R, S, T, and U; upper group, bottom to top: U, V, and W. Bald Eagle Canyon in foreground, Big Dry Wash at left. Iron-ore-bearing area extends westward through the saddle just left of the center of picture.

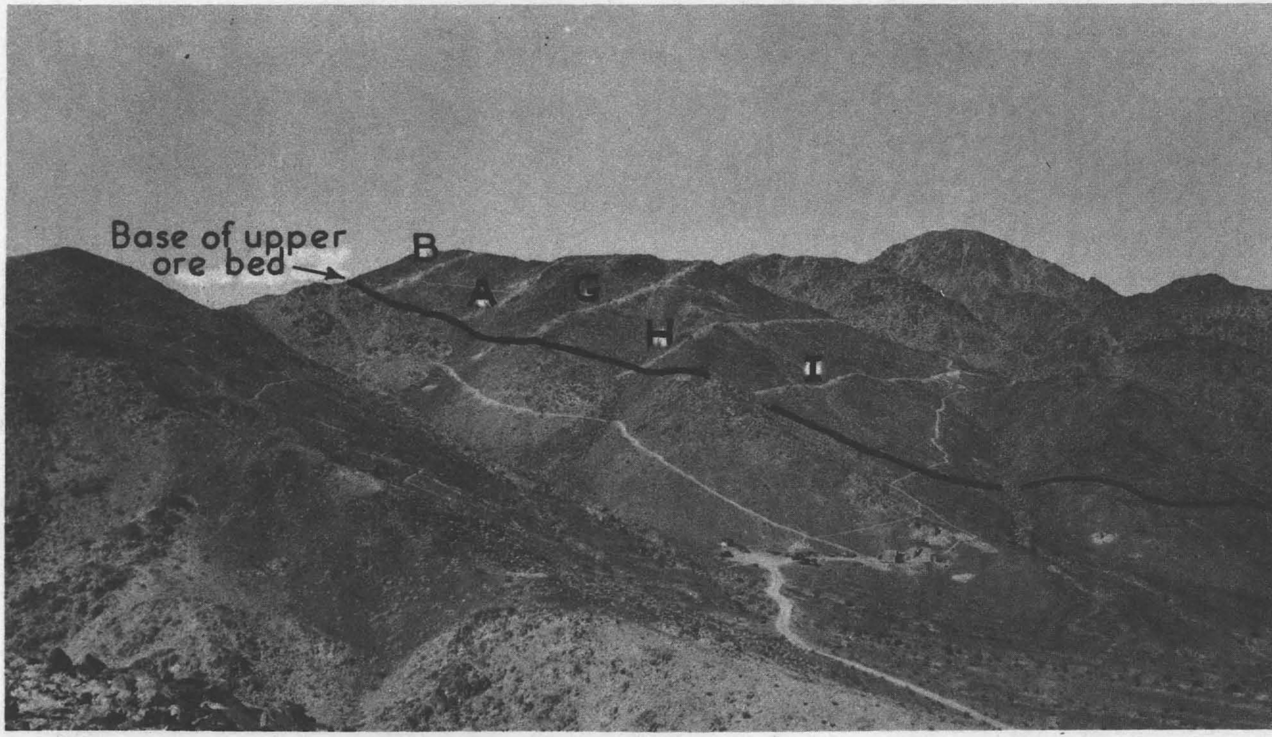

FIG. 11. North deposit on North Hill, seen from the southeast. Irregular white lines across the hill in the center of the picture are trenches (left to right, B, A, G, H, and I). Other white lines are trails. U. S. Bureau of Mines field buildings and road to Desert Center at lower right.

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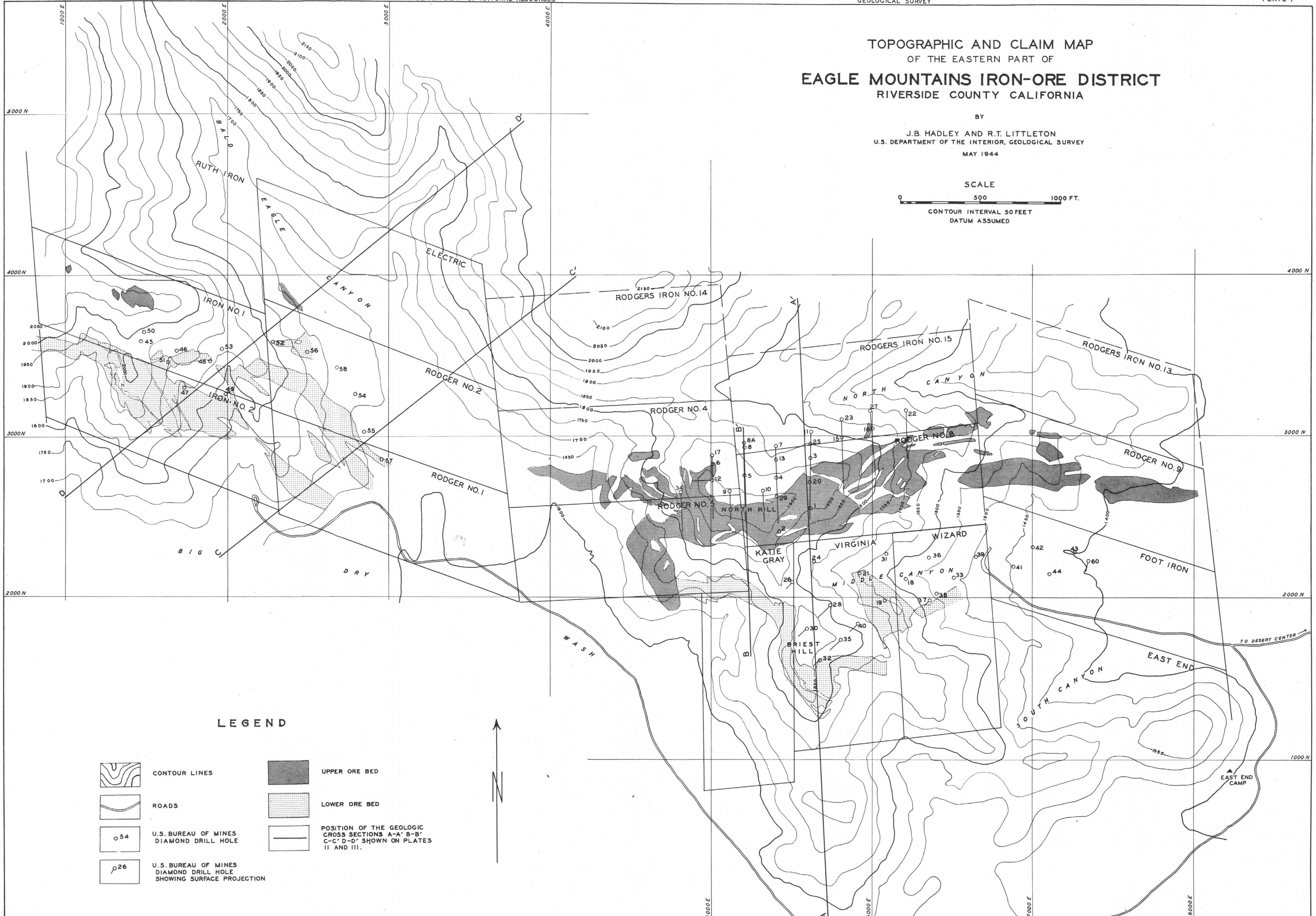
PLATE I



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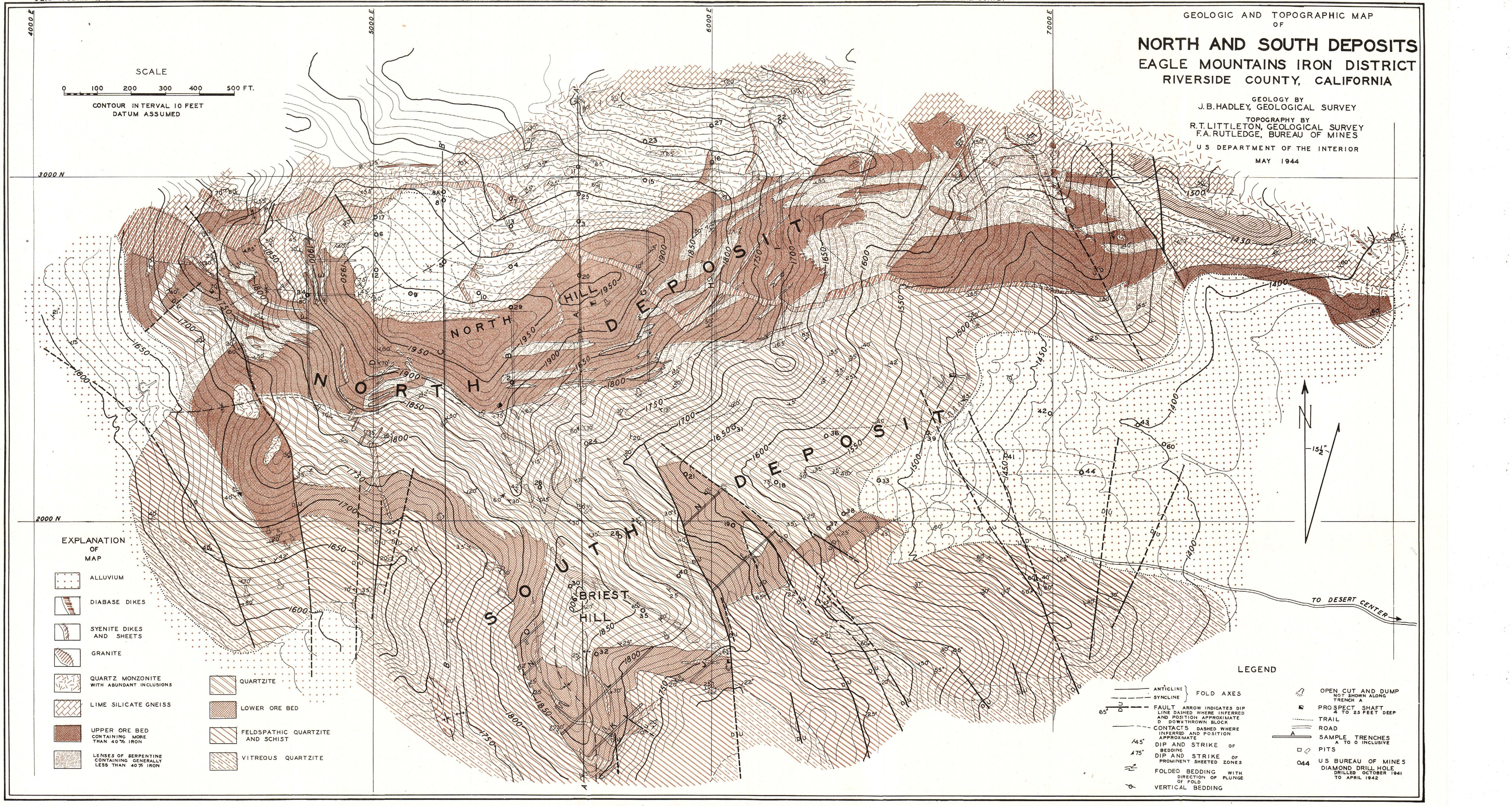
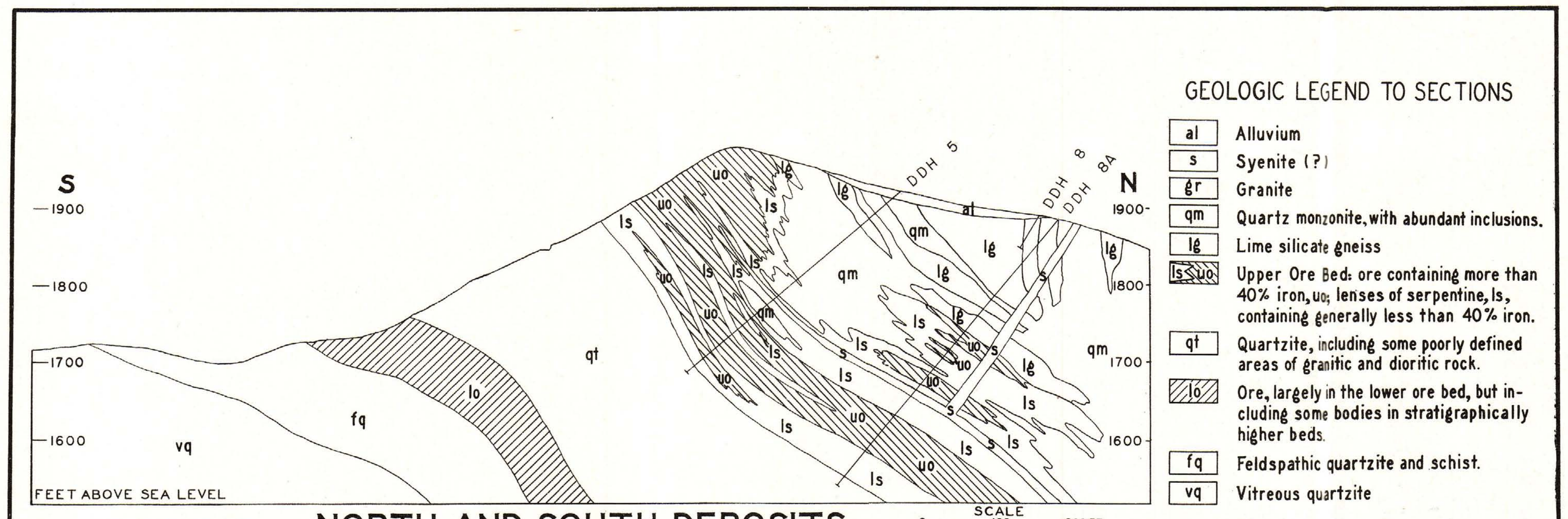
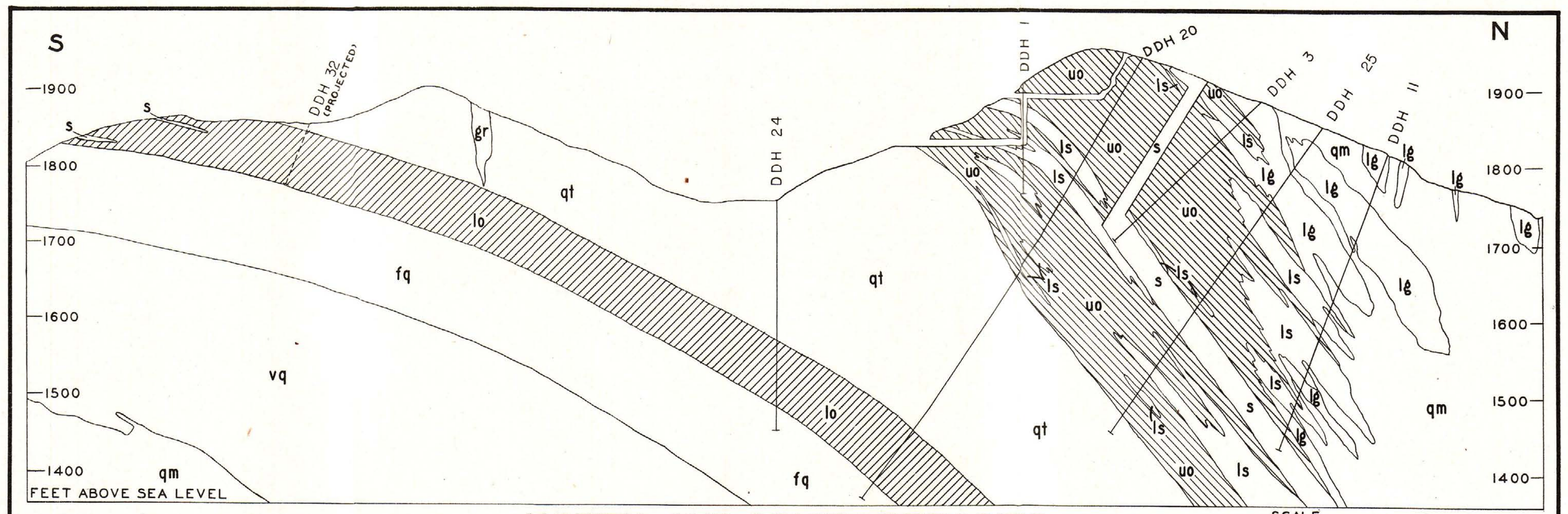


STRUCTURE SECTIONS



SECTION B-B' NORTH AND SOUTH DEPOSITS



SECTION A-A' NORTH AND SOUTH DEPOSITS

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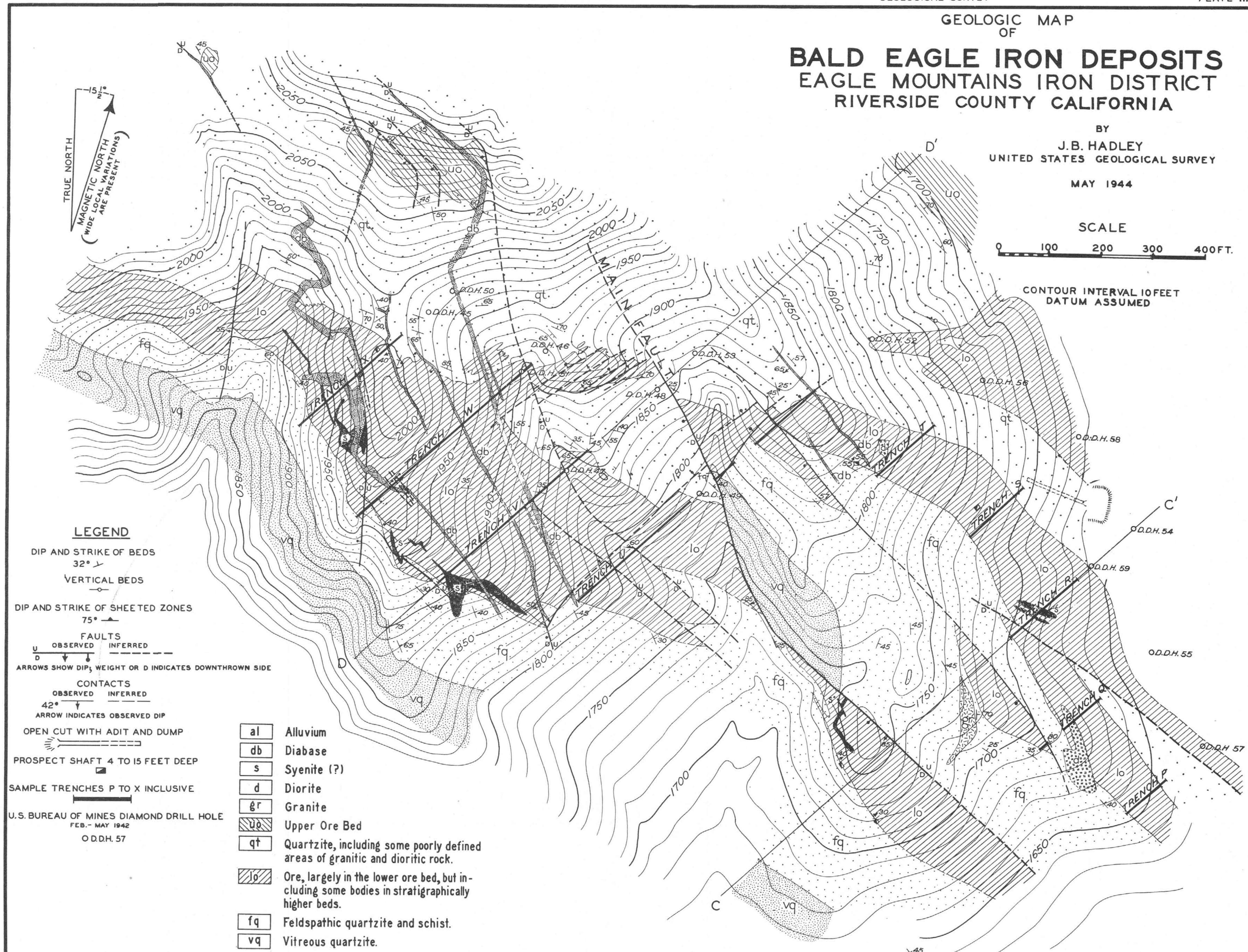
PLATE III



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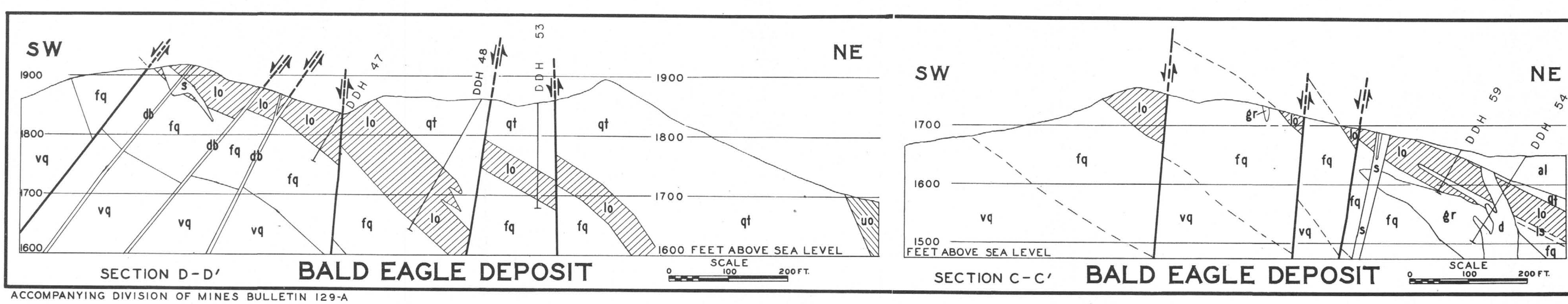

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