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THE IRON DEPOSIT OF CERRO HUACRAVILCA, JUNIN *

by

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SINTESIS

En el cerro Huacravilca se encuentran concentraciones de magnetita, de forma aproximadamente tabular, en zonas a lo largo del contacto entre el stock del cerro Huacravilca y la caliza triásica adyacente. Las rocas ígneas del stock, monzonita cuarcífera o granodiorita, y la caliza están fuertemente alteradas cerca del contacto. La monzonita cuarcífera ha sido reemplazada por ortosa, granate y epidota. La caliza se ha convertido en tactita constituída principalmente por granate, diopsida y magnetita y, en menor cantidad, una serie de silicatos y sulfuros. Generalmente los cuerpos de magnetita contienen bastantes impurezas, mayormente silicatos. Las masas de magnetita esencialmente pura y de tamaño regular no son muy abundantes. La mena común consiste de láminas alternadas de magnetita y caliza alterada. La oxidación es mayormente superficial aunque también se encuentra hematita a mayores profundidades. Es probable que ninguno de los cuerpos contenga más de unos cuantos millones de toneladas de magnetita y además la extracción selectiva de gran parte de esta mena sería muy difícil. Las posibilidades económicas del yacimiento son muy limitadas debido a la baja ley de la mena, el pequeño tonelaje probable y la distancia a los centros de consumo.

INTRODUCTION

The iron deposit of Huacravilca is on the southwest flank of Cerro Huacravilca, a prominent high peak in the southern tip of the Department of Junín about 50 Km by air south-southwest of Huancayo and 6 Km south-southeast of the lead and zinc mine of Cercapuquio. The road from Huancayo to Cercapuquio and the Santa Beatriz mine passes within 4 Km of the deposit.

The northwestern part of the deposit, including most of the mineralized area, was mapped with plane table and telescopic alidade on a scale of 1/5,000 by a joint commission of the Instituto Nacional de Investigación y Fomento Mineros and the U. S. Geological Survey in September 1954 under the auspices of the Foreign Operations Administration (Fig. 1). Four days were spent on the field work. We wish to thank the Compañía de Minas de Cercapuquio for providing accomodations at Cercapuquio and transportation to our campsite at Huacravilca. In particular, we acknowledge the aid of Sr. Aurelio Miranda, Assistant Manager, and Sr. Guillermo Flórez, Mine Superintendent.

The general geology of the region is described by Harrison (1956) and the iron deposit has been described briefly by Dueñas (1918) in a report dedicated mainly to a discussion of its economic possibilities. The area has been prospected, apparently for copper, but little or no ore of any kind has been produced.

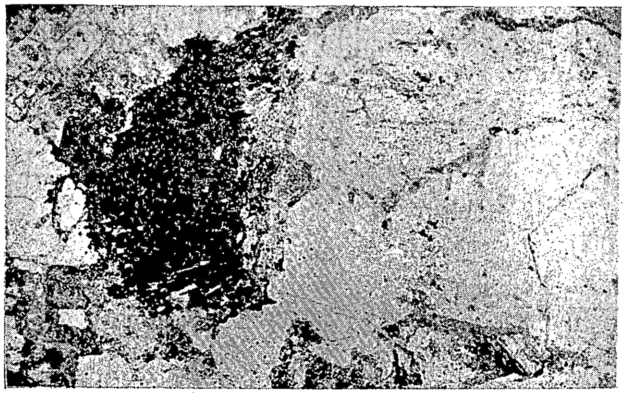
GENERAL GEOLOGY

Cerro Huacravilca is a ragged peak 5060 m high that rises 400 to 600 m above the surrounding undulating but somewhat dissected terrain. It is composed of a medium-grained equigranular to porphyritic quartz monzonite or granodiorite. According to Harrison (1956, p. 45) this rock forms a roughly circular stock 3 Km long in an easterly direction and 2.5 wide, intruded into dark gray thin to thick-bedded limestone of Triassic age.

A large part of the stock seems to be composed of a light gray to pinkish gray rock in which plagioclase feldspar, quartz, biotite and occasional grains of pyroxene and hornblende can be distinguished in hand specimens. Feldspar phenocrysts reach a length of 1 cm. Under the microscope, an equigranular variety from the southwest side of the stock, about 900 m east-northeast of Lake Pucacocha and 100 m from the limestone contact, is seen to consist of plagioclase $An_{(40-45)}$ quartz, and a little perthitic orthoclase and ragged biotite in a groundmass of quartz and potash feldspar (Fig. 2). A few irregular aggregates of pyroxene, sphene, and apatite, possibly representing altered biotite, are also present. Rosiwal analyses of two specimens of the rock gave the following results:

	(1) *percent*	(2) *percent*
Plagioclase	33	34
Orthoclase	32	31
Quartz	28	27
Biotite	2	5
Pyroxene, etc.	5	3

The rock of both these analyses is a quartz monzonite. A more feldspathic variety from the ridge directly south of the summit of the peak has the following mineral composition: Plagioclase, (An 20-25) 56 percent; orthoclase, 13 percent; quartz, 8 percent; biotite, 11 percent;



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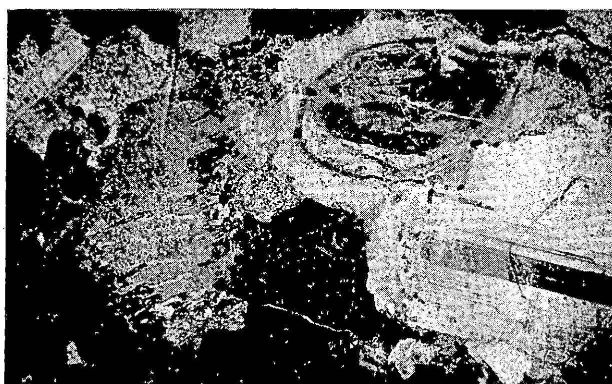

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Figure 2A. Cerro Huacravilca quartz monzonite, 900 m ENE of Lake Pucacocha. Quartz and plagioclase (white), orthoclase (mottled gray) and biotite with rim of pyroxene granules. Plane polarized light, x22. 2B. Same field, crossed nicols.

pyroxene, 12 percent. This rock is granodiorite rather than quartz monzonite. A hornblende-bearing quartz monzonite from the same ridge has the mineral composition: Plagioclase (An 20-25), 39 percent; orthoclase, 33 percent; quartz, 21 percent; hornblende 7 percent.

Aside from the stock, the only igneous rocks seen were a small body of fine-grained rhyolite porphyry 750 m north of Lake Pucacocha and a dike 2 to 3 m wide of porphyritic latite or monzonite just south of the lake. The rhyolite consists of embayed phenocrysts of quartz 5 mm or more across, smaller sericitized phenocrysts of orthoclase, and a few thoroughly altered grains of what was probably a pyroxene in a granular groundmass of quartz and orthoclase.

The limestone is generally a fine-grained dark gray rock, often with wavy bedding. The beds range in thickness from a few centimeters to a meter and average perhaps 20 to 30 cm. Nodules of chert are not abundant. The limestone is folded and locally is highly contorted. No fossils were found in the area mapped, although a careful search was made. Along the west edge of the mapped area the limestone is overlain by sandstone and siliceous shale.

The southwest part of the mapped area is underlain by a sequence of peculiar thin-bedded light-colored rocks that could not be identified with certainty. In appearance they range from very fine grained punky shale-like rocks to fine-grained quartzite. Under the microscope, the quartzite-like rock is seen to consist entirely of irregularly intergrown granular quartz and orthoclase in approximately equal proportions (Fig. 3). An identical rock crops out at the base of the north tip of

Figure 3. Intergrowth of quartz and orthoclase, altered sedimentary (?) rock from SW corner of mapped area. Slide is slightly below focus, Becke line is within quartz patches. Plane polarized light, x40.

the north ore body, where the country rock is known to be limestone, and the quartz-orthoclase rock may therefore be a completely altered limestone, but it may also represent a former shale or calcareous shale interbedded with limestone.

The region has been severely glaciated and the lower slopes of valley walls have been steepened notably. Lake Yanacocha lies in a deep cirque on the southwest flank of Cerro Huacravilca (Fig. 4). Much of

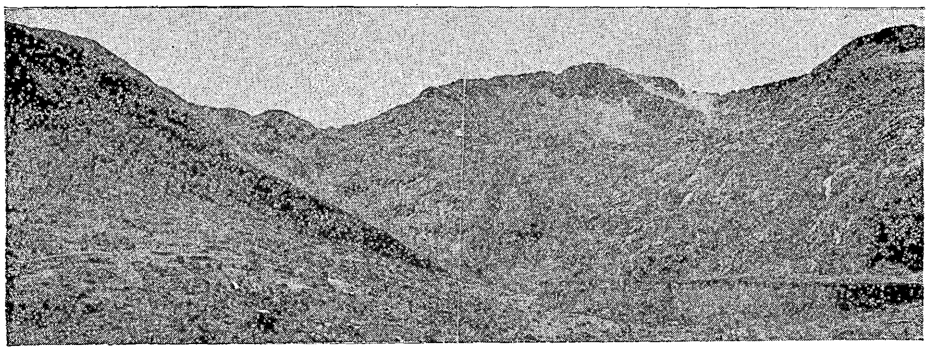


Figure 4. Lake Yanacocha (altitude 4,500 m) and lower slopes of Cerro Huacravilca, looking northeast. Dark outcrops at extreme right and right center are garnet-magnetite rock shown in figure 10. Mineralized areas on northwest ridge (left side of photograph) are covered with talus. Hummocky terrain in background is underlain by quartz monzonite.

the mineralized area, particularly the northwest ridge (Fig. 4, left side) is covered with talus.

CONTACT METAMORPHISM

Along the contact between the stock and the limestone, both rocks have been altered to varying degrees. One of the manifestations of this "contact" metamorphism is the iron deposit itself, which consists of local concentrations of magnetite along the contact, especially in the limestone.

The igneous rock is altered as much as 75 m or more from the limestone contact, although intense alteration is mainly confined to a zone 25 m or less in thickness. In order to study the progressive changes in the intrusive rock, a suite of specimens was collected at various distances from the southeast contact of the northwesternmost ore body (see map). At 75 m from the iron ore contact, biotite is slightly altered to pyroxene.

Fifty meters from the contact, biotite is largely converted to an aggregate of poikilitic pyroxene, sphene, and apatite and the groundmass is flooded with orthoclase (Fig. 5). At 30 m from the contact, plagioclase is

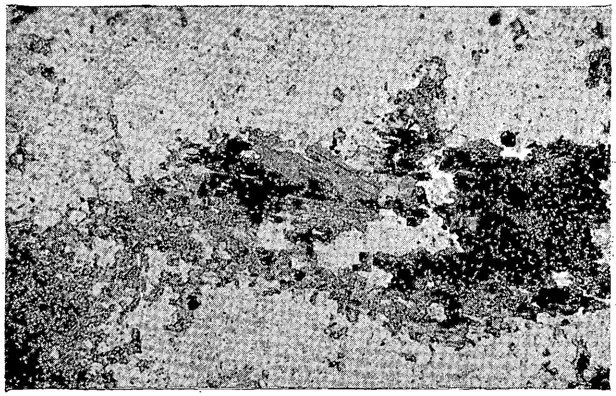


Figure 5. Altered quartz monzonite 50 m from southeast contact of northwest ore body. Biotite altered to aggregate of pyroxene, sphene, and apatite. Groundmass is largely aggregate of quartz and orthoclase. Plane polarized light, x40.

changed to albite and partly replaced by orthoclase, pyroxene is less abundant, and the rock is veined and partly replaced by garnet (Fig. 6). At

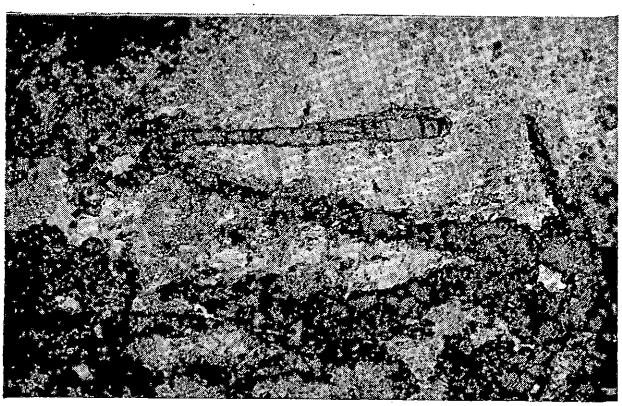


Figure 6. Veinlets of garnet (dark) in highly altered quartz monzonite, 30 m from southeast contact of northwest ore body. Plane polarized light, x22.

the contact the rock is almost completely replaced by garnet with a little epidote, plagioclase has disappeared, and only a little orthoclase and pyroxene remain.

Intrusive rock immediately underlying the N-shaped magnetite body 750 m south-southeast of Lake Pucacocha is highly altered. Plagioclase is replaced by sericite and chlorite; biotite is almost completely converted to an aggregate of pyroxene, sphene, apatite, and calcite; pyroxene is altered to chlorite; and the groundmass is flooded with orthoclase. In some places the rock has been thoroughly epidotized through a thickness of as much as 50 m.

In summary, the characteristic alteration of the quartz monzonite at or near limestone or iron ore consists of the conversion of biotite to aggregates of colorless pyroxene, sphene, and apatite and the wholesale introduction of potash feldspar into the groundmass. Epidotization and garnetization are less widespread but locally are intense.

Contact alteration of the limestone ranges in intensity from very slight to extreme. In the least-altered rocks the only metamorphic effects have been recrystallization of calcite to grains 0.1 to 0.5 mm across and the formation of a little tremolite. As alteration increases in intensity, the limestone is converted to tactite consisting mainly of garnet, diopside and magnetite in varying proportions (Fig. 7). Less abundant metaso-

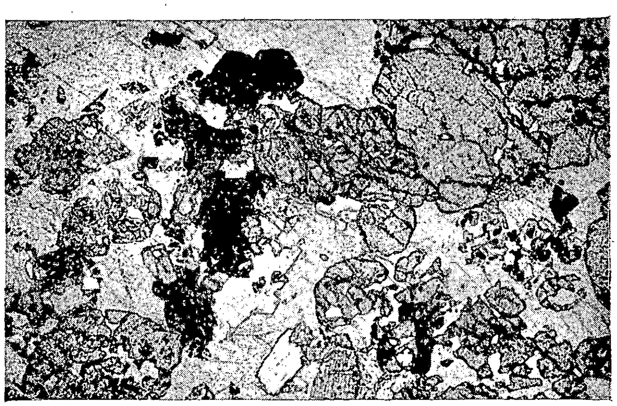


Figure 7. Tactite from southeast of Lake Yanacocha. Consists of garnet (gray, high relief), pyroxene (gray, bottom center, with cleavage), phlogopite (white), and magnetite (black) in matrix of calcite (light gray). The matrix of the entire field is a single grain of calcite. Plane polarized light, x22.

matic minerals include pale to bright green phlogopite, epidote, and scapolite as well as the sulfides pyrite, chalcopyrite, pyrrhotite, and sphalerite.

The garnet is yellow-brown to greenish-brown. Its refractive index varies somewhat but averages 1.82 to 1.83 and its specific gravity is about 3.6. On the assumption that the garnet is essentially a calcium-iron-aluminum variety, these data would indicate a composition of 50 to 60 percent andradite (Winchell, 1951, p. 491).

Phlogopite has a very small optic angle and refractive indices beta and gamma about 1.590, indicating a variety with very little iron.

Scapolite seems to be less abundant than the other metasomatic minerals, as it was identified in altered limestone from only two localities. A bed of flat-lying limestone about 1 to 1.5 m thick that crops out some 650 m southwest of Lake Pucacocha has been converted to a dark greenish gray rock consisting mainly of an interlocking aggregate of scapolite grains with some reddish-brown biotite, pyroxene and pyrite. This bed strongly resembles a sill. The refractive indices of the scapolite are approximately O = 1.560, E = 1.545, indicating a composition of about 60 percent of the marialite molecule and 40 percent of the meionite molecule (Winchell, 1951, p. 353). The overlying fine-grained limestone contains scattered euhedral prims of scapolite 0.3 to 0.4 mm. long. Scapolite is abundant in tactite southeast of Lake Yanacocha.

The sulfide minerals occur sporadically and in general are associated with magnetite. Pyrite is widespread in small amounts. A little chalcopyrite was seen in the northwest ore body associated with sphalerite, in the north ore body, and on the southeast ridge (see map) associated with pyrrhotite.

No well-defined sequence of formation of the tactite minerals could be detected, but in general diopside and phlogopite seem to be early minerals, as they are replaced by both garnet and magnetite. Garnet is also replaced by magnetite, which appears to be the latest metamorphic mineral to form.

IRON DEPOSITS

Location and dimensions

Concentrations of magnetite occur at various places along the contact between the Cerro Huacravilca stock and the adjoining limestone. The five principal ore bodies in the area are shown on the map, but it should be noted that outlines of ore bodies are only approximate in most places because of the gradational nature of the contacts.

The northwest deposit is the largest. It trends roughly northeast and can be traced more or less continuously for about 900 m along the strike, although only about 500 m can be considered ore. The maximum thickness of the iron-bearing zone is about 50 m but the average thickness is considerably less, probably 5 to 10 m; true thickness is difficult to determine as the dip is uncertain in most places.

The north ore body is an irregular tabular mass with maximum dimensions of about 300 m by 200 m and a thickness of 10 to 20 m. It dips 25° to 35° in a general westward direction.

Two small ore bodies lie 650 and 700 m respectively south-southeast of Lake Pucacocha. The more westerly is very small and consists of almost pure magnetite. The east, N-shaped ore body averages perhaps 5 m in thickness and dips about 35° WSW.

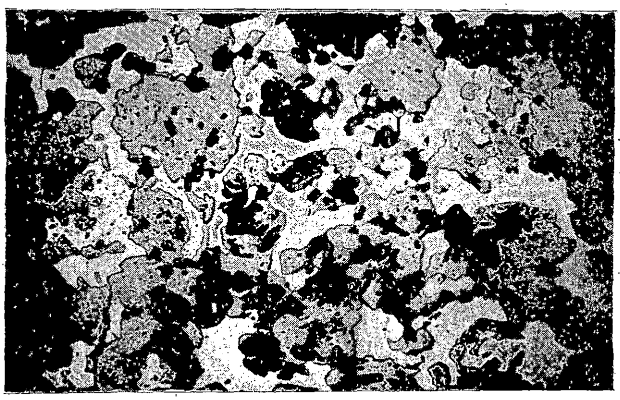
The southeast ore body comprises three small masses near the east shore of Lake Yanacocha and an extensive but low grade deposit that extends eastward across the southeast ridge beyond the mapped area. This deposit is perhaps 900 to 1000 m long and has the form of a very irregular more or less vertical roof pendant or septum of partly replaced limestone.

Although practically all of the alteration and mineralization is at or near the limestone-monzonite contact, a little alteration was noted elsewhere. About 150 m southwest of the prominent hill just northwest of Lake Pucacocha, a narrow zone of cavernous hematite and limonite 60 m long crops out in sandstone that overlies the limestone. No magnetite or sulfide minerals were seen. Some 600 m north of the lake, a zone of silicified limestone with garnet and pyrite crops out for 100 m or so. The zone strikes N 15° W, appears to dip vertically, and is about 3 m wide. Thirty meters farther north is a small isolated outcrop of iron oxide in limestone. This alteration zone is near the small body of rhyolite porphyry and may be related to it.

Mineralogy

The ore is extremely variable in composition and ranges from disseminated magnetite through layered magnetite-tactite to essentially solid massive magnetite. The bulk of the ore, however, is impure magnetite containing perhaps 40 to 50 percent of other minerals, mainly silicates.

The northwest deposit consists largely of "pepper and salt" ore with a little interstitial chalcopyrite and sphalerite locally (Fig. 8) and



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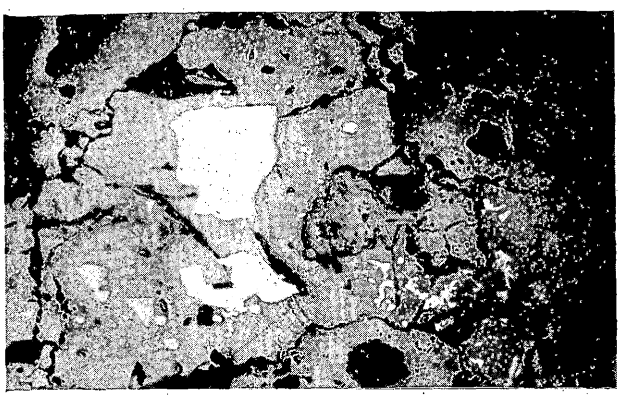

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Figure 8A. Magnetite-chalcopyrite ore, north side of northwest ore body. Chalcopyrite (white) and a little sphalerite (light gray) interstitial to magnetite (dark gray). Black areas are gangue. Reflected light, x45. 8B. Aggregate of chalcopyrite (white) and sphalerite (gray, smooth) in matrix of magnetite (gray, rough). Reflected light, x75.

considerable pyrite especially at the southwest end. It probably contains only 50 to 60 percent of magnetite.

The north ore body is made up of granular magnetite that has replaced a calcite-phlogopite rock. The ore ranges from layered to practically massive magnetite, but probably contains an average of only 50 to 60 percent of magnetite. Locally it contains considerable pyrite (Fig. 9).

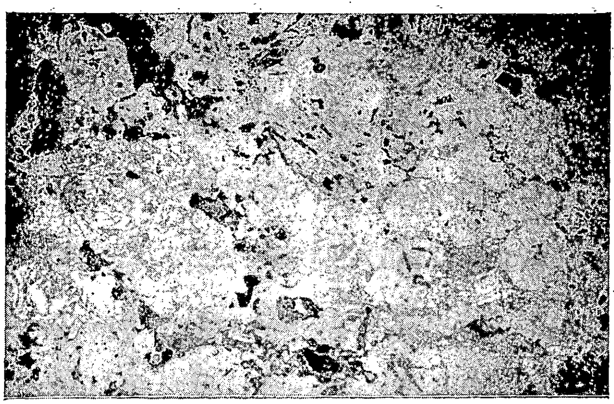

Figure 9. Magnetite-hematite-pyrite ore from north ore body. Hematite (medium gray) and pyrite (white) in aggregates interstitial to magnetite (light gray). Reflected light, x45.

The smaller of the south ore bodies consists of nearly solid granular magnetite with considerable interstitial bright green phlogopite.

The southeast ore body is the most variable of all in composition. It is composed largely of altered limestone containing narrow layers of magnetite. One small mass of pyrrhotite and chalcopyrite was seen. The three small ore bodies near Lake Yanacocha are made up of a rather striking rock composed essentially of light greenish brown garnet and granular magnetite in variable but roughly equal proportions (Fig. 10). Minor minerals include pale green phlogopite, epidote, quartz, calcite, and scapolite. Magnetite clearly replaces all the other minerals and was the last new mineral to form in the sequence of alteration of the original limestone.

Figure 10. Garnet-magnetite rock from southeast of Lake Yanacocha. Subhedral grains of garnet (light gray) and a little phlogopite (white) replaced by magnetite (black). Plane polarized light, x22.

Structure

In general the ore bodies seem to be roughly tabular masses with a footwall of igneous rock and a hangingwall of variably altered limestone. The north ore body is an isolated plate resting on intrusive rock and capped by only a small patch of limestone, the rest of the roof having been stripped off by erosion. The magnetite concentrations are irregular and discontinuous, but all seem to be at approximately the same position relative to the contact between limestone and intrusive rock, that is, no magnetite bodies were found at any appreciable distance from the contact in either limestone or igneous rock.

The iron ore nearly everywhere is massive, but locally, such as along the northwest side of the northwest ore body, it has been brecciated.

Oxidation

All the ore bodies and iron-bearing rocks are oxidized to some extent, but the oxidation in general is superficial. No large masses of hematite or "limonite" were seen. Magnetite of the northwest ore body is veined by hematite and some breciated ore is cemented by hematite. An appreciable amount of hematite veins and fills interstices in granular magnetite of the north ore body (Fig. 11).

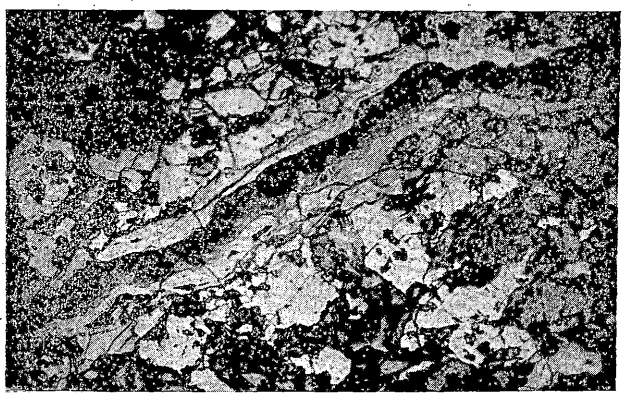

Figure 11. Magnetite-hematite ore veined by supergene (?) hematite. Magnetite is white; hematite light gray; dark gray and black areas are gangue. Reflected light, x45.

A sizeable area on the west slope of the central ridge south of the south ore bodies is mantled by a superficial breccia consisting of talus fragments as much as a few centimeters across cemented by porous yellow-brown iron oxide. From a distance this breccia-covered area appears to be an extensive gossan, but this appearance is due entirely to transported iron oxide that has been leached by surface waters from iron ore outcrops above and redeposited downslope.

The large areas of outcrop filmed by iron oxide are deceiving, as they give the impression of a very extensive mineralized zone, whereas actually only a very small proportion of the iron-stained rock is magnetite ore.

Origin

The iron deposits have formed by replacement of limestone at contacts with quartz monzonite or granodiorite of the Cerro Huacravilca stock. Similar deposits have been described from many places, and the various ideas about their origin are well known. The ore-bearing fluids are believed to have been derived from the stock, probably during a late stage of its consolidation inasmuch as the stock at contacts with iron ore or limestone has undergone alteration similar to that shown by the limestone. Large amounts of iron, silica, aluminum, and potassium and smaller amounts of magnesium, sulfur, copper, zinc, sodium, and chlorine have been introduced into the contact zone. It seems possible that part of the iron was derived from the breakdown of biotite in the contact phases of the stock, as biotite through a zone various tens of meters thick is altered to an aggregate of minerals none of which seems to contain much iron (diopsidic (?) pyroxene, sphene, apatite). This theory will be tested more thoroughly in a paper now in preparation on the Rondoní iron deposit in Huánuco. A similar theory has been proposed by Mackin (1954) for some of the contact iron deposits of Iron County, Utah, U.S.A.

Economic Possibilities

The preceding discussion indicates that the economic possibilities of the Cerro Huacravilca iron deposit are limited by at least two unfavorable factors.

1. The amount of high grade ore in sight or reasonably expectable is small. Most of the ore is rather impure and siliceous and much of the high grade ore is so intimately mixed with country rock that it could not be mined selectively with much success. In the absence of systematic sampling, the average grade of the various ore bodies cannot be stated exactly, but it seems likely that none will contain more than 60 percent iron and the two largest will average considerably less.

2. The total amount of all grades of ore available are relatively small. No accurate calculation of reserves can be made without additional information and exploration, but the following estimates are believed to be of the right order of magnitude. The specific gravity of the ore is taken as 4.

a) Northwest ore body: usable ore is about 500 m long along the strike, average thickness 10 m, tonnage available 20,000 per meter of depth, 1,000,000 to 2,000,000 tons probably available.

b) North ore body: 300 m long, 100 m average width, 15 m average thickness, tonnage available 1,500,000 to 2,000,000.

c) South ore bodies: only the eastern deposit has any appreciable tonnage, perhaps 150,000 to 200,000 tons.

d) Southeast ore body: no estimate is made for this deposit, as practically no minable ore was seen. The magnetite is so thoroughly mixed with barren rock that large-scale mining would be very difficult or impossible. The southeastern extension of this ore body was not studied, but is reported to be similar to the part mapped.

The distance from rail transportation and possible markets also is an unfavorable factor but might not be decisive in itself. However, the combination of low grade, limited tonnage, and distance from the coast indicates that the deposit cannot be considered as a promising source of iron ore either at present or in the foreseeable future.

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