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Geology of the Acari iron mining district Arequipa, Peru

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GEOLOGY OF THE ACARI IRON MINING DISTRICT

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BY

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ABSTRACT

The Acari Iron Mining District, part of a tilted uplifted fault block, comprises an area about 300 square kilometers, in the southern part of the coastal belt of Peru. It is in the foothills of the western range of the Andes and it is dominantly formed by granodioritic and granitic intrusive rocks which belong to the Andean batholith of Cretaceous-Tertiary age. The intrusive rocks are overlain by a central, elongated, northwest trending band, of metasedimentary and volcanic rocks.

The magnetite deposits of Acari district are long, dike-shaped bodies, which fill two systems of fractures in the granodiorite intrusive, located in the southwest portion of the district. One fracture system, includes both the Mastuerzo and Campana Zone, has NWN trend. The other fracture system, the Pongo Zone, trends NE. The ore consists predominantly of black, massive, compact, microporous, fine-grained magnetite characterized by colloform texture. Its average grade is about 60-66% Fe with 0.10-0.20% P. The deposits are characterized by a vertical zoning which plunges southward, consisting of: 1) an upper magnetite ore zone, 2) a transitional zone, and 3) a lower barren amphibole zone. Two successive stages of fracturing and faulting, one forming transverse faults, the other longitudinal faults, have affected the magnetite deposits. The deposits are believed to have resulted from two principal endogenetic processes, one was the injection of rich-iron fluids into fractures in the granodiorite intrusive, the second was hypogenetic alteration of the magnetite deposits by barren hydrothermal

solutions, which probably were derived from the crystallization of the granite intrusive in the northeastern portion of the district.

Three stratiform hematite deposits containing, about 31-37% Fe occur within the outcrop area of Mississippian (?) age of metasedimentary rocks at the headwater of the Loza Valley. Fairly consolidated black magnetite sands overlie the granite intrusive in Cerro Conchudo. They contain approximately 6% Fe.

Copper veins consisting of discontinuous ore shoots of oxidized minerals in long, east-west trending fissures occur within the granite intrusive, or as fractures filling in felsic dikes or quartz veins within the Dark Volcanics and within the granodiorite intrusive.

Chapter I

INTRODUCTION

LOCATION

The studied area is in the southern part of the Republic of Peru, 30 kilometers from the Pacific coast. The area is approximately rectangular and covers about 300 square kilometers. It is bounded by 75° 35' to 75° 46' west longitude, and 15° 21' to 15° 22' south latitude.

The Acari Iron Mining District is in the northern extremity of the department of Arequipa, province of Caraveli, district of Bella Union. Topographic sheet No. 16b of Yauca, National Chart of Peru, at 1:200,000, with a contour interval of 50 meters, covers the area. The general reconnaissance geologic map includes the mineral claims under the title "Acari" and the neighboring area of Pongo zone. They are controlled by the Cia. Pan-American Commodities S.A.

ACCESSIBILITY

The community for the Acari Iron mine is at the outlet of the Cardonal valley, 500 meters above sea level, and 5 kilometers south of the crushing plant. The later is 830 meters above sea level. A private asphalt highway some 60 kilometers in length leads to the port. The mining district is mainly accessible through the port. Approximately 25 kilometers from the crushing plant the highway has an underpass beneath the Pan American Highway at 525 kilometers from Lima. A small aircraft landing strip is also available about 12 kilometers south of the camp.

Several gravel roads and trails provide access to the different portions of the mining district. These include: The Cardonal Valley road to the plateau, the Pongo road which rises to the plateau by the south slope of Yuyuca hill, the Calapampa Valley road which also goes to the plateau, and the Tranca Baja Valley trail to the plateau. A gravel road of 20 kilometers length also joins the mining community to the small town of Acari. The town of Nazca lies 75 kilometers to the northwest.

PURPOSE AND SCOPE OF THE INVESTIGATION

In the detailed study of this iron mining district, five major objectives were outlined:

1. To synthesize, evaluate and interpret available geophysical and geological information on the Acari Iron Mining District.
2. To determine the possible cause or causes of the mineralogical bottoming of the magnetite deposits of the Acari District. Vein 1A, in the Mastuerzo zone, was chosen for detailed microscopic study of the transitional zone between the overlying ore zone of magnetite and the underlying barren zone consisting of amphiboles.
3. To offer a reasonable theory of genesis for this type of magnetite deposit.
4. To determine the possible relationships between the local geology and the ore deposits.
5. To point out probable geological and geophysical guides that might prove useful in future exploration programs in this district.

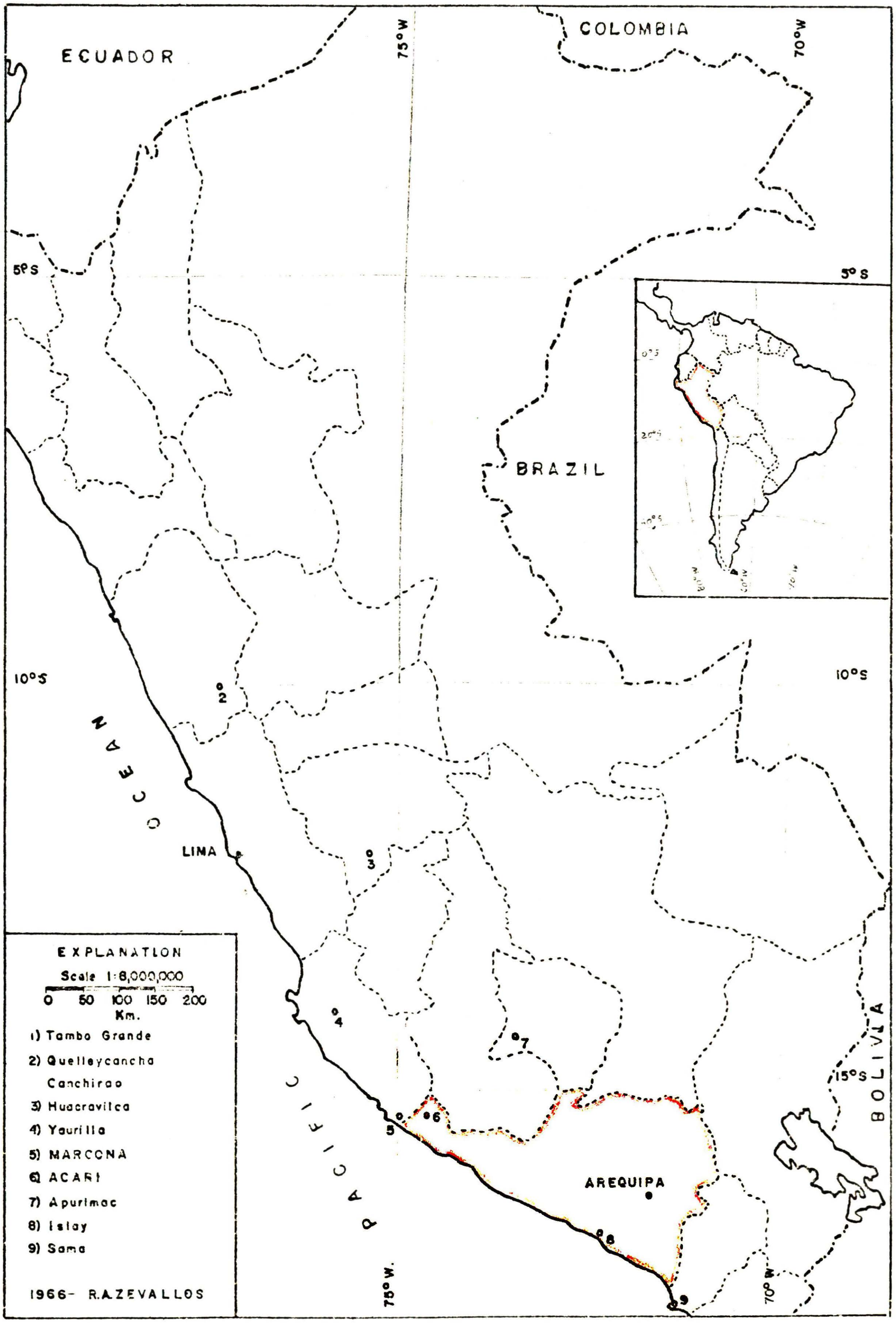


Figure 1- Index Map showing the Acari Iron Mining District and other iron in Peru

Between January, 1959, and December, 1964, the writer had the opportunity of participating in various phases of the development of the Acari Iron Mining District. He also studied the geology and mineral deposits of the area covered by the "Acari" claims and the surrounding areas, including the Pongo zone. All of the areas are shown on the general geologic map (Plate 1).

During late 1964, a compilation of available geologic information and field work was completed for a general reconnaissance geologic map of the area. Photomosaics at 1:20,000 of the Aero Service Corporation of Philadelphia (1952), a general topographic map at the same scale by E. Kleiman (1952) and a claim map at a similar scale by V. Velazquez (1960), were used as compilation bases.

Laboratory work began at the Acari Iron mine with the preparation of the general geologic map at a scale of 1:20,000, compilation of longitudinal vertical sections of Vein 1 and Vein 1A, of the Mastuerzo zone, and construction of geological cross sections, each 50 m. apart, at 1:1,000, and development of a stratigraphic section for the district. At the University of Missouri at Rolla, further work included a topographic-geologic map of the mining district at 1:50,000, geological cross sections and longitudinal sections, at 1:2,000, a partial magnetic map of the Mastuerzo zone, at 1:5,000, and other illustrations and sketches to complete the investigation.

Laboratory study at the University included the petrography of the country rock and ore microscopy of the mineral deposits. Sixty-four thin sections and fifty-one polished sections were studied. Photomicrographs were made utilizing both plane and polarized light of thin sections and polished sections. Macrophotographs also were prepared for polished flat surfaces of selected hand specimens. These specimens were originally collected by the writer and by Francisco Arbizu, resident geologist of the Acari Iron mine.

The report and laboratory investigations were completed during the Summer and Fall of 1966, and as time permitted during the Fall and Spring of the preceding year.

PREVIOUS WORK

Before this work only reconnaissance geologic maps at very small scale covered the study area. These included the schematic geologic chart of Peru by Steinman and Lisson (1939), a generalized geologic map of Peru at 1:8,500,000 by Broggi (1945) and the more recent geologic map of Peru at 1:2,000,000 by E. Bellido and F. Simmons (1957).

Other geological information on the Acari Iron Mining District is mainly in the form of private reports belonging to the Cia. Pan-American Commodities S.A. These reports mainly relate to the geological background, economics and exploitation of the mineral deposits.

In 1956, the main magnetite deposits of the Mastuerso and Campana zones were described by Schmidt Thome. The current author, in 1959, prepared a geological study of the Mastuerso zone as part of the requirements for the professional grade of Geological Engineer at the Universidad Nacional San Agustin de Arequipa, Peru. In 1961, a special report was prepared on the iron deposits of the Pongo zone. Another private report was prepared in February 1962 by D. Bradley on Gordon Hill, including La Mancha area mapped by D. Borkowski. Both of these are on the Mastuerso zone. Borkowski continued graduate research at the University of Clausthal, Germany, with a microscopic study of the intrusives of the Gordon Hill and La Mancha areas. Information on this study is not available.

A compilation was made of the many private reports of the company files in late 1964. This included geologic studies of the various areas noted above, detailed geologic maps of many of the working mines, an aeromagnetic map, ground magnetic maps, drill core and cutting descriptions, production, reserves and exploitation of mines. Reports were written by S. Thome, R. I. Erickson, G. Hoffmann, M. Tealdo, D. Borkowski, J. Cook, S. Sadner, D. Bradley, R. A. Zevallos, Parker Gay, L. H. Lizarraga, H. Varillas, F. Arbizu, M. Carrizales and J. Moretti.

HISTORY OF THE MINING DISTRICT

To acquaint the reader with the relatively recent history of the mining district, the following details are included in this report.

Prior to 1952 no references are known on the Acari Iron Mining District. In 1952, several mining claims were located in the district in the following order:

1. The "Amado I", "Amado II" and "Pongo" in the Pongo zone by H. Amado and others.
2. The "ACARI" claims of the Cia. Pan American Commodities S.A. covering almost all the district with the exception of the Pongo zone.
3. Claims by the Corporacion del Santa in the Pongo zone.

A systematic exploration program was initiated after 1952 by the Cia. Pan American Commodities S.A. This included an aeromagnetic survey, several ground magnetic surveys, physical exploration by trenching, diamond drill coring, percussion drilling, tunneling, drifting, and systematic sampling of the deposits.

Open pit mining began in March, 1959, at the vein of the Mastuerso zone. A production rate of 100,000 long tons per month to Wells Overseas Limited was established. Pan American built a 60 km. long two lane asphalt highway from the mine to the port at the Bay of San Juan, about 1 km. north of Marcona's port. Here a dock and stockpiling and shiploading facilities were constructed so that ore carriers could be loaded at a rate of 1500 tons per hour. At the mine a crushing and magnetic cobbing plant was constructed with a capacity of 500 tons per hour.

The Acari project was financed through the American Overseas Finance Company of New York, and the Ore Marketing Corporation of Panama. With the exhaustion of the reserves of the Vein 1, Pan American began the underground mining of Vein 1A by sub-level stopping in October, 1961. By August of 1964 the contractor Cia. Bronzzini Hnos. began mining of Veins 5 and 6 in the Campana zone. Work has been extended to the iron deposits of the Pongo zone.

IRON DEPOSITS OF PERU

Recent prospecting, especially in the Coastal and Andean zones of the Peruvian territory, has led to the discovery of a broad variety of iron deposits. Yet, with the exception of the deposits now in production at Marcona and Acari, little information is available.

Currently there are references on the following iron deposits, from north to south: Tambo Grande (Piura); Huamachuco (Trujillo); Moro, Fatima, Pariacoto, Quelleycancha, Canchirao and Aija (Ancash); La Molina (Lima); Huacravilca and Gallosencca (Junin); Otoca and Querco (Huancavelica); Marcona, Yaurilla and Tunga (Ica); Tintay and Chalhuanca (Apurimac); Acari, Chala and Islay (Arequipa); Livitaca, Chumbivilcas and Canas (Cuzco); North Ilo and Morro Sama (Moquegua); Santa Lucia (Puno). Large iron deposits occur in the department of Apurimac, approximately 300 km. from the coast.

A brief description of the main known iron deposits of Peru is given in Table I to acquaint the reader with the general character of these deposits.

ACKNOWLEDGMENTS

The author expresses his sincere appreciation to Dr. Paul D. Proctor, Professor of Geology at the University of Missouri at Rolla and Dean of the School of Science as advisor for the thesis and his guidance, helpful suggestions and friendly discussions. He also supervised the initial writing of the manuscript. The completion of the thesis was done under the advisement of Dr. Richard D. Hagni, Associate Professor at that University. His assistance is gratefully acknowledged.

The author also expresses his gratitude to Dr. Guillermo Dasso, President of the Cia. Pan American Commodities S.A., for permission to work on and complete this research, and for the use of maps and information prepared by the writer while he worked for Pan American.

TABLE I. - Main Iron Deposits of Peru (1966)

DEPOSIT - DEPARTMENT	SHAPE	ORE	% FE	HOST-ROCK	TYPE	RESOURCES	AUTHOR
Marcona - ICA	Manchas	Massive porous martite magnetite	57-58	Hornfels Volcanics	Replacement	1×10^9	F.W. Atchley (1957)
Acari - AREQUIPA	Dike-shaped deposits	Massive, colloform magnetite	60-66	Granodiorite	Magmatic injection	20×10^6	A. Zevallos (1964)
Yaurilla - ICA	Dike-shaped deposits	Hematite Magnetite	58-62	Andesite, granodiorite	Magmatic injection	5×10^6	A. Zevallos (19640
Huacravilca - JUNIN	Mantos	Magnetite		Limestone and quartzose monzonite	Replacement, igneous metamorphic contact	4×10^6	F.S. Simmons and E. Bellido (1956)
Quelleycancha-ANCASH	Tabular bodies	Magnetite	50-64	Shale, granodiorite	Igneous metamorphic contact	1×10^6	A. Zevallos (1961)
Canchirao - ANCASH	Mantos	Hematite, magnetite	40-56	Sandstones, shales and limestones	Near igneous contact	5×10^5	A. Zevallos (1961)
Tambo Grande - PIURA	Beds	Hematite	41-51	Sedimentary rocks	Sedimentary (Venturo, 1904)	12×10^6	I.N.F.M.
Islay - AREQUIPA	Beds	Hematite	35	Gneiss	Sedimentary	1×10^6	J. Fernandez Concha (1956)

Special thanks are due to my friend Ingo Francisco Arbizu, present resident geologist of Acari Iron Mine, for his interest and help in collecting a part of the writer's specimens.

Cordial thanks are also due to Dr. A. C. Spreng, Professor of Geology at the University of Missouri at Rolla, for his help in taking photomacrographs and photomicrographs of specimens studied for the thesis research.

Chapter II

GEOGRAPHY

PHYSIOGRAPHIC FEATURES

Peru is on the west side of South America, between 0° and 18° 20' south latitude, and is characterized from west to east by three parallel physiographic belts which extend longitudinally across Peru from the Bolivian border on the south to Ecuador on the north. These include the coast, the Andean Range and the jungle.

The Acari Iron Mining District is in the southern portion of the coastal belt, 30 kilometers inland from the coast. This district is in the foothills of the western range of the Andes. Within the district topographic characteristics are those of the stage of late youth of an arid erosion cycle. This region is an uplifted fault block with deep longitudinal valleys cutting into the south slope. It is composed of an intrusive rock core partly covered by sedimentary relics and volcanic rocks.

Three main geomorphic units are recognized: 1) The block-fault mountain, whose truncated top, the so-called "pampa San Francisco" is a plateau at 1400 meters elevation. This unit actually rises from 400 in the coastal plain to 1400 meters elevation in the plateau. It is approximately 20 kilometers long and 2 to 5 kilometers wide. The surface of the plateau is nearly flat with few hills which attain altitudes of 1700 and 1900 m. 2) The coastal plain at 400 meters elevation is adjacent to the fault block on the west and southwest border. The surface is generally flat and the slope is gentle and toward the shore line. 3) The alluvial fans forming apron-like masses at the mouth of the main valleys descend from the plateau to the coastal plain. The rigorous dissection suggests recent uplift of the region.

CLIMATE

The cold Peruvian ocean current and the Andean range are the main elements asserting influence on the climate of the region. The current decreases the temperature of the coastal area, which is delightfully low with respect to the latitude, it impedes the amount of evaporation from the Pacific Ocean. Eastward, the Andean Range interrupts the broad sweep of the humid southeast winds passing over the land from the Atlantic Ocean.

Water vapor movement from the low evaporation rate of the Pacific Ocean current is hindered by the mountainous body to the east. A fog is formed periodically and affects the southwest part of the Acari region. This is especially true in the early hours of the day and the nights. It is specially characteristic of winter (June to August). In the summer (January to March) the effect is generally a strong abundant rainfall.

Paracas, known in the northern hemisphere as dust-devils or spiral movements of dusty masses of air, are especially characteristic in the afternoons in this climatic region.

WATER SUPPLY

Only a limited amount of water is available for the Acari Iron Mining District. Water supply for personal and mine operations are obtained from a well in the Jaguay area, 20 kilometers west of the mine camp.

Chapter III

REGIONAL GEOLOGIC SETTING

GENERAL STATEMENT

The study of the local geology of the Acari Iron Mining District has been correlated with regional geology from the fairly recent geologic map of Peru at 1:2,000,000 by E. Bellido and F. Simmons (1957).

Valuable geologic information has been provided by W. F. Jenks (1948 and 1956), G. Petersen (1954), W. Ruegg (1957), and J. Fernandez Concha (1956), from geologic studies in the neighboring areas of Arequipa, Ica and Marcona.

PRE-ORDOVICIAN - LOWER PALEOZOIC

The oldest rocks of Peru have been grouped as Pre-Ordovician and included rocks of Archean and Paleozoic age. These consist of phyllites, schists, gneisses and granites and they outcrop in the Coast Cordillera, Central Cordillera and in the south and central portion of the Eastern Cordillera. In the Coastal Cordillera these rocks occur south of 14° south latitude, including Lomas.

W. F. Jenks (1956) notes that:

> Knowledge of the basement rock of the Coastal and Cordilleran portion of Peru is still limited. Precambrian rocks undoubtedly occur in the country, and perhaps are widespread. It is evident that intense metamorphism of Paleozoic rocks exist in many places, so that it seems unwise to assume that the schists and gneisses are dominantly Precambrian. Strong metamorphosed Mesozoic formations of more than local distribution have not been recorded.

The nearest reference to rocks of Lower Paleozoic age, is in Rio Grande (Ica). Here a series of metamorphosed dark slates are considered of Silurian-Devonian age (G. Petersen, 1954). Some slates and quartzites which outcrop on the west side of the city of Ica are considered to be Silurian (W. Ruegg, 1957).

UPPER PALEOZOIC CARBONIFEROUS (PERMIAN)

Upper Paleozoic rocks have been described in portions of the central Peruvian coast and at the junction of the Grande and Nazca rivers. At Caballa port red quartzites and dark slates crop out which belong to the Ambo group (G. Petersen, 1954).

In the area of Marcona and San Juan Bay, La Justa, Faro and La Punta formations of quartzites, marbles, slates, carbonaceous slates and coal seams crop out. These are probably of the Ambo group (J. Fernadez Concha and Rosenzweig, 1956). These formations are considered members of the Marcona formation which enclose the iron mantos ("Manchas") of the Marcona Mining District (Marcona Company data).

JURASSIC-CRETACEOUS (VOLCANIC SEDIMENTARY FACIES)

Bellido and Simmons (1957) note that:

> Volcanics of submarine origin, associated with marine sediments of Jurassic-Cretaceous age, outcrop in the western flank of the Andean. This sequence of diabasic flows, porphyritic diabases, tuffs, etc., reach considerable thickness.

These volcanic-sedimentary rocks have been called the Andean formation of diabases-melafires (Steinmann, 1930), formation of porphyries, porphyritic formation and porphyritic facies. In Peru this formation is interbedded with strata of Jurassic and Cretaceous age.

These rocks outcrop in Caballa port, in the lower and middle course of the Grande River, between Marcona and Lomas, in Chala and in Ocona. In Grande River, the volcanic rocks are interbedded with sediments of Middle and Upper Jurassic (Ruegg, 1953).

At Arequipa, the Chocolate volcanics comprise 900 m. of andesite, basalt and trachyte flows, tuffs and agglomerates, and interbedded slates, quartzites, calcareous reefs and limestones with fossils of Lower Jurassic age (Jenks, 1948).

LOWER CRETACEOUS

Cretaceous formations comprise about 75% of the outcrops of Mesozoic rocks in Peru. They occur in all of the western Cordillera from 13° south latitude northward and their outcrops extend from the coast to the Amazonian basin.

Outside of the Acari area, bituminous, black limestones outcrop in Portachuel, Nazca (Ica) and belong to the Albionian (Petersen, 1954). W. Ruegg (1957) records:

> The Cretaceous rocks which are restricted to the valley of Ica and the Andean foothills and have undergone much alteration by the Andean batholith. Like elsewhere, the sequence begins with continental sediments (Neocomian), grading upward into more calcareous marine rocks which have locally furnished Albiomian ammonites. Volcanic rocks are abundantly interbedded in the lower part of the sequence. The highly contorted rock near Palpa, characterized by giant concretions, are judged to be Lower-Middle Cretaceous.

Fernandez Concha (1950) mapped small outcrops of Cretaceous rocks in the area of Marcona.

CRETACEOUS-TERTIARY INTRUSIVE ROCKS

Along the Western Cordillera, principally located in the basin of the Pacific Ocean, the so-called Andean batholith crops out. This body crops out continuously from Trujillo southward. The batholith is a complex of many types of plutonic rocks which vary in composition from gabbro to granite, but the main rock type is granodiorite. Small later intrusions of rhyodacite and monzonite occur within the batholith.

Douglas (1920) and Steinmann (1930) offer general descriptions of the batholith. Subsequent studies include that of Vielmeter (1935), Jenks (1948), and Jenks and Harris (1953) in the region of Arequipa; Egeler and DeBoy (1954) and Bodenlos and Ericksen (1955) in the Cordillera Blanca.

The batholith apparently was intruded beginning with Cretaceous time but continuing into the Tertiary (Steinmann, 1930). Jenks (1956) reports:

> The main part of the intrusion apparently took place in early Upper Cretaceous (Lower Senonian) time, yet in the late Upper Cretaceous igneous activity appears to have been at a minimum.

CRETACEOUS-TERTIARY VOLCANICS

A widespread and thick accumulation of volcanic rocks occurs along the Western Cordillera. These consist of agglomerates, breccias, tuffs, and flows, which largely are andesitic in composition and stratified in form.

Steinmann (1930) presents a generalized description of these rocks. Two main series of volcanic rocks, the Tacaza Volcanics (Lower) and the Sillapaca Volcanics (Upper) have been recognized in southern Peru by Jenks (1946) and Newell (1949).

The Tacaza volcanics are considered Cretaceous-Tertiary volcanics, although the age is uncertain. In the region of Lake Titicaca, basaltic flows, breccia flows, agglomerates and tuffs of greenish gray and chocolate color comprise this group.

Newell and Ahlfeld (1949) tentatively correlated the Tacaza volcanics with the Mauri volcanic series of Bolivia of probable Miocenic age (Douglas, 1914).

CENOZOIC VOLCANIC ROCKS

The Cenozoic volcanic rocks are of Pliocene age and have been described in southern Peru as "Sillapaca Volcanics" by Jenks (1946). They consist of flows, flow breccias, tuffs and agglomerates of andesitic composition, basalt flows, and the so-called sillares of rhyolitic tuffs near Arequipa (Jenks, 1948; Fenner, 1948; and Jenks and Goldich, 1956). The petrography of the volcanic rocks of Arequipa has been described by Hatch (1885), Douglas (1920), and Jenks and Goldich (1956).

The thickness of the Chachani volcanics of the Arequipa region equivalent of the Sillapaca volcanics is approximately 2,800 m. (Jenks, 1948).

QUATERNARY SEDIMENTS

Along the Peruvian coast Quaternary silt, sands and gravels form part of the coastal plains, the fluvial plains, and piedmont plains. They also occur in fluvial, marine terraces and dunes of

Quaternary age.

Chapter IV

STRATIGRAPHY

The regional geology was described in the preceding chapter. The present chapter deals with the details of local geology within the Acari Iron Mining District, particularly a review of the stratigraphic and lithologic sequence.

A generalized stratigraphic correlation of the Acari region with regions to the north (Ica) and to the south (Arequipa) is given in Table II. A more detailed rock sequence for the Acari Iron Mining District is shown in Figure 2.

LOMAS COMPLEX

The Lomas Complex consists of gneisses, schists, phyllites, and red granite. In the Las Penuelas area, well-formed pigmatic folds occur in the gneisses. These rocks are well exposed at the port of Lomas, Las Penuelas beach, and at the San Juan Bay, west of the district where they probably constitute the basement rock.

The age of the Lomas Complex has not been determined but as with all the oldest Peruvian rocks it is considered Pre-Ordovician (Bellido and Simmons, 1957).

METASEDIMENTARY ROCKS

Metasedimentary rocks probably constitute the oldest rocks in the Acari Iron Mining District. Two separated outcrop areas are known. One is on the east flank of the upper course of the Loza Valley. Here it is composed dominantly of pink stratified quartzitic sandstones and quartzites on an anticlinal structure plunging about 50° NE. Three hematite deposits, the so-called 7, 8 and 9, occur within the sequence. Deposits 7 and 8 are clearly stratiform.

The other outcrop area to the southwest is in the outlet of the Quebrada de los Chilenos Valley. Here the dominant rocks are pink quartzites. They are metamorphosed, massive, and they do not contain hematite deposits.

The northeastern outcrop is intruded by the granitic intrusive, in its northeastern border and any southwest extension would be unconformably covered by the dark volcanics. The southwestern outcrop zone is intruded in the northwestern part by the granodioritic intrusive. It is overlain unconformably along its NE border by the Chocolate Volcanics.

The lithologic characteristics, metamorphism and presence of hematite deposits suggest a correlation with the Marcona formation. This formation, in turn, has been correlated with the Ambo group of Lower Carboniferous age (Fernandez Concha and Rosenzweig, 1956).

CHOCOLATE VOLCANICS

The Chocolate Volcanics cover a continuous northwest trending belt 10 km. in length and 0.5 to 2 km. in width. They occupy the south slopes of the hills Campana, Pan de Azucar and Loza.

The Chocolate Volcanics are formed principally of porphyritic andesite with phenocrysts of plagioclase and colored dense matrix. The upper part of the sequence is chocolate colored andesite, while the lower part consists of greenish gray andesite. In the Acari

TABLE II.- Generalized correlation of stratigraphic sequenees.

ERA	Period	Epoch	Formations: North ICA G. Pertson 1954	Acari A. Zevallos 1966	South Arequira W. jenks 1948	Others
CENOZOIC	Quaternary	Recent	Salines Terraces Dunes	Clastic deposits	Morraines mud-flood	
		Pleistocene	Tupara F.	White Tufts	Chachani Volcanics	Sillapaca Volcanics
	Tertiary	Pliocene				
		Miocene	Huamani f. Pisco f.	Dark Volcanics	Sotillo f.	Tacaza & Nazca Vol.
		Oligocene				Camana f. Mocueana f.
		Eocene				Paracas f.
		Paleocene				
MESOZOIC	Cretaceous	Upper Middle Lower	Black lime Stone	Limestone (?)	Arcurquim murco.	
	Jurassic			Choclate Volcanics	Yura f. Socosani f. Choclate f.	
	Triassic					
PALEOZOIC	Permian					Mitu Group
	Pennsylvanian					
	Mississipian		Sandstones & slates Paraeas.	Metasedimentary Rocks		AmboGroup (Marcona f.)
	Devonian					
	Silurian					
	Ordovician		Rio Grande slates			
PRE-ORDOVICIAN OR ARCHAIC			Punta Huaco Gneiss	Lomas Complex	Charcani Gneiss	

region the thickness of these volcanics is between 200 and 300 m.

On the southwest slope of the Cerro Campana the contact between the intruded volcanics and the granodiorite intrusive is well shown. This is near the outcrops of Veins 5 and 6 (See PLATE 1). The contacts of the Chocolate Volcanics with the underlying metasedimentary and with the overlying Dark Volcanics appear to be angular unconformities.

The lithologic and stratigraphic characteristics permit broad correlation with the Chocolate Volcanics of the region of Arequipa (Jenks, 1948). His suggested name is adopted in this thesis. Similar rocks occur in Grande River, between Marcona and Lomas, Chala and Ocana (Ruegg, 1953). These volcanics have been called "diabase-melaphyre" by Steinmann (1930). Jenks (1948) believes that the Chocolate Volcanics must be of Jurassic and probably of Lower Jurassic age.

DARK VOLCANICS

The Dark Volcanics are widespread and cover a broad belt of N 40° W trend, about 20 km. in length and from 3 to 5 km. in width. They occupy approximately the southwest half of the plateau.

This rock series consists of some basalt flows and tuffs, but it is predominantly gray andesite and porphyritic andesite. The latter contains phenocrysts of plagioclase and pyroxene in a fine-grained matrix.

The Dark Volcanics enclose copper veins, numbered 15 and 16, and the "Pluto" gold vein. They are related to dikes which cut older rocks and which have been referred to as late green andesite porphyry.

These volcanic rocks cover the erosional surface cut across the Chocolate Volcanics, granodiorite and granite intrusives. Locally they underlie a white tuff.

The dark volcanic rocks are correlated with the Nazca volcanics and the Tacaza volcanics. The Tacaza volcanics are considered to be Tertiary age (Jenks, 1946; Newell, 1949). It is possible, however, that their age ranges from Upper Cretaceous to Upper Tertiary (Cerro de Pasco staff).

WHITE TUFFS

Discontinuous outcrops of White Tuffs are distributed along the plateau. They overlie the erosional surface cut on the Dark Volcanics and the granite intrusive. The thickness of the white tuff ranges from 10 to 50 m.

These pyroclastic rocks consist of a heterogeneous mixture of porous white matrix enclosing phenocrysts of glass and andesitic fragments. They are white on the fresh surface and grayish pink on the weathered surface. They do not contain any mineral deposits. The white tuffs are related to dikes and pyritic stocks that cut the Dark Volcanics.

The White Tuffs are correlated with the Chachani Volcanics of Arequipa (Jenks, 1948). These latter are composed principally of rhyolitic and dacitic tuffs called the "sillar". The Chachani Volcanics in turn are correlated with Sillapaca Volcanics. Newell (1949) indicates that the Sillapaca Volcanics range from Pliocene to Recent in age.

GRAPHIC REPRESENTATION OF
STRATIGRAPHIC SEQUENCE AND IGNEOUS INTRUSIONS
OF ACARI REGION

By: A. Zevallos C

Date: September 1964

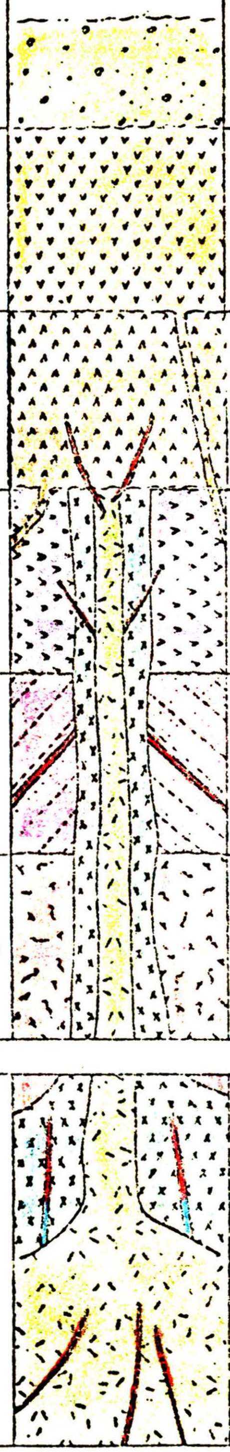
AGE	STRATIGRAPHIC COLUMM	Unconformities	DESCRIPTION	PROBABLE FORMATION	THICKNESS (Meters)
Quaternary		Disconformity	*Alluvium; culions sands bearing titanium and iron (C° Conchudo)*		50±
Tertiary		Angular Unconformity	*White Tuff (Plateau)*	Pisco (?) Formation	100±
Tertiary		Angular Unconformity	*Dark basic Flows Country rock of gold and copper veins (Pluto, 15 vein)*	Nazca Volcanics (?)	300±
Jurassic (?)		Angular Unconformity	*Chocolate and green Volcanics*	Cerritos Formation (?)	400±
Paleozoic		Angular Unconformity	*Quarzite, arenaceous hornfels Country rock of taconite beds of the Lozo quebrodo*	Marcona (?) Formation	
Pre-Cambrian			*Pink granite schist, gneiss and granitized zones.*	Lomas Complex	
Cretaceous			*Granodioritic intrusive, including light colored porphyry and granodiorite country rock of iron veins of Acari and Ponga*	Intrusives	
			Granitic intrusive including acidic and basic stocks. Country rock of copper veins of plateau (Génova, Acari VIII, and Cobre Acari)		

FIGURE 2.- Stratigraphic Jequence and Igneous Intrusions of the Acari Iron Mining District.

CLASTIC DEPOSITS

In Quaternary times, the last erosional and constructional stage produced many small areas covered by alluvial gravels and eolic deposits of sands on the plateau. These include for example, the windblown magnetiferous sands of Cerro Conchudo. The main valleys of the region have been filled by alluvial fans that descend from the plateau to the coastal plains. Thus, in the north part of the Acari region, we have the large valleys of Tranca Baja, Calapampa and Romerill, which are almost of E-W trend. In the southern part, from west to east, are the valleys of Pongo, Yuyuca, Mastuerso, Cardonal, Militar, Quebrada de los Chilenos, San Francisco, Pan de Azucar and Loza, and the Acari River, all of which have a N-S trend. All of the valleys have extensive alluvial fans at their mouths.

HISTORICAL GEOLOGY SUMMARY

The oldest Pre-Ordovician rocks crop out beyond the Acari Iron Mining District, where they are called the "Lomas Complex". Within the Acari region, the oldest formation is a metasedimentary unit composed dominantly of highly metamorphosed pink quartzites. These enclose the hematite deposits of the Loza Valley. They are correlated with the Marcona formation, which is possibly Mississippian in age.

The Chocolate Volcanics rest unconformably on the metasedimentary rocks in the Quebrada de los Chilenos Valley. They consist of porphyritic andesitic flows of green and chocolate color. These volcanics are correlated with the Chocolate Volcanics of the Arequipa region and they are of Jurassic age.

The Andean batholith probably was intruded at the close of Cretaceous time. Here it was formed by an early granodiorite intrusive and by a later granite intrusive. Granodiorite occurs in the southwestern part and granite in the northeastern part of the Acari Iron Mining District. These intrusive rocks are the host rock for the known magnetite deposits and copper veins.

During Tertiary time intense erosion denudated most of the overlying volcanic and metasedimentary rocks and some parts of the batholith. Following this period of deep erosion, widespread vulcanism produced dark flows of basalt and andesite which covered the entire area. These volcanic rocks, which contain copper veins, correlate with the Tacaza Volcanics.

Block faulting, during the process of formation of the Andean Cordilleran, was followed by deep erosion of the uplifted blocks. This produced the Acari tilted fault-block upon which was exposed a central northwest trending band of volcanic and metasedimentary remnants, located between the granodiorite and granite intrusives, along the southwest border of the plateau.

At the close of Tertiary time, the pyroclastic White Tuffs were deposited. A subsequent erosion cycle formed the main valleys that bisect the Acari region.

Still later, in Quaternary time, the flood plains, alluvial fans and coastal plain were developed. During this time the black magnetite sands of the Cerro Conchudo zone probably were formed.

Chapter V

INTRUSIVE IGNEOUS ROCKS

GENERAL FEATURES

The intrusive rocks, which occur in the Acari Iron Mining District, belong to the Andean batholith of Cretaceous-Tertiary age. They form the core of the uplifted fault-block and are now largely exposed due to intense erosion. The intrusive rocks represent stages of intrusion from granodiorite to the granite. The two intrusive bodies are discussed separately because of the differences in occurrence, composition, structure and type of ore deposits enclosed in these two host rocks.

The granodiorite intrusive occupies the southwest part, and the granite intrusive the northeast part of the mining district. As noted earlier, part of the erosional surface on these intrusive bodies, including their intrusive contacts, have been nonconformably covered by later volcanic rocks.

Jenks (1955) in a paper on the plutonic rocks of the Arequipa region made the following statement:

> The part of the batholith within the Arequipa quadrangle is a fair sample of what may be expected in the coastal batholith elsewhere in the southern departments of Arequipa and Moquegua.

Jenks (1948) distinguished five stages of intrusion in the region of Arequipa (Table III). The granodiorite and a fine-grained granite, belonging to the last stages. If it is possible to consider similar processes in both regions, on the data available, the intrusives of the Acari region also could belong to the last stages.

TABLE III.- Modes of some specimens of intrusive rocks of the Arequipa region (W.F. Jenks and E.G. Harris, 1953) and of the Acari region (R.A. Zevallos, 1966).

REGION AND INTRUSIONS	QUARTZ	K-FELDSPAR	PLAGIOCLASE	HORNBLENDE	BIOTITE	ACCESSORIES	TOTAL	TYPE OF ROCK AND LOCATION
AREQUIPA REGION								
1) Huasamayo Tonalite.	31	12	48	7	1	1	100	Tonalite(AR385). West slope 1 km. NW. of junction of Yura and Chili rivers.
	40	31	24	-	4	1	100	Quartz Monzonite (AR250). Railway cut at pass between Vitor and Quishuarani.
	36	18	31	-	11	4	100	Granodiorite (AR247). Ridge NW of Yura River, 4 km. NE of junction of Chili River.
2) Tingo Complex.	2	0.5	45.5	45	-	7	100	Diorite(AR84). Hill 2 km. NE. of Tiabaya.
	24	30	37	6	2	1	100	Granodiorite(AR83). Hill at Sachaca.
3) Caldera Intrusive.	29	41	23	-	5	2	100	Granite(AR357). Arequipa-Ramal higway at km. 42 .
	21	42	29	3	3	2	100	Quartz Monzonite (AR278). Vitor at Morocoro.
	24	24	34	9	5	4	100	Average composition of granodiorite.
	18	16	45.5	11.5	5	4	100	Average composition of tonalite.
	-	-	61.4	36.8	-	1.6	100	Gabbro(AR367). Summit of Cerro Gloria.
4) Tiabaya Granodiorite	10	8	50	22	9	1	100	Tonalite(AR255). West slope of Cerro Gloria.
	21.7	25.3	42	5.5	3.4	2.1	100	Average composition of granodiorite.
5) Late Acid Intrusives.								
ACARI REGION								
1) Granodiorite Intrusive	10	22	42	20	-	6	100	Granodiorite(A-28). Representative. West slope of Gordon Hill.
	6	27	46	13	-	8	100	Granodiorite(A-35). North slope of Gordon Hill.
	16	34	30	18	-	12	100	Quartz Monzonite Porphyry (A-29). Representative . West slope of Gordon Hill.
	-	24	36	26	-	14	100	Monzonite Porphyry(A-26). Representative. South slope of Gordon Hill.

In Table III are presented the modes of some specimens of the main intrusive rocks of the Arequipa region, collected by Jenks, and of the Acari region collected by the writer.

Steinmann (1929) considers the principal igneous activity occurred in the Eocene to early Oligocene (Incaic orogeny). Jenks (1956) suggests that the main part of the intrusive activity apparently took place in early Upper Cretaceous (Lower Senonian), and that in late Upper Cretaceous time igneous activity was at a minimum.

GRANODIORITE INTRUSIVE

As early as 1959, the writer considered that the intrusive rocks of the Mastuerso zone formed from several igneous facies of one intrusion. He termed this, the "Mastuerso Series".

Bradley (1962) in his report on Gordon Hill and on La Mancha parts of the Mastuerso zone, pointed out three types of rock: 1) light medium-grained granodiorite, 2) light colored porphyry and 3) dark hornfels. These units were noted on the geologic plan, mapped by him and Borkowski.

The granodiorite intrusive occupies the southwestern part of the mining district, largely along the southwest slope of the plateau. The body trends NW and is some 15 km. in length and from 2-5 km. in width. It extends from the Romerillo Valley to the Quebrada de los Chilenos Valley, including the hills Pajayuna (1653 m.), Pongo (1650 m.), Yuyuca (1686 m.), Huanaco (1550 m.), Mastuerso (1550 m.) and Campana (1678 m.).

Megascopic and microscopic features of the granodiorite intrusive permit subdivision into three types of igneous rocks. These constitute different igneous facies of one intrusive body: 1) fresh, white, medium-grained granodiorite with abundant and regular distribution of magnetite (6-10%), and irregular distribution of hornblende and quartz, 2) a "pink porphyry" on fresh surface, classified as quartz monzonite porphyry, with a higher content of quartz and abundant magnetite distributed in a pink, fine-grained matrix, and 3) the so-called "hornfels" are actually monzonite porphyry with abundant magnetite (14%).

The granodiorite shows a phaneritic, holocrystalline, hypautomorphic, equigranular texture and characteristically abundant, medium grained (3-4 mm.), elongated crystals of calc-alkalic feldspar (10-50% An; predominantly oligoclase). These plagioclases generally exhibit polysynthetic and carlsbad twinning. There also is a lesser proportion of medium grained orthoclase. Other medium-grained, green crystals of hornblende (2-3 mm.) dominantly exhibit poikilitically distributed small magnetite crystals. Locally the hornblende is partially surrounded by rims of small grains of magnetite. Small anhedral grains of quartz are irregularly distributed throughout the rock. Small crystals of magnetite are regularly distributed among the larger crystals. One exposure of white granodiorite consists only of plagioclase with disseminated magnetite in an area of no known magnetite deposits. The main granodiorite occupies approximately 92% of the total area of the granodiorite intrusive.

The so-called pink porphyry is a quartz monzonite porphyry that shows a holocrystalline, hypautomorphic, porphyritic texture. Phenocrysts make up more than 50% of the rock. These are medium-grained crystals of plagioclase, largely oligoclase, with polysynthetic twinning, and medium-grained crystals of hornblende containing abundant magnetite crystals. The matrix consists of very fine-grained cloudy, pink orthoclase with disseminated larger grains of quartz (16%) and magnetite (9%). The quartz monzonite porphyry occupies 5% of the total areal extent of the granodiorite intrusive.

The so-called hornfels and dark porphyry is a monzonite porphyry which has holocrystalline, hypautomorphic and porphyritic texture, with phenocrysts making up more than 50% of the rock. The pink porphyry differs in the absence of fine quartz grains, the increase of fine magnetite grains and in the presence of medium-grained dark brown hornblende that gives a dark tone to the rock. The monzonite porphyry occupies 3% of the total area of the granodiorite intrusive.

In summary the granodiorite intrusive exhibits the following characteristics:

1. It encloses the magnetite deposits which fill two main sets of fractures; one of N 45° E trend, and the other of N 30° W to N 10° E bearing.
2. The principal rock is a white, medium-grained granodiorite, with the dominant mineral a medium-grained calc-alkalic feldspar, largely oligoclase, generally accompanied by green hornblende.

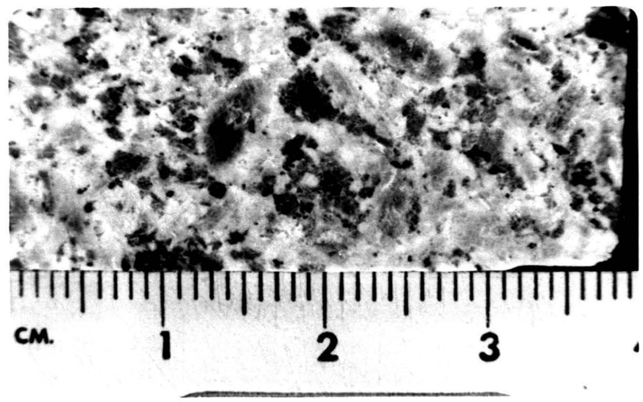


Figure 3- photograph of a sawed slab of a typical specimen of light, medium-grained granodiorite. Mastuerzo zone, specimen A-35.

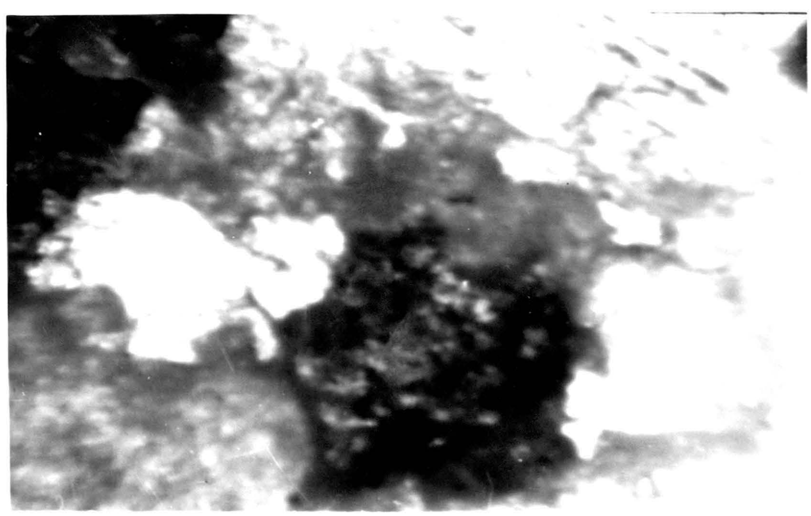


Figure 4- Photomicrograph of typical light medium-grained geanodiorite showing plagioclase (polysynthetic twinning), anhedral grains of quartz (white) and hornblende (dark gray) with poikilitic distribution of magnetite (black). Mastuerzo zone, specimen A-35, thin section, crossed nicols. 32 X

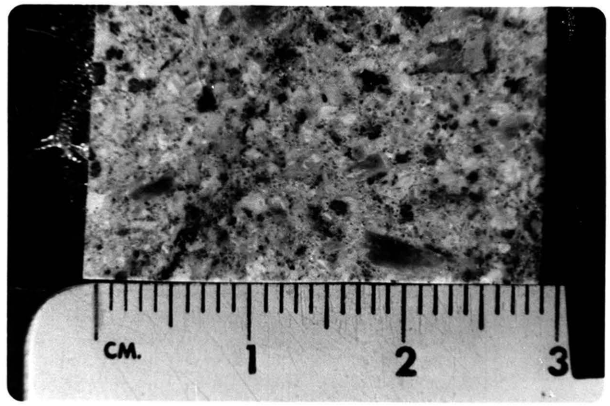


Figure 3- photograph of a sawed slab of a typical specimen of light, medium-grained granodiorite. Mastuerzo zone, specimen A-35.

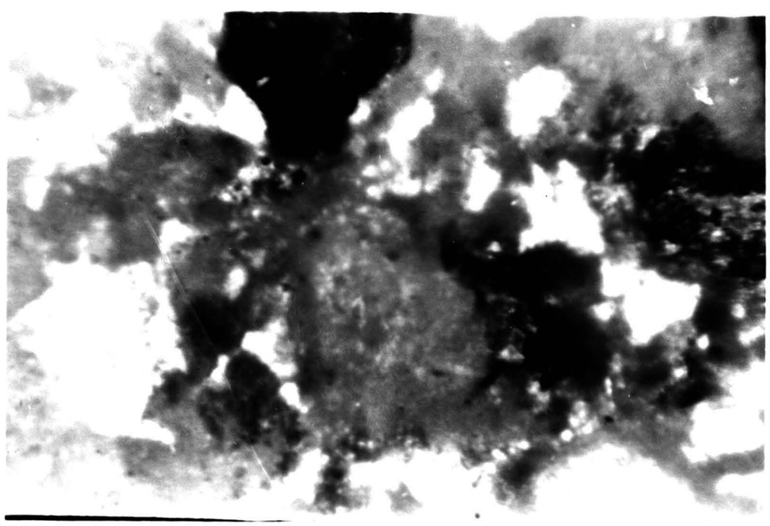


Figure 4- Photomicrograph of typical light medium-grained geanodiorite showing plagioclase (polysynthetic twinning), anhedral grains of quartz (white) and hornblende (dark gray) with poikilitic distribution of magnetite (black). Mastuerzo zone, specimen A-35, thin section, crossed nicols. 32 X

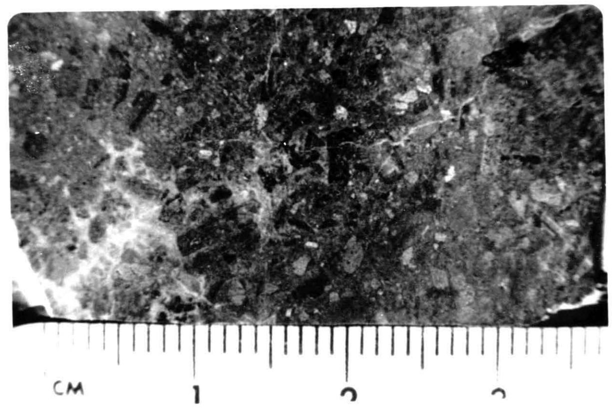


FIGURE 7.- Photograph of a sawed slab of a typical specimen of monzonite porphyry (dark porphyry). Mastuerzo zone, specimen A-26.

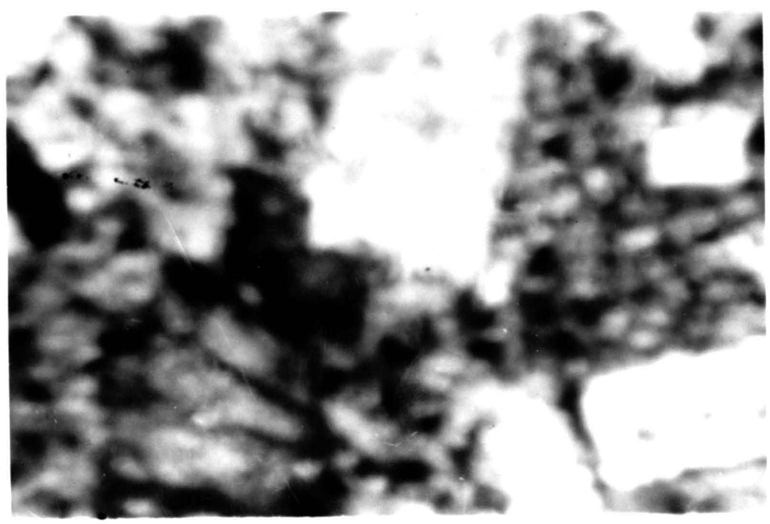


Figure 8- Photomicrograph of typical mozonite porphyry, showing phenocrysts of plagioclase (white) and brown hornblende (dark gray), surrounded by a fine- grained matrix of plagioclase and orthoclase (gray) with disseminated magnetite (black). MAstuerzo zone, specimen A-26, thin section, plane polarized light. 32 X.

GRANITE INTRUSIVE

The granite intrusive is in the northeastern portion of the Acari region, mainly underlying the plateau. Here it occupies a northwest trending belt 20 km. by 2 km.

The dominant rock is a reddish granite composed of euhedral crystals of orthoclase which range from medium-grained (3-4 mm.) to fine-grained. Quartz occurs as medium-grained grains. Black, large crystals of pyroxenes (augite) and tourmaline (4-5 mm.) form some phenocrysts. These occur in the extreme southeast portion of the intrusive. In the extreme northeast part, the intrusive shows segregations of mafic and felsic rocks of fine-grain.

Briefly, the granite intrusive exhibits the following characteristics:

1. It encloses the copper veins which strike N 60° W to almost east-west.
2. Granite is the dominant rock, and the principal minerals are pink orthoclase, quartz and black pyroxenes.

Chapter VI

STRUCTURAL GEOLOGY

GENERAL STATEMENT

The Acari Iron Mining District lies within an uplifted fault block with a larger vertical displacement on the south side than the north. In the latter area the displacement is almost imperceptible.

The district is divided into three structural units: 1) the southwest unit formed by the granodiorite intrusive and 2) the northeast unit constituted by the granite intrusive, which belongs to the Andean or Coastal batholith. But they were intruded at different times. Different fracture patterns are present in the two intrusive bodies. 3) Between the intrusives an intermediate unit occupies an elongated area of northwesterly trend. It is composed of intruded older metasedimentary and volcanic rocks, and younger volcanic rocks nonconformably overlying the intrusive bodies.

The structural pattern of the Acari region can be observed in the vertical sections across the area shown in Plate 2.

ACARI TILTED FAULT BLOCK

The Acari Iron Mining District is considered to be part of one of the several fault blocks uplifted during the process of formation of the Andean Cordilleran.

Data on the dimensions of the fault block follow. The northern border is approximately 25 km. long and trends N 80° W. This corresponds to the valley Tranca Baja which drains westward to the coastal plain and the Calapampa Valley which descends eastward to the Acari River. Vertical displacement along this border was very small. The west border is approximately 12 km. long and trends N 25° W. It now constitutes the steep scarp of the west slope of the Cerro Pajayuna. The eastern border is about 15 km. long and trends N 10° E. It forms the scarp of the west slope of the Acari River. The southern border is about 20 km. long and trends N 65° W. The deep denudation of the of the south border is partly due to the presence of longitudinal fractures which form a system of parallel valleys. Vertical slip was maximum along the south border.

Features which support the existence of this tilted fault block are:

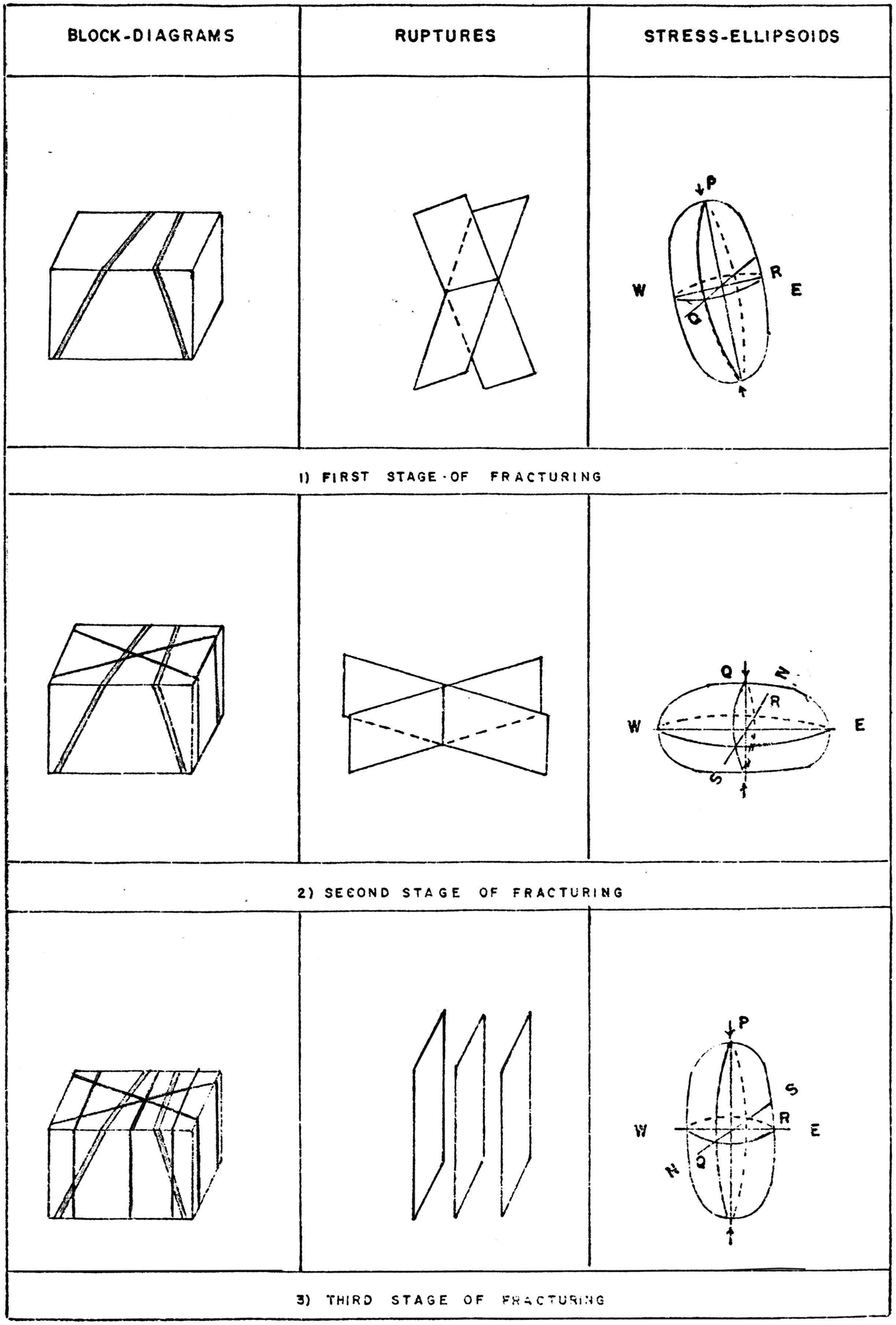
1. The steep fault scarp on the west and east border. In the south border the initial relief due faulting has been modified by erosion.
2. The post-intrusion dark volcanics that lie, in the coastal plain, westward of the Acari region are also horizontal.
3. The inclined northeastern plunge of the fold in the metasedimentary rocks, within the Loza Valley.

SOUTHWEST STRUCTURAL UNIT

The southwest structural unit is composed of granodiorite. It represents the first stage of intrusion in the Acari region. Structural information pertaining to this unit is abundant because the granodiorite intrusive encloses important magnetite deposits.

Within the southwest unit three main fracturing stages can be discerned. The stages are discussed from oldest to youngest. 1) The first stage of fracturing has produced two principal systems of fractures. One system, the Pongo zone, strikes from N 60° E to N 40° E, and dips 60-80° West. The other system of fractures, the Mastuerzo and Campana zones, strikes from N 50° W to N 15° E and dips 60-80° East. 2) The second stage of fracturing produced transverse fractures, which have effected horizontal and vertical displacements in the fractures belonging to the first stage. The strike of these transversal fractures ranges from N 70° W to N 80° E and the dip varies from 70° to 80° south or north.
3) The third stage of fracturing is constituted by longitudinal fractures which trend N-S with a steep dip toward the east or west.

The relationship of rupture to stress in the different fracturing stages are shown in the diagram of the Figure 9. In the first fracturing stage the greatest principal stress axis was sub-vertical and inclined northeastward. For this reason the two systems of fractures close northeastward. They would have been parallel if the principal stress had been vertical. The intermediate principal stress axis was sub-horizontal and in a northeast-southwest direction. And the least principal stress axis was sub-horizontal and northwest-southeast. During this stage stress pressure has produced shear fractures. These shear fractures were then filled by the iron-rich fluids forming the

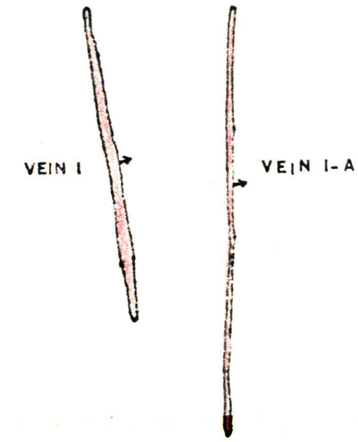

BLOCK-DIAGRAMS
RUPTURES
STRESS-ELLIPSOIDS
P
R
W
E
Q
1) FIRST STAGE OF FRACTURING
Q
N
R
W
E
S
2) SECOND STAGE OF FRACTURING
P
S
R
W
E
N
Q
3) THIRD STAGE OF FRACTURING

magnetite deposits. Subsequently the upper part of this fracturing pattern has been eroded.

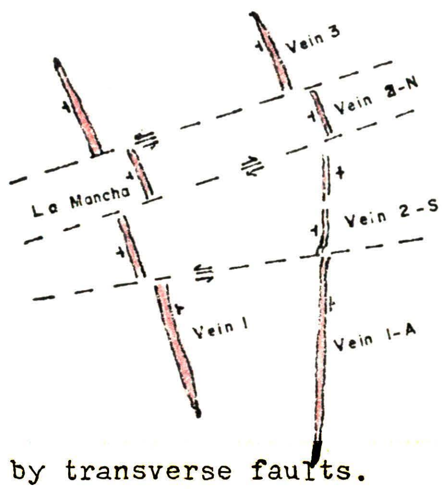
In the second fracturing stage, the greatest principal stress axis was horizontal and almost east-west; the intermediate principal stress axis was vertical, and the least principal stress axis was horizontal and north-south. The east-west compression stress at this stage probably was caused by the emplacement of the granite intrusive to the north. The sub-vertical shear fractures which it produced, displace the magnetite deposits in earlier shear fractures. Their horizontal slips are approximately 1 to 200 m. and the vertical displacement is 1 to 50 m.

In the third stage of fracturing, the greatest principal stress was vertical, which caused the lifting of the Acari fault block, the intermediate principal stress axis was horizontal and north-south and the least principal stress axis was horizontal and east-west. Compressive stress during this stage produced longitudinal tension fractures, along which subsequent erosion developed a system of longitudinal valleys on the south side of the Acari tilted fault block. These longitudinal faults have produced the complicated structural pattern shown in the Figure 10. Movement along the longitudinal faults was of rotational nature with the maximum vertical slip of over 100 m. located at the south extremity. These faults are zones, commonly from 0.50 to 2.00 m. wide, which exhibit abundant gouge and breccia.

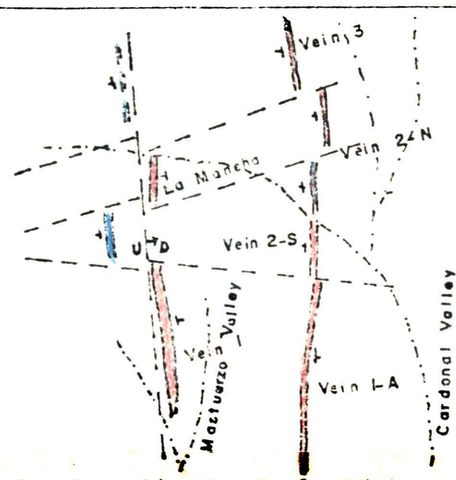
A diagramatic explanation of the modification which the magnetite deposits 1 and 1A of the Mastuerzo zone have suffered by the various stages of fracturing is given in Figure 10. Fractures



(A) Fractures of the first stage of fracturing in the granodiorite filled by iron-rich fluids.



(B) Faulting produced by transverse faults.



(C) Faulting produced by longitudinal faults.

FIGURE 10.- Diagram showing the different stages of faulting of the veins 1 and 1-A, Mastuerzo zone, Acari Iron Mining District.

of the first stage (Figure 10A) were filled by the iron-rich fluids which formed the magnetite deposits called veins 1 and 1A. Then the transverse faults of the second stage (Figure 10B) produced displacements of the magnetite deposits. During the third stage of fracturing a large longitudinal fault lifted the west side of the Mastuerzo zone, which subsequently was deeply eroded. The following features support that interpretation. 1) The west side of the longitudinal fault consists almost completely of granodiorite, which belongs to the deeper part of the granodiorite intrusive. In contrast, the east side is formed by granodiorite and pink porphyry, igneous facies characteristic of the peripheral portion of the intrusive body. 2) In the open trench in La Mancha deposit, the contact between unconsolidated material on the east and fresh rock on the west could be clearly observed. 3) The wide structure of amphiboles on the west side and between the north extremity of the vein 1 and the south extremity of the La Mancha deposit coincides with the widths observed in vein 1 and La Mancha deposits.

NORTHEAST STRUCTURAL UNIT

The northeast structural unit is composed of granite intrusive. The granite belongs to the second stage of intrusion in the Acari region.

The main system of fractures observed in this structural unit belongs to the first stage of fracturing. These are a system of transverse fractures, which are long structures from 1-5 km. in length. They strike from N 60° W to N 80° E, and dip very steeply to the north. Copper veins are found in some of these fractures in the Acari region. This system of fractures has been produced by the same compressive stress which formed the transverse fractures of the second stage of fracturing in the southwest structural unit. They are also shear fractures.

The second stage of fracturing in the northeast structural unit is represented by the same longitudinal N-S fractures found in the southwest structural unit. However, the rotational movement along the fractures in this unit has produced smaller displacements.

INTERMEDIATE STRUCTURAL UNIT

The intermediate structural unit has its longest dimension in a northwesterly direction and it is located between the southwest and the northeast structural units. Pre-intrusives rocks (the Metasedimentary rocks and Chocolate Volcanics) and some post-intrusives rocks (the Dark Volcanics and White Tuffs) comprise the main rock types of this unit.

Between the pre-intrusive rocks, the metasedimentary rocks have been strongly metamorphosed and folded. They consist principally of quartzites and hornfels. On the east slope of the upper course of the Loza Valley, the metasedimentary rocks exhibit a net anticline whose axis strikes N 14° E and plunges about 60° NE. These rocks enclose stratiform hematite deposits. The flows of the Chocolate Volcanics, which gently dip southeastward, do not show any predominant system of fractures.

Between the post-intrusive rocks the Dark Volcanics exhibit a system of fractures which trends from N 20° W to N 40° W and dips very steeply. These fractures are filled by felsic dikes and by veins containing quartz, copper and gold. The White Tuffs lies horizontally on the plateau and it does not exhibit any principal system of fractures. The White Tuffs are correlated with the felsic dikes and pyritized stocks.

SEQUENCE OF TECTONISM AND METALLIZATION

A close relationship between the tectonic processes which produce the fracturing of the rocks and the metallization processes which cause the formation of metalliferous deposits appears to exist in the Acari region.

The following is the probable sequence of the metallization and tectonic processes which took place in the Acari Iron Mining District:

1. Formation of miogeosyncline in the Upper Paleozoic (Metasedimentary rocks).
2. Formation of an eugeosyncline in the Jurassic (Chocolate Volcanics).
3. Emplacement of the granodiorite intrusive.
4. Formation of the fractures in the pre-iron mineralization fracturing stage, including two main systems. One strikes from N 60° E to N 40° E and dips 60-80° West. The second strikes from N 50° W to N 15° E and dips 60-80° East.
5. Iron mineralization.
6. Hypogenetic alteration of the magnetite deposits.

7. Emplacement of the granite intrusive.
8. Formation of the pre-copper mineralization transverse fractures. A system of fractures which trends from N 60° W to N 80° E and dips very steep northward or southward.
9. Widespread volcanic activity including the eruption of the Dark Volcanics and emplacement of andesitic dikes.
10. Copper mineralization.
11. Formation of the post-mineralization north-south longitudinal fractures.
12. Uplifting of the Acari fault block.
13. Pyroclastic activity producing the widespread White Tuffs and emplacement of the felsic dikes and pyritic stocks.
14. Later erosive period which eroded the longitudinal fractures to form longitudinal valleys in the south slope of the uplifted fault block.

Chapter VII

ECONOMIC GEOLOGY

GENERAL SUMMARY

The metallic mineral deposits of the Acari Iron Mining District are classified according to structural and lithologic setting, mineralogy and genesis. At least classes of four mineral deposits are recognized:

1. Magmatic injection magnetite deposits
2. Stratiform hematite deposits
3. Magnetite black sands
4. Hydrothermal copper veins

MAGMATIC INJECTION MAGNETITE DEPOSITS

DISTRIBUTION

The magmatic injection magnetite deposits occur within the granodiorite intrusive. Based on their geographic position, three zones are distinguished:

1. Mastuerzo zone
2. Campana zone
3. Pongo zone

OCCURRENCE

The geologic setting for all of the magnetite deposits in all three zones is that of ore dike filling of fracture zones by magnetite. The magmatic injection iron deposits fill two main sets of fractures developed in the granodiorite intrusive. One set, which strikes from N 40° E to N 60° E and dips 60° to 70° northwestward, includes the iron deposits of the Pongo zone. The other set ranges from N 20° W to N 15° E and dips from 70° to 80° to the east. Magnetite deposits of the zones of Mastuerzo and Campana are included in this latter group. Transverse faults showing both vertical displacements up to 50 m. and horizontal displacements up to 200 m. cut these deposits. Some of the magnetite deposits also have undergone vertical displacements of more than 100 m. along longitudinal faults.

MINERALOGY AND TEXTURE

The mineral composition and texture of the upper part of this type of iron deposit is simple. Black, fine-grained, massive and compact magnetite is almost the only mineral. Very small amounts of apatite give the ore less than 0.15% phosphorus. Surface exposures have been oxidized to hematite and martite. The magnetite also occurs as more or less disseminated crystals, and as fillings of networks and small fissures and stockworks in the host rock. Near the important fault zones the magnetite is brittle and pulverized. Some vugs (1 cm.) in the magnetite ore are filled by crystalline quartz.

While the upper portions of the iron deposits are dominantly magnetite, the deposits exhibit marked mineralogical changes with depth. At intermediate depths in these mineral deposits, veinlets composed principally of actinolite (10-20 mm.) or actinolite mixed with octahedral magnetite cross the massive magnetite. These veinlets also exhibit rosettes of specularite. Pink to white

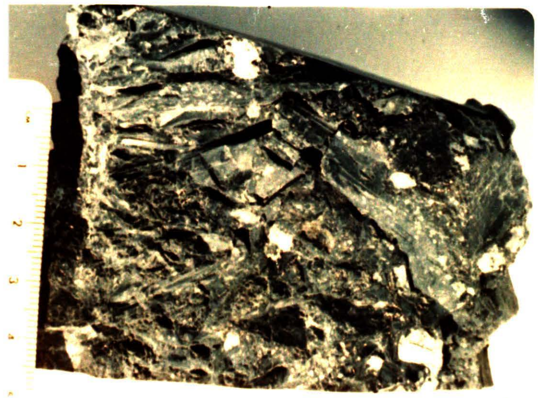


Figure 11- Photograph of hand specimen from a veinlet composed by a mixture of large crystals of actinolite (green), apatite (white) and secondary magnetite (gray), cutting the primany magnetite body. Mastuerzo zone, 944 level, Vein 1A, specimen A-11.

Figure 11- Photograph of hand specimen from a veinlet formed by by a octahedral crystals of magnetite , with one of their granodiorite wall rock. Pongo zone, Vein 1A, specimen A-27.

apatite grains (1-2 mm.) are present throughout the massive magnetite and within the actinolite veinlets. The apatite occurs as disseminations and as thin stringers, and it increases in amount with depth. In this intermediate zone the mineral deposits show transitional stages from magnetite in the upper part to quartz, carbonates (calcite, dolomite, ankerite) or amphiboles (actinolite) or mixtures of them in the lower part. Specimens were collected from the transitional zones of vein 1A of the Mastuerzo zone for detailed megascopic study of the hand-specimens and microscopic study of their thin and polished sections.

In the lowest portions of these deposits the dominant minerals are amphiboles (actinolite) mixed with lesser quantities of apatite, carbonates, quartz, and greenalite (?). The texture generally is fine-grained (1 mm.) and equigranular.

MEGASCOPIC DESCRIPTION

The megascopic study of the hand specimens comprised 49 specimens from the mineral deposit and 13 specimens from the host rock. One polished flat surface was prepared on each specimen. The thin and polished sections were prepared parallel to that flat surface. The results of the megascopic study of the specimens of the transitional zones observed in the underground workings of the vein 1A of the Mastuerzo zone are summarized below:

1. In the 744 level, from south to north, the specimens show gradual changes from a mixture of amphiboles and carbonates to massive magnetite. The amphibole-carbonate specimens exhibit a

grayish green color and a fine-grained texture. Some medium size crystals of apatite (5 mm.) and actinolite (3-4 mm.) are present. The magnetite specimens are cut by veinlets (10 mm. wide) of actinolite with some apatite (5 mm.). The crystals of actinolite occur with their long axis normal to the walls of the veinlets. Polished surfaces of the magnetite specimens reveal colloform texture in which the scalloped layers locally are replaced by amphibole (see Figures 13 - 18).

2. In the 8 raise, from the 744 level to the 810 level, the lowest specimen is a fine-grained matrix of amphiboles and carbonates with rare disseminated crystals of apatite (5 mm.). The intermediate specimens show a colloform texture, in which some of the cavities among the scalloped layers have been filled by apatite and carbonates. The upper specimen shows massive magnetite with colloform texture and some disseminated crystals of apatite (See Figures 19-22).

3. In the 810 level, from south to north, the specimens gradually vary in composition from magnetite to amphibole-carbonate. The magnetite specimens show colloform texture with botryoidal free surfaces. In some specimens the scalloped layers of magnetite are cut by veinlets (1-5 mm. in width) consisting of apatite, calcite and lesser quantities of quartz (See Figures 23 and 24).

4. In the 870 level, from south to north, the specimens gradually change in composition from magnetite to silica-amphibole. The magnetite exhibits colloform texture. The transitional specimens show relicts of magnetite surrounded by fine-grained quartz. One specimen shows scalloped layers of magnetite surrounded, cut and

Figure 13- Photograph of a polished flat surface of an amphibole specimen showing colloform texture. Quartz fills interlayer cavities. Mastuerzo zone, Vein 1A, 744 level, specimen A-62.

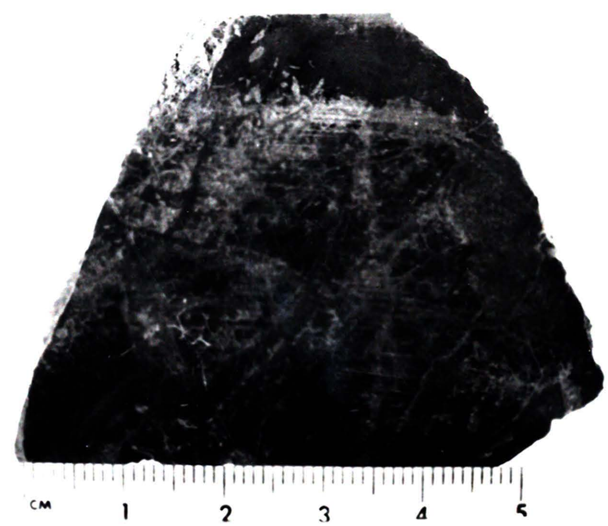


Figure 14 - Photograph of a polished flat surface of a specimen showing magnetite in the upper and lower parts, and scalloped layers in the middle portion Mastuerzo zone, 744, level, Vein 1A, specimen A-3.

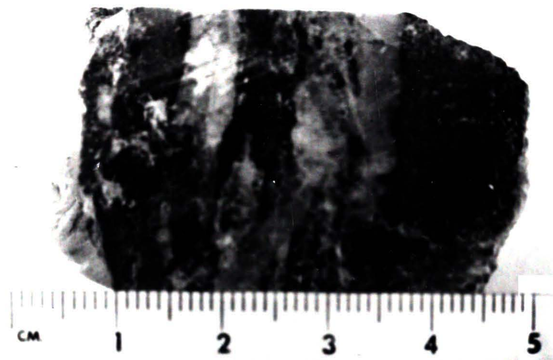


Figure 15- Photograph of a polished flat surface of a colloform magnetite specimen . Quartz (light gray) forms veinlets and fills the cavities between the scalloped layers of magnetite. Mastuerzo zone, 870, level, Vein 1A, specimen A-10.

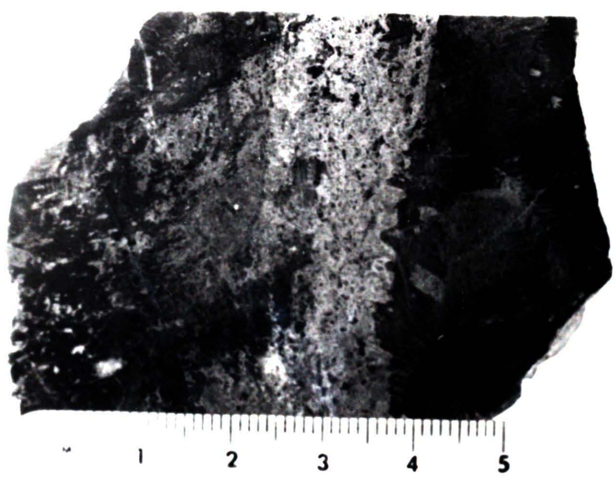


Figure 25- Photograph of a polished flat surface of an amphibole specimen showing colloform texture. Quartz fills interlayer cavities. Mastuerzo zone, 870, level, Vein 1A, specimen A-10.

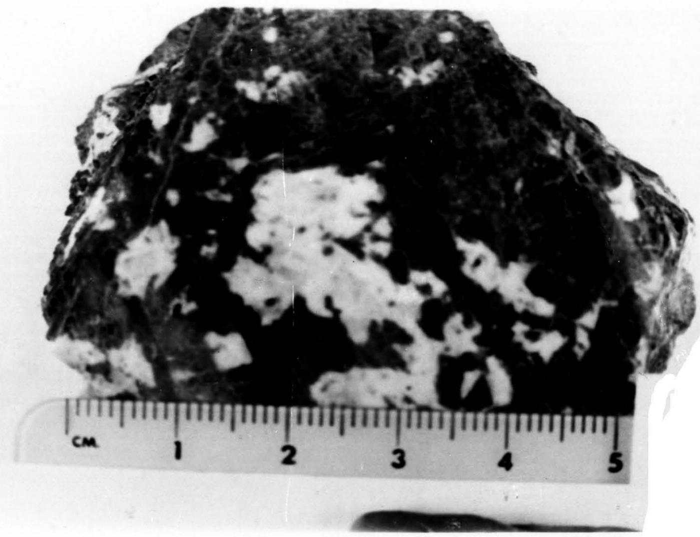


FIGURE 17.- Photograph of a polished flat surface showing large crys - tals of actinolite (gray) and apatite (white) which are part of a veinlet which cuts the colloform massive magne- tite. Mastuerzo zone, Vein 1A, 744 level, specimen A-2.

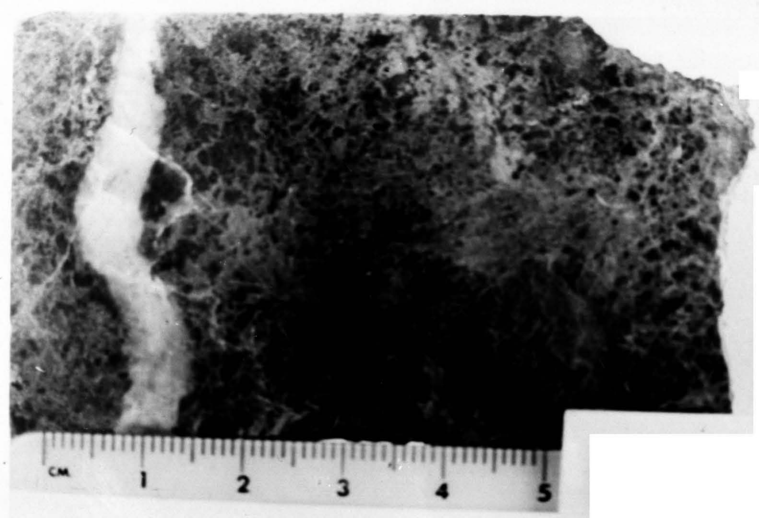


Figure 18- Photograph of a polished flat surface of a specimen from the amphi- bole barren zone. It consists of a amphiboles, apatite, and carbonates with nin-grained and colloform texture. It is crossed by a quartz veinlet (white). Mastuerzo zone, Vein 1A, 741 Specimen, A-1

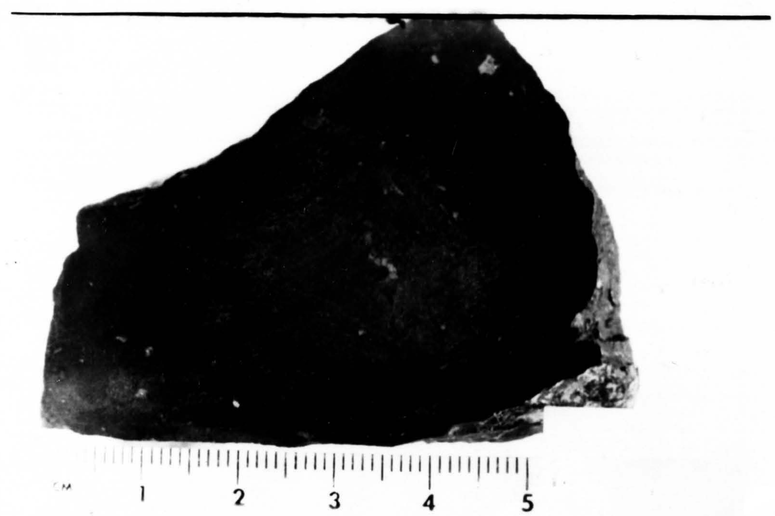


Figure 19- photograph of apolished flat surface of a magnetite specimen showing colloform texture. Mastuerzo zone, Vein 1A, upper part of 8 raise, specimen A-8.

Figure 20- Photograph of a polished flat surface of a specimen of colloform magnetite with apatite, carbonates and amphiboles, filling its cavities. Mastuerzo zone, middle part of 8 raise, specimen A-7

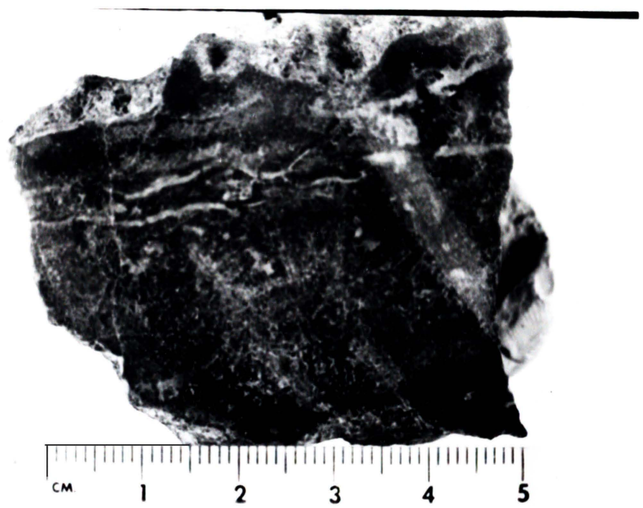


Figure 21- Photograph of a polished flat surface of a specimen showing scalloped layers of magnetite with apetite , carbonates and amphiboles filling cavities. Mastuerzo zone, middle part of a 8 raise, Vein 1A, specimen A-5

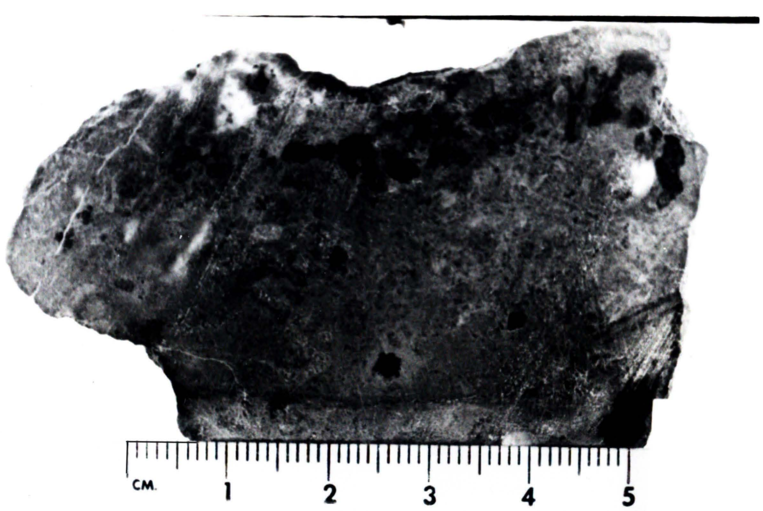


Figure 22- Photograph of a polished flat surface of a specimen which consists of amphiboles, carbonates, apatite and quartz, and which exhibits colloform texture. Mastuerzo zone, Vein 1A, lower part of 8 raise, specimen A-5

Figure 23- Photograph of a polished flat surface of a specimen of a colloform magnetite. In the upper part the youngster free surface is botryoidal. All of the scalloped layers are convex toward the freee layer. Synersis fractures are present. Mastuerzo zone, Vein 1A, 810 leel, specimen A-17

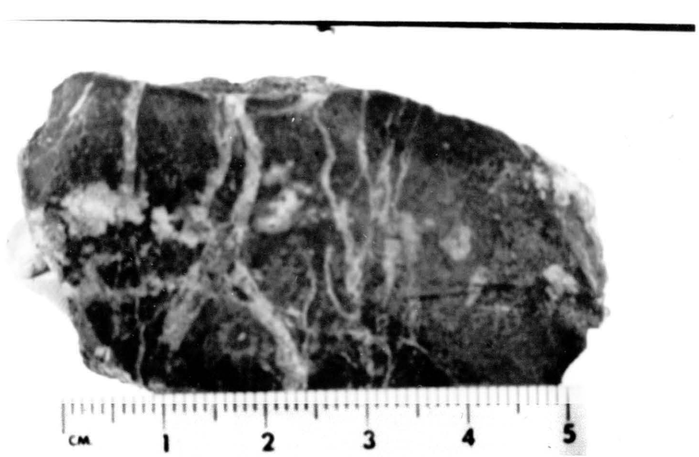


Figure 24.- Photograph of a polished flat surface of a specimen composed of colloform magnetite. Carbonates, apatite and quartz fill interlayer cavities and transverse fractures. Mastuerzo zone, Vein 1A, 810 level, specimen A-14

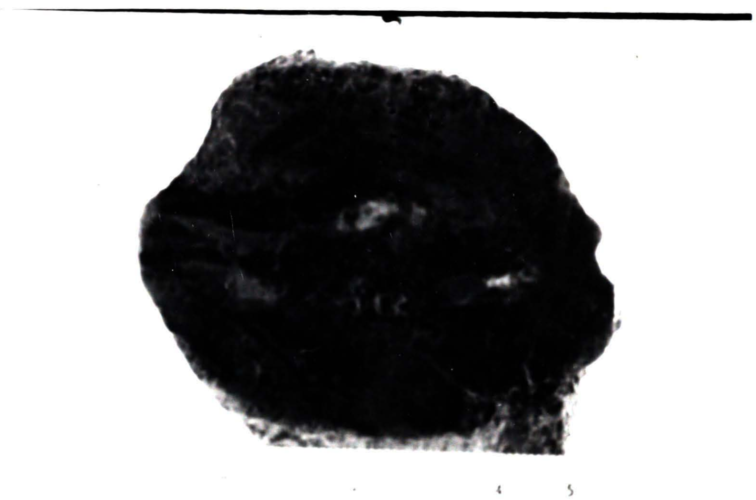


Figure 25- Photograph of a polished flat surface of an amphibole specimen showing colloform texture. Quartz fills interlayer cavities. Mastuerzo zone, 870, level, Vein 1A, specimen A-10.

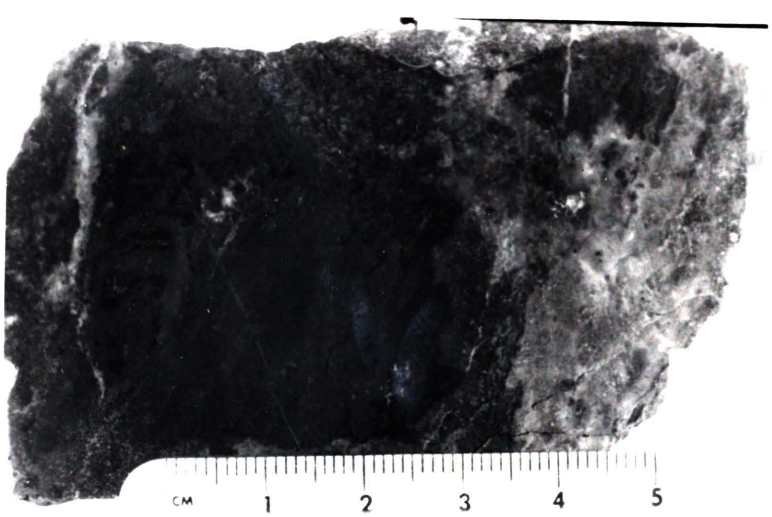


Figure 26- Photograph of a polished flat surface of specimen showing colloform magnetite surrounded by quartz which cut and fills some of the interlayer cavities. Mastuerzo zone, 870, level, Vein 1A, specimen A-9.

Figure 25- Photograph of a polished flat surface of a specimen which consists largely of quartz surrounding magnetite renmants. They exhibit colloform texture. Mastuerzo zone, Vein 1A, 870 level, specimen A-20

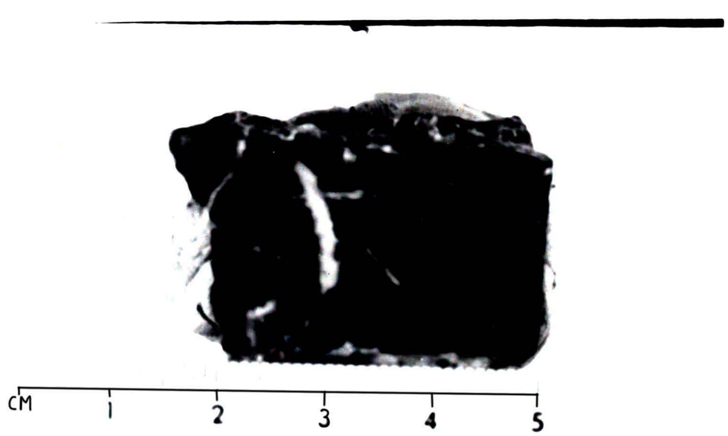


Figure 28- Photograph of a polished flat surface of a specimen of colloform magnetite. Quartz and calcite fill some interlayer cavities and transverse fractures. Mastuerzo zone, Vein 1A, 870 level, specimen A-19

FIGURE 29.- Photograph of a polished flat surface of a specimen showing colloform magnetite cut by a veinlet composed of large crystals of actinolite (bright gray), apatite (white) and secondary magnetite. Mastuerzo zone, Vein 1A, 944 level, specimen A-11.

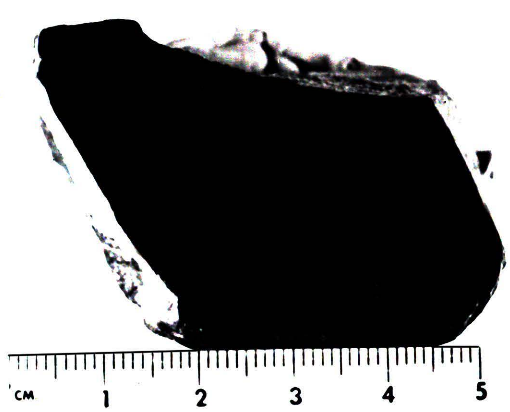


Figure 30- Photograph of a polished flat surface of a pure magnetite specimen with colloform texture. Mastuerzo zone, Vein 1A, 944 level, specimen A-25.

replaced by quartz. Specimens at the north extremity show scalloped layers composed by amphiboles (See Figures 25 - 28).

5. In the 944 level, from south to north, the magnetite passes gradually to amphibole. One specimen of magnetite exhibits a veinlet (30 mm.) formed dominantly by large crystals of actinolite (10-30 mm.) mixed with apatite, secondary octahedrohs of magnetite and quartz, while its walls consist of colloform magnetite. Another specimen exhibits a veinlet of colloform magnetite (10 mm.) enclosed in granodiorite (See Figures 29-30).

6. The colloform texture generally is observed only on well polished surfaces of the specimen. Colloform texture also has been observed in specimens from the 1010 level, and from surface specimens above the 810 and 1010 levels.

MICROSCOPIC STUDY

The microscopic investigations comprised the preparation and study of 51 thin sections and 51 polished sections of the ores and 13 thin sections of the host rock. The identification of the constituent minerals was made by employing index of refraction determinations on crushed fragments by the oil immersion method and by determining diagnostic optical properties in thin sections. The results are summarized below:

1. In the 744 level, the amphibole-carbonate vein has a fine-grained matrix composed principally of greenalite (?), calcite and ankerite. The matrix encloses masses of calcite with polysynthetic twinning, radiate prochlorite and amphiboles containing small

magnetite grains. In some specimens the apatite surrounds amphiboles which contain magnetite. Relicts of the magnetite scalloped layers are observed in the specimens of the amphibole-carbonate rock (Figure 31). Polished sections show that the magnetite has a microporosity following the scalloped layers. The magnetite exhibits core replacement texture in which the amphiboles invade the core of the host mineral and leave the rim unreplaced (See Figures 31-36).

2. In the 8 raise, the amphibole-carbonate rock shows a fine-grained matrix formed principally of calcite and apatite. Relicts of calcite enclosing radiate green crystals of prochlorite and cummingtonite are present. The amphiboles contain magnetite crystals in their border. The specimens of the transitional zone exhibit scalloped layers of magnetite replaced by calcite and apatite. The magnetite is microporous following the scalloped layers (See Figures 37-42).

3. In the level 810, veinlets of apatite and quartz cut the magnetite ore. Epidote partly surrounds specularite. The matrix of the amphibole-carbonate structure is composed dominantly of amphiboles, calcite and apatite. Calcite is found with remnants of disseminated magnetite. The magnetite is microporous.(See Figures 43 and 44).

4. In the 870 level, the magnetite exhibits rim replacement texture, being surrounded by apatite and quartz. The quartz shows mineral zoning. The scalloped layers of the magnetite are replaced by amphiboles, calcite and quartz. The magnetite is cut by some veinlets of quartz. The magnetite is microporous and the difference

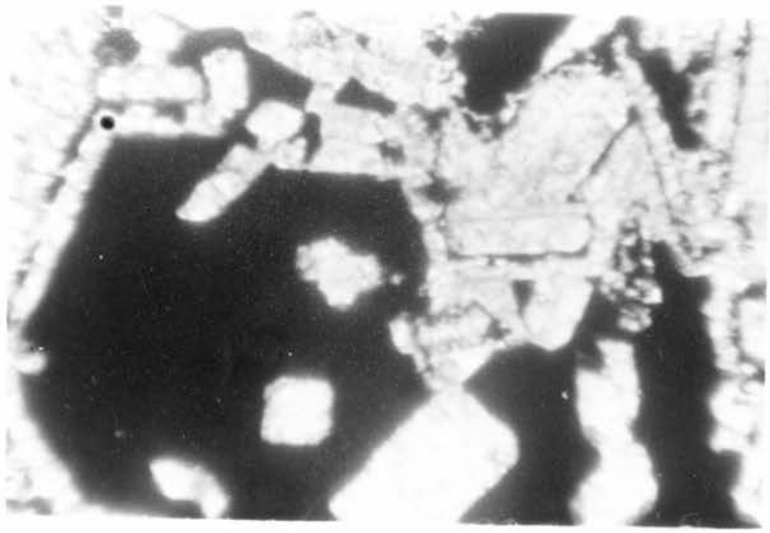


Figure 31- Photomicrograph of a this section showing amphibole crystals (gray) formed by replacement along the cavities in the colloform magnetite (black). Mastuerzo zone, Vein 1A, 744 level, specimen A-56. 32 X, plane polarized light.

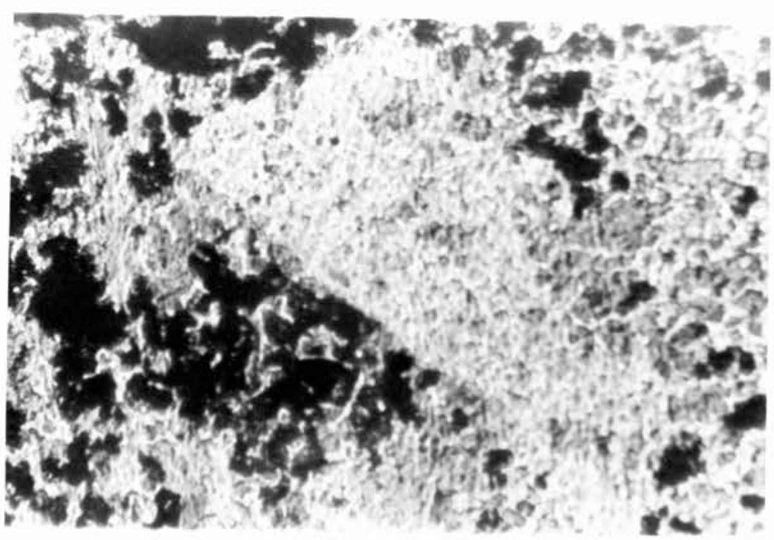


Figure 32. - Photomicrograph of a polished section showing magnetite with colloform and microporous texture. Mastuerzo zone, Vein 1A, 744 level, specimen A-56. Plane polarized light, 100X.

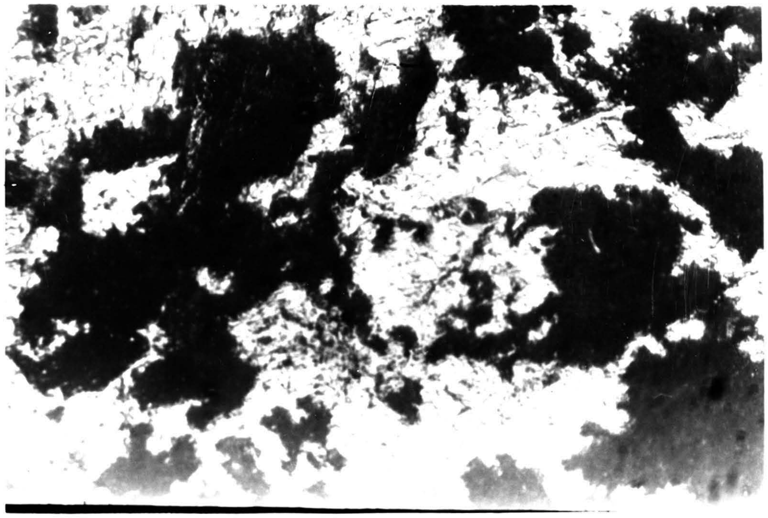


Figure 33- Photomicrograph of a polished section showing colloform and microporous magnetite. Mastuerzo zone, Vein 1A , 744 level , specimen A-54 . 100 X. Plane polarized light.

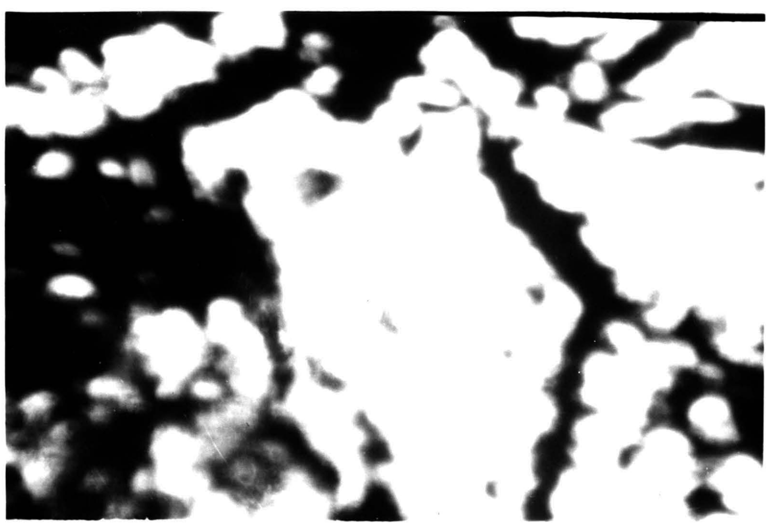


Figure 34- Photomicrograph of a thin section showing scalloped layers magnetite. (black) amd replace by amphibole (gray). Mastuerzo zone, Vein 1A , 744 level , specimen A-3 . 32 X. Plane polarized light.

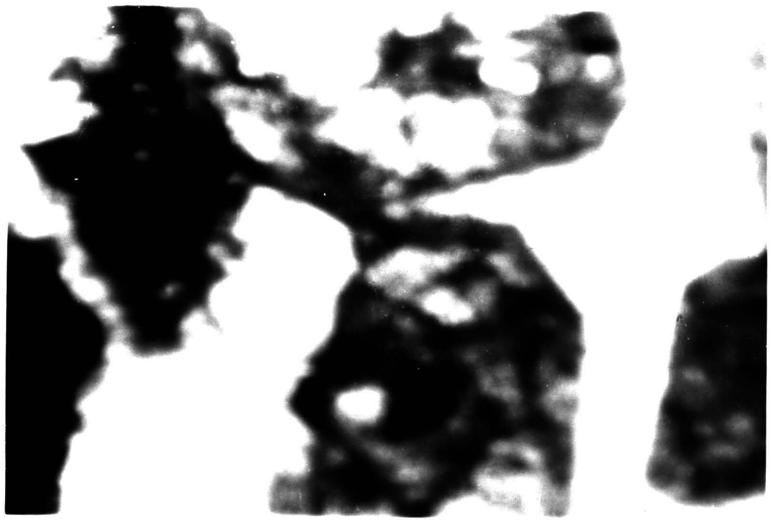


Figure 35- Photmicrograph of a thin section showing large crystals of amphibole (dark gray) with poikilictic distribution of grains of magnetite (black), surrounded by quartz (white) Mastuerzo zone, Vein 1A, 744 level, specimen A-2. Plane polarized light. 32 X

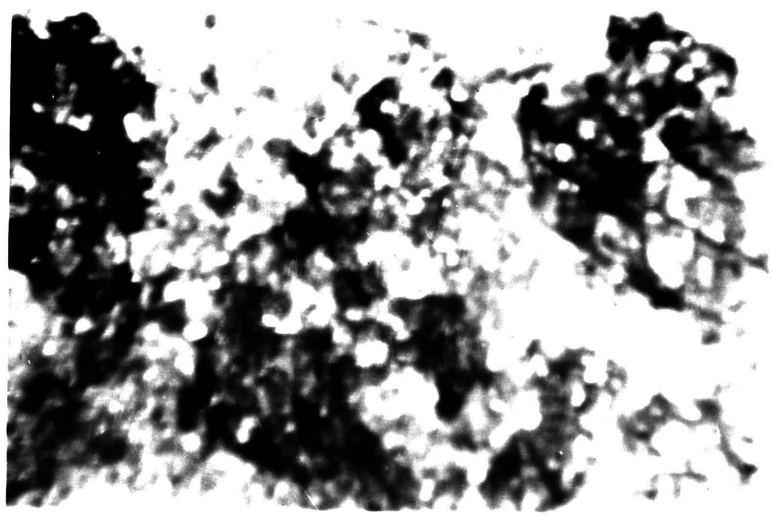


Figure 36- Photomicrograph of a thin sectio n showing metacrysts of amphiboles (dark gray) conatining replacement remnants of magnetite (black), surrounded by a matrix formed by carbonates (light gray), apatite (white), quartz (white) and amphibole. Mastuerzo zone, Vein 1A, 744 level, specimen A-1. Crossed nicols. 32 X.

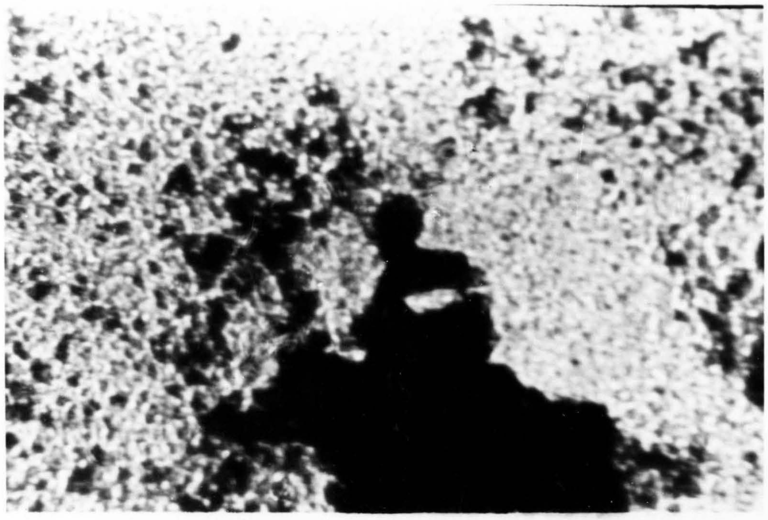


FIGURE 37.- Photomicrograph of a polished section showing magnetite with colloform and microporous texture. Mastuerzo zone, Vein 1A, upper part of 8 raise, specimen A-8. Plane polarized light. 100 X.

FIGURE 38.- Photomicrograph of a thin section showing a scalloped layer of magnetite (black) and calcite, apatite and quartz (white) filling the cavities. Mastuerzo zone, Vein 1A, middle part of 8 raise, specimen A-7. Plane polarized light. 32 X.

FIGURE 39.- Photomicrograph of a thin section showing colloform magnetite (black) and cavities filled with apatite,carbonates and quartz (white), and amphiboles (gray) formed by metasomatism. Mastuerzo zone, Vein 1A, middle part of 8 raise, specimen A-7.

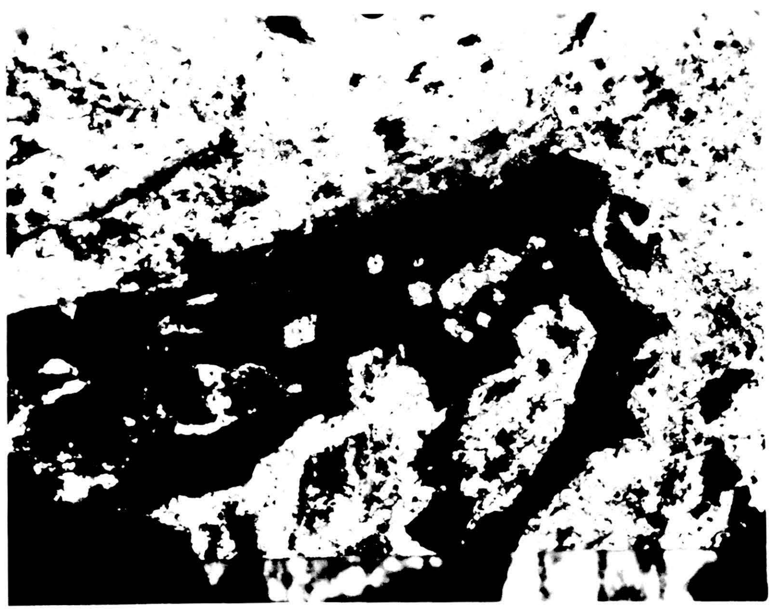


FIGURE 40.- Photomicrograph of a thin section showing a scalloped layer of magnetite (black) surrounded by a matrix composed of quartz (white), abundant apatite (white) and replacing amphibole (gray). Mastuerzo zone, Vein 1A, middle part of 8 raise, specimen A-6.

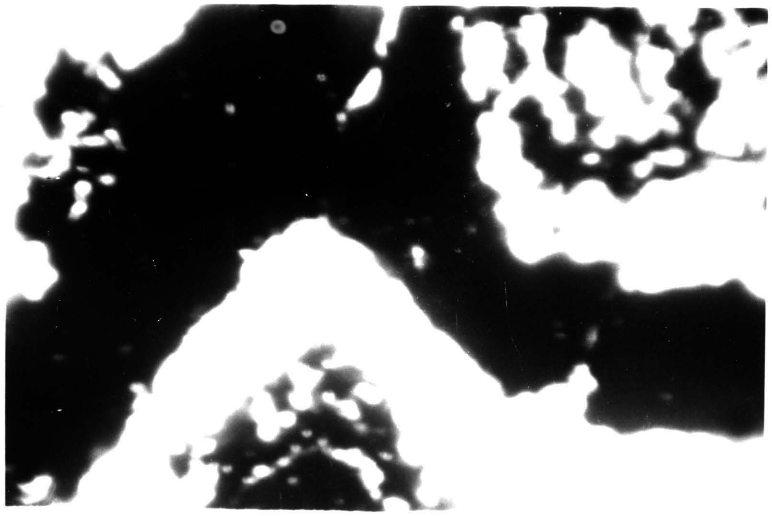


Figure 41- Photomicrograph of a thin section showing a scalloped layer of magnetite with calcite, apatite and quartz filling the cavities. Mastuerzo zone, Vein 1A, middle part of 8 raise , specimen A-6. Plane polarized light. 32 X.

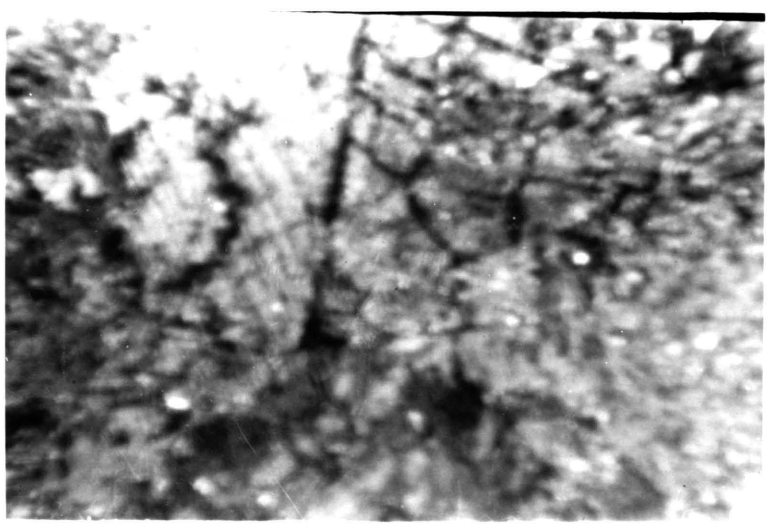


Figure 42- Photomicrograph of a thin section showing metacrysts of amphibole with renmant grains of magnetite (black) surrounded by calcite (with cleavage), apatite and quartz (white) . Mastuerzo, Vein 1A, lower part of 8 raise, specimen A-5. Crossed nicols. 32 K.

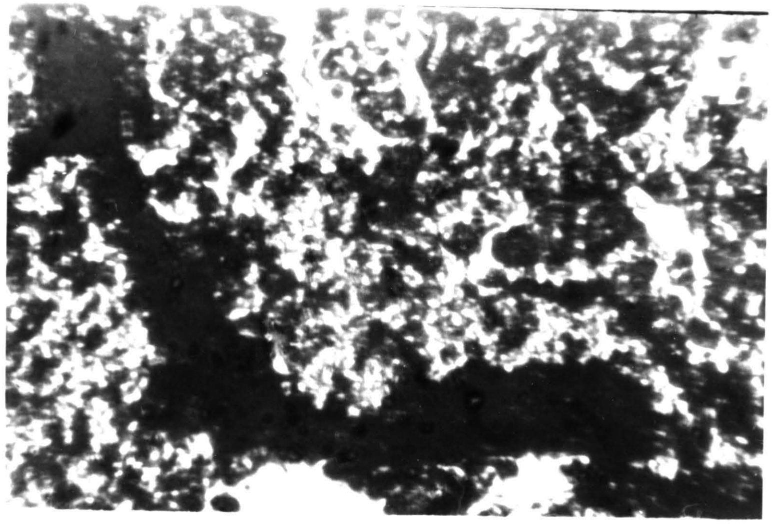


FIGURE 43.- Photomicrograph of a polished section showing magnetite with colloform and microporous texture. Mastuerzo zone Vein 1A, 810 level, specimen A-17. Plane polarized light. 100 X.

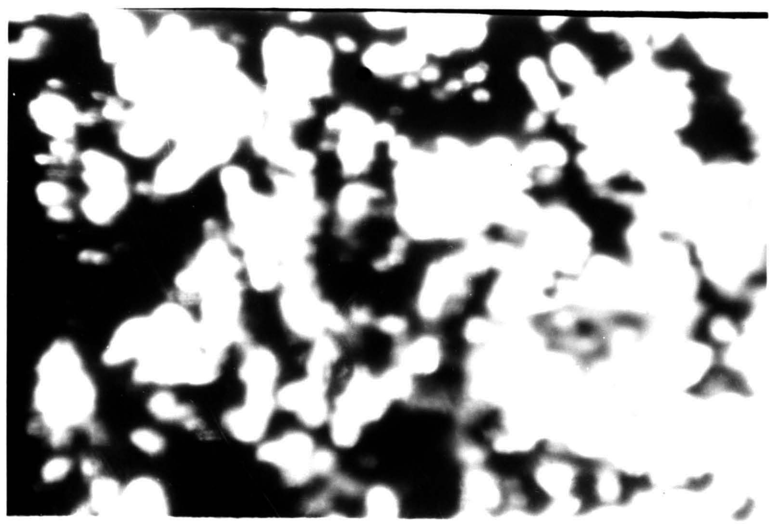


Figure 44- Photomicrograph of a thin section showing magnetite veinlets (black) crossing the pink porphyry host rock, composed plagioclase phanocrysts (elongated, white) and matrix formed by a mixture of plagioclase and orthoclase (dark gray) and small grains of quartz (white). Mastuerzo zone, Vein 1A 810 level, specimen A-12. Plane polarized light. 32 X.

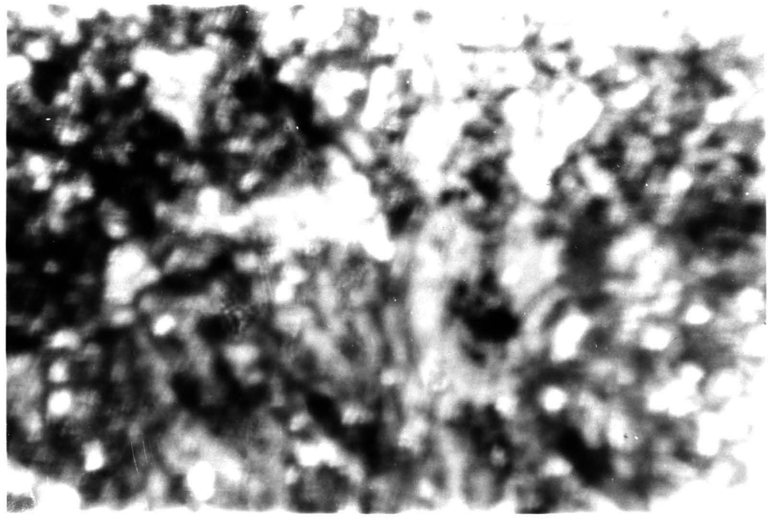


figure 45- Photomicrograph of a thin section of an amphibole specimen showing crystal of amphibole containing grains pf magnetite (black), apatite (gray) and quartz (white). Mastuerzo zone, Vein 1A, 870 level, specimen A-10. Plane polarized light. 32 X.

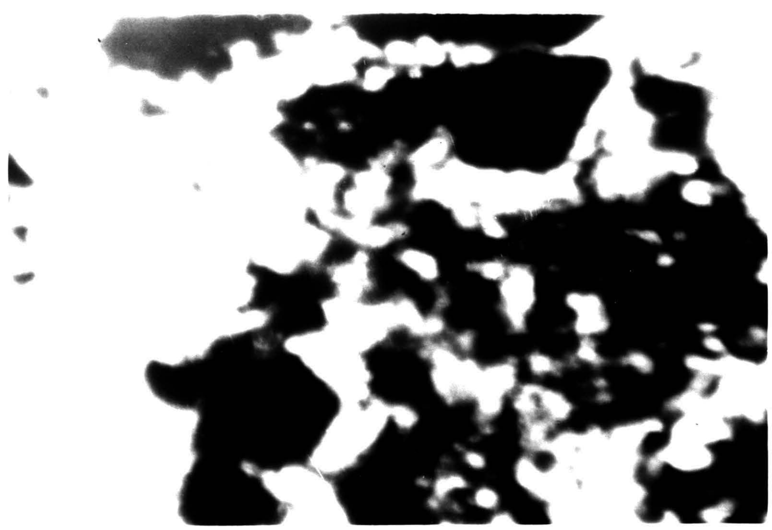


Figure 46- Photomicrograph of a thin section magnetite renmants surrounded by quartz. Mastuerzo zone, Vein 1A, 870 level, specimen A-9. Plane polarized light . 32 X.

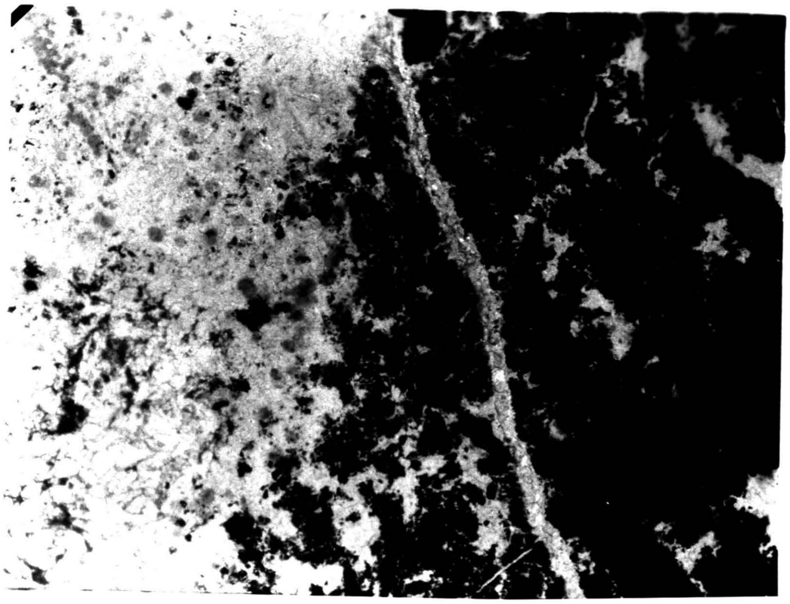


FIGURE 47.- Photomicrograph of a thin section showing the replacement front composed by quartz (light gray) entraneing upon magnetite (black). Mastuerzo zone, Vein 1A, 870 level, specimen A-9.

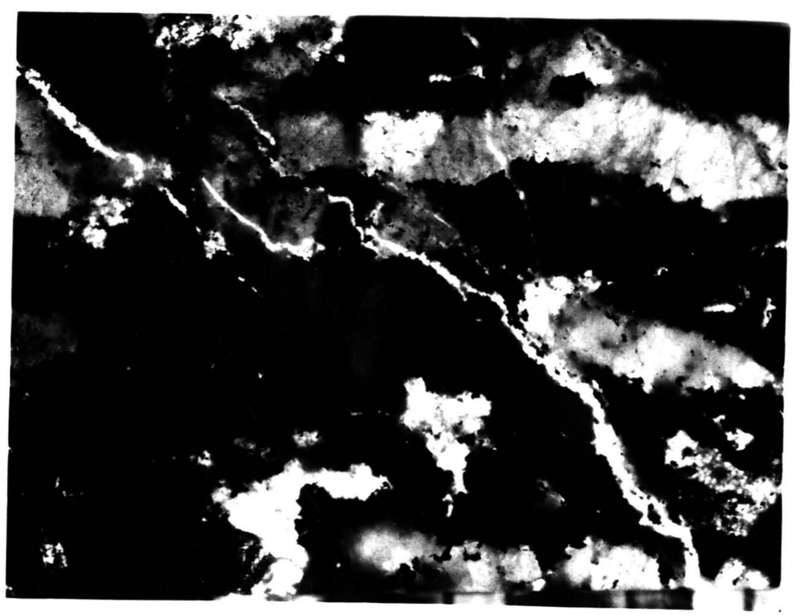


figure 48- photomicrograph of a thin section showing cavities between the scalloped layers of magnetite (black) filled by quartz (white). Mastuerzo zone, Vein 1A, 870 level, specimen A-20.

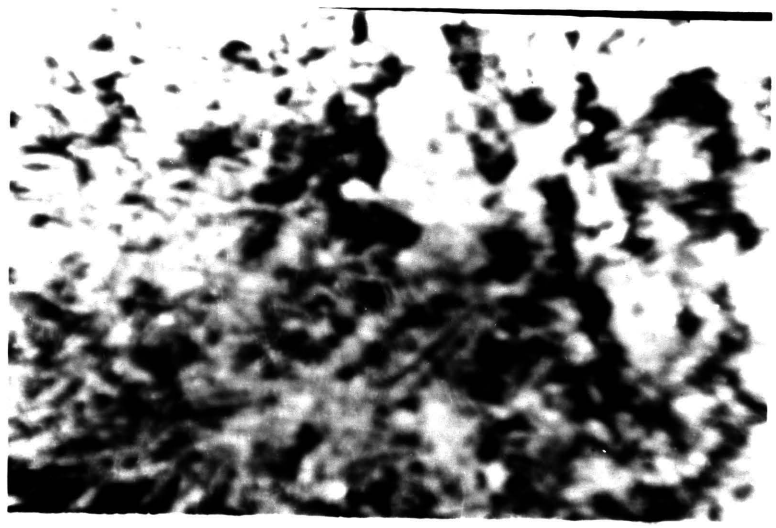


Figure 49- Photomicrograph of a thin section showing renmants of magnetite surrounded by quartz exhibiting colloform texture. Mastuerzo zone, Vein 1A, 870 level, specimen A-19. Plane polarized light.32 X

Figure 50- Photomicrograph of a polished section showing magnetite with microporous and colloform texture. Mastuerzo zone 870 level, Vein 1A, specimen A-18,Plane polarized light. 100 XA.

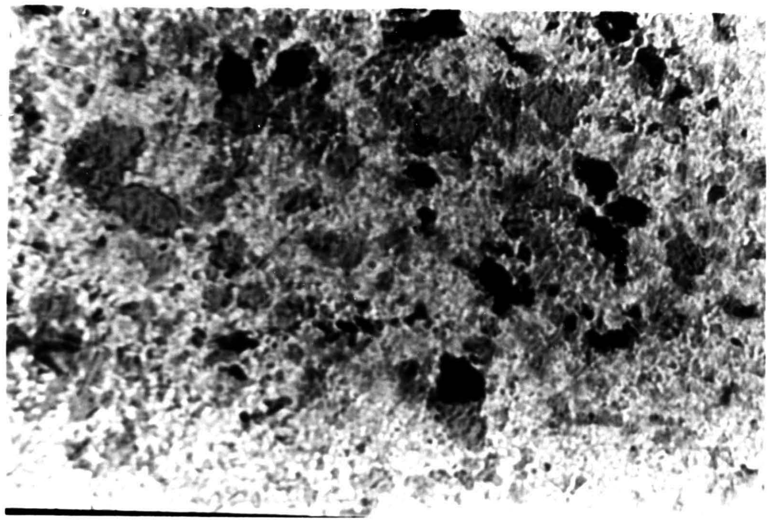


Figure 51- photomicrograph of a polished section showing magnetite (white and gray) with microporous and colloform texture. Mastuerzo zone, Vein 1A

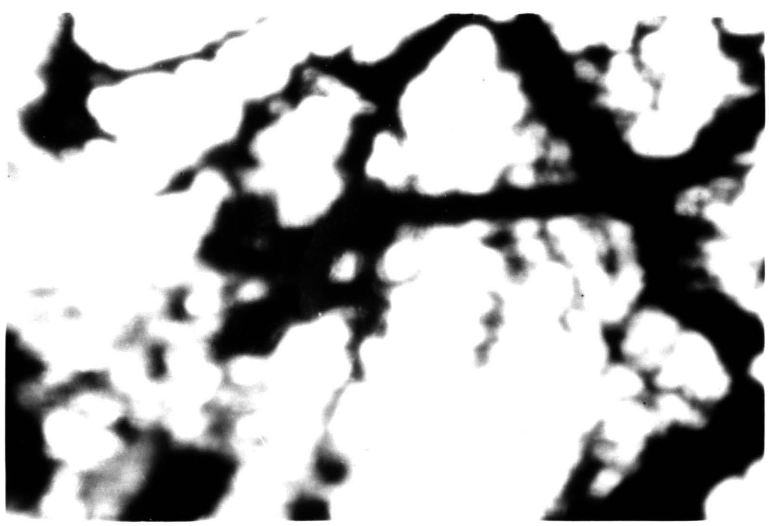


Figure 52- Photomicrograph of a thin section showing magnetite veinlets (black) crossing the granodiorite host rock. Mastuerzo zone, Vein 1A, 944, specimen A-41. Plance polarized light. 34 X.

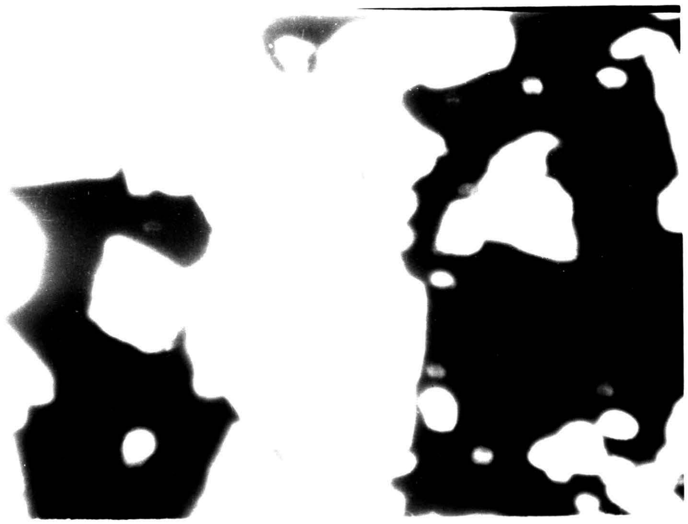


Figure 53- photomicrograph f a thin section showing amphiboles (white) which is surrounding and replacing magnetite (black). Mastuerzo zone, Vein IA, 944 level, specimen A-11. Plane polarized light. 32 X.

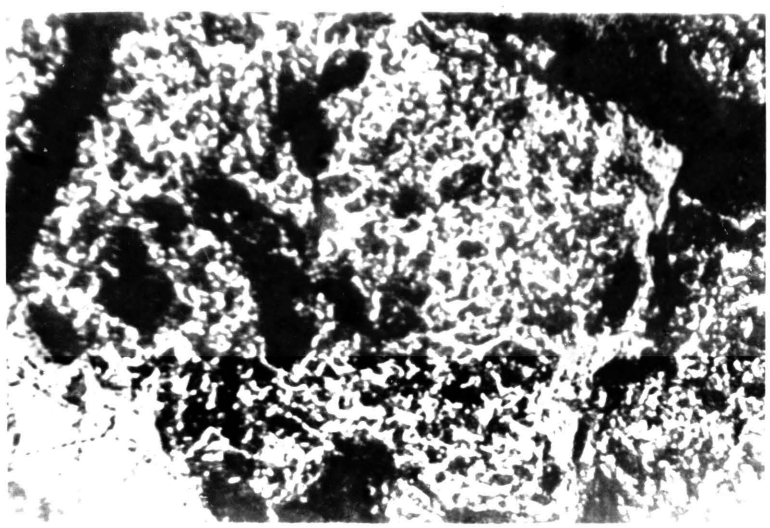


Figure 54- Photomicrograph of a polarized section showing magnetite (white) with microporous and colloform texture. Mastuerzo zone, Vein IA, 944 level, specimen A-10. Plane polarized light. 100X.

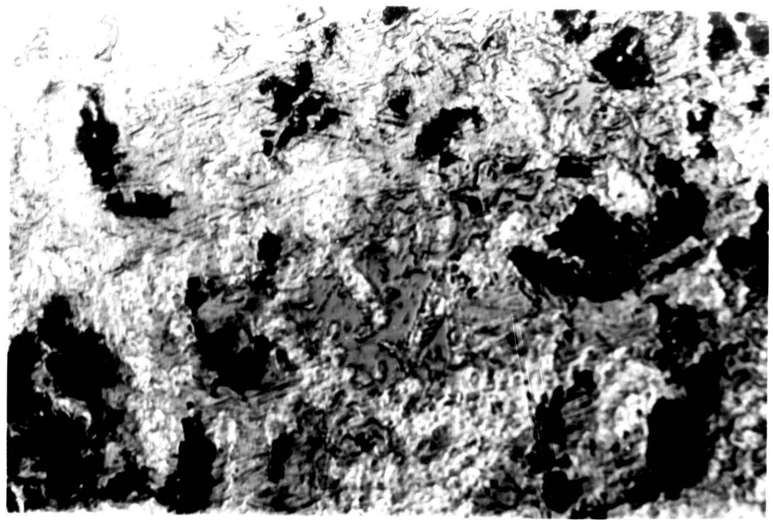


Figure 55- Photomicrograph of a polished section of a specimen from surface showing magnetite with microporous and colloform texture. Mastuerzo zone, Vein LA, above 1010 haulage level, specimen A-43. Plane polarized light.

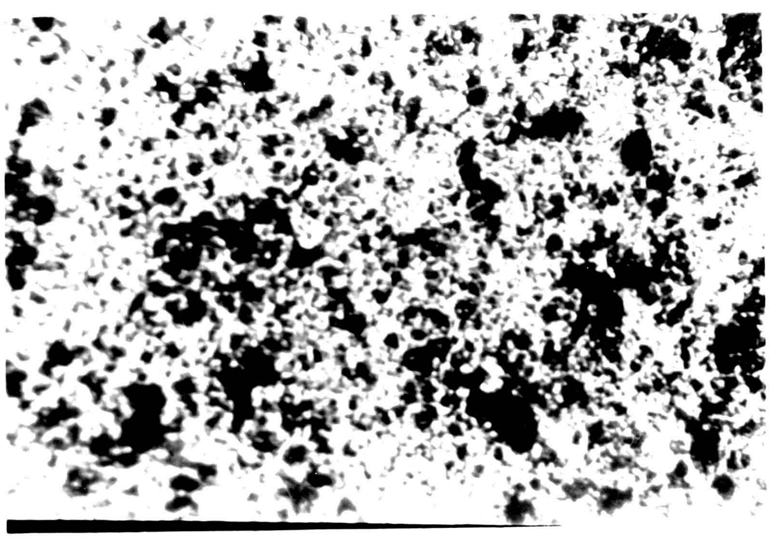


Figure 56- Photomicrograph of a polished section of a specimen from surface showing mahnetite with microperous and colloform texture.

between cavities of the polished relief and the non-polished looks different (See Figures 45-50).

5. In the 944 level, the amphiboles that replace magnetite exhibits both core and rim replacement textures. Calcite, apatite and amphiboles surround crystals of magnetite. Magnetite is microporous following the scalloped layers. Veinlets of magnetite that penetrate in the host rock present a triangular net-shape. (See Figures 51-54).

ZONING AND PARAGENESIS

The time sequence of mineral deposition is known as the paragenesis of a deposit; the changes in spatial distribution is described as zoning.

The particular characteristics of the vertical zoning of these type deposits of the Acari Iron Mining District require a definition of the concept of zoning and the processes which cause it. Thus, Emmons (1924, 1927) considers that zoning is conditioned by the degree of solubility of chemical compounds which depends on the temperature of these solutions. S. S. Smirnov (1937) believes that zoning depends on the change of metal-bearing source chamber and on the pulsation character of segregation from ore-bearing emanation; according to Korolev (1938, 1949) zoning is determined by the interaction of the development of rock formation in time and space with a subsequent deposition of minerals from hydrothermal solutions; and Korzhinskij (1942) believes that zoning may originate due to various geochemical mobilities of the elements. Kutina (1957) summarized the concept of hydrothermal zoning of the European geologist with the classification presented in Table IV.

TABLE IV - Zoning Classification (Kutina, 1957)

	Monoascendent		
			Normal
Primary Zoning		Zoning without rejuvenation	
			Reverse
	Polyascendent		
		Rejuvenation zoning	Normal
			Reverse

V. I. Smirnow (1965) considered:

> Zoning in ore bodies, ore deposits and regional zoning may be defined as a type of regular distribution of elements and minerals conditioned by regular changes in the mineralogical and chemical composition of the ores in space. This regularity is controlled by ore deposition in time, in changing geological and physio-chemical conditions of the environment. Usually, but not always, there is a close relationship between the paragenesis and zoning and these two should be studied together.

C. F. Park (1965) stated:

> Zoning in ore deposits is any regular pattern in the distribution of minerals or elements in space; it may be shown in a single orebody, in a mineral district, or in a large region. Although zoning is related to the spatial distribution of elements and minerals, both time and space must be considered in the study of zonal phenomena. The term paragenesis as used in the United States, is the distribution in time, or sequence of minerals or elements. Paragenesis, as widely used in Europe, is an association of minerals having a common origin.

Such zoning may be produced either by exogenetic or endogenetic processes. Endogenetic processes could be subdivided into polyascendent and monoascendent, and those responsible could be either barren or ore fluids. Accordingly the magnetite deposits of the Acari Iron Mining District are believed to display an endogenetic polyascendent vertical zoning, which originated by two stages. First, filling of fractures in the granodiorite intrusive, by iron-rich ore fluids and secondly, hypogenetic alteration produced by barren fluids.

The underground geology together with the megascopic and microscopic study of specimens from the magnetite deposits of the Acari region show a vertical zoning with the following characteristics:

1. An upper magnetite ore zone, formed predominantly of black, massive, compact, microporous, fine-grained, strongly magnetic, colloform magnetite. Apatite is sparsely disseminated. Calcite veinlets and a small vug filled with quartz crystals are rare. Hematite and martite occur as secondary oxidation products at or near the surface outcrop. The vertical dimension ranges from 50 to 150 m. Total iron content ranges between 60-67% Fe; phosphorus content averages 0.09-0.20% P.

2. A transitional zone, the upper part of which consists of a series of stringers or veinlets of amphiboles mixed with magnetite cutting the magnetite bodies. In this zone the proportion of apatite increases. Apatite occurs as disseminations and veinlets in the magnetite ore and in veinlets of amphiboles and amphiboles mixed with magnetite. Carbonates and quartz also occur as disseminations and veinlets. The amphiboles are coarse to medium-grained and they exhibit crustiform structure.

In the lower part of the transitional zone the content of magnetite gradually decreases with depth, being finally replaced by variable proportions of amphiboles, apatite, carbonates and quartz.

The entire transitional zone, between the upper magnetite ore zone and the lower barren zone of amphiboles, has a vertical thickness between 20 m. and 50 m.

3. The lower barren zone of amphiboles generally is formed by dominant medium to fine-grained amphiboles. The dominant amphibole is actinolite. Carbonates and apatite also are abundant. This amphibole zone constitutes the deeper parts of the magnetite deposits.

The paragenetic sequence of the magnetite deposits of the Acari region, derived from the megascopic and microscopic study, is outlined in Table V . Magnetite and a very small quantity simultaneously deposited apatitie were the only primary minerals. The first stage in the process of hypogenetic alteration consisted of the simultaneous deposition of carbonates, apatite and quartz in the fissures, cavities and pores in the magnetite deposits. Late metasomatic changes caused the formation of amphiboles (actinolite, cummingtonite and hornblende), specularite, prochlorite and greenalite (?). Finally, the residual iron-rich hydrothermal solutions, which migrated upward, through fissures, redeposited magnetite, amphiboles and some carbonates and apatite. Supergene alteration was responsible for the development of martite and hematite at the surface.

HOST ROCK ALTERATION

The host rock for the magmatic injection magnetite deposits was the granodiorite intrusive. Two main rock types are present in the unaltered intrusive: medium-grained granodiorite and pink porphyry. There is also a lesser proportion of dark porphyry. The pink porphyry is a quartz monzonite porphyry and the dark porphyry is a

TABLE V. - Paragenetic Sequence of the Magnetite Deposits, Acari Iron Mining District, Peru.

MINERALS	MAGMATIC	HYPOGENETIC ALTERATION Depositional	Metasomatic	Hydrothermal	SUPERGENETIC ALTERATION
Magnetite	---			---	
Apatite	---	---		---	
Calcite		---		---	
Quartz		---		---	
Prochlorite			---		
Epidote			---		
Actinolite			---	---	
Cummingtonite			---		
Hornblende			---		
Greenalite(?)			---		
Specularite			---		
Martite					---
Hematite					---

TABLE VI. - Chemical Analysis of the Magnetite Deposits of the Acari Region.

SAMPLE	Fe	P	SiO_2	Mn	MgO	SO_4	Al_2O_3	CO_2	CaO	TiO_2	Cu
(1)	64.20	0.056	5.26	0.11	0.98	0.06	0.84	0.10			0.02
(2)	66.00 (a)	0.190 (c)	2.98	0.08 (d)	0.43	0.06 (e)	0.54	0.50			0.01
(3)	55.11 (b) 36.15	0.202	4.25	0.15	1.10	0.042		0.80	1.17	0.10	
(4)	66.48	0.091	3.31	0.14	0.91	(f) 0.005	0.43		1.01	Trace	Traces

(1) Duisburg-Huckinger, Germany (1954). Vein 1 (Mastuerzo zone).
(2) Duisburg-Huckinger, Germany (1954). Vein 1 (Mastuerzo zone).
(3) Dr. Weiss (1956?). Vein 1 (Mastuerzo zone)
(4) Mine Laboratory (1959). Typical analysis of shipping ore.
(a) Fe_3O_4 (b) Fe_2O_3 (c) P_2O_5 (d) MnO (e) SO_3 (f) S

a monzonite porphyry. The pink porphyry and the dark porphyry correspond to the peripheral portions of the main intrusive body which consists largely of equigranular, medium-grained granodiorite. The pink porphyry and the dark porphyry are abundant in the Mastuerzo zone, while granodiorite is the dominant host rock in the Campana and Pongo zones.

Adjacent to the magnetite deposits, within 0.50 to 2.00 m., the host rock is dark green due to partial alteration to chlorite. The chloritization is the most conspicuous alteration process, but the content of epidote and hornblende containing small crystals of magnetite also increase. The intensity of alteration increases with depth. At the Campana zone, where some deposits exhibit their transitional zone, kaolinization is evident at the surface. Magnetite is abundantly disseminated and in veinlets in the host rock near the magnetite deposits.

GRADE AND CHEMICAL COMPOSITION

The typical ore of the Acari Iron Mining District, considered from a commercial viewpoint, is classified as direct-shipping, blast furnace, non-Bessemer (0.10 - 0.20% P) lump ore, with an average grade 60-66% Fe. The ore generally receives a premium price due to its lump structure and it does not suffer any penalties from impurities.

Some chemical analysis of the Acari iron ore are shown in Table VI. These analyses are approximately representative of the chemical composition of the magnetite deposits of the Acari region. In Table VII representative iron and phosphorus assays are given for the main iron deposits of the Acari region.

TABLE VII. - Representative assays of the main iron deposits of the Acari Iron Mining District.

ZONE	DEPOSIT	LEVEL	BLOCK	NUMBER SAMPLES	% Fe	% P
Mastuerzo	Vein 1	968 tunnel		1	60.10	0.081
		1023 level		Average	66.25	0.045
		1056 level		Average	65.64	0.122
		1080 level		Average	66.41	0.063
	La Mancha			10	±59-63	±0.35
	Vein 1A	772 level	744-1	Average	61.45	0.309
		810 level	810-3	Average	65.72	0.126
		810 level	810-8	Average	62.47	0.267
		870 level	870-A	Average	65.12	0.101
		990 level	944-S	Average	65.60	0.097
		1010 level	1010-G	Average	63.51	0.090
	Vein 2S	Surface		Average	67.29	0.132
		1010 level		Average	63.79	0.181
	Vein 2N	S Segment		Average	65.32	0.179
		N Segment		Average	65.45	0.089
	Vein 10	742 level		2	66.36	0.363
	Vein 14			4	63.33	0.205
	Vein 17	944 level		Average	65.24	0.203
Campana	Vein 5		NW Segment	Average	60.40	0.17
			SE Segment	Average	61.00	0.20
	Vein 6	1205 level		3	56.95	0.167
Pongo	Vein 4	Surface		Average	65.78	0.212
		Percussion		Average	49.36	0.284
	Vein 3E	Surface		Average	64.00	0.207
	Vein 2	Surface		Average	64.88	0.159
	Vein 9	Production		Average	67.01	0.047
	Vein 1	Surface		Average	67.38	0.088
Loza	7		E Segment	1	37.03	0.026
	8		W Segment	1	29.98	0.017
	8		E Segment	2	33.25	0.029
Cerro Conchudo	Consolidate			Average	46.00	
	Dune			Average	3.00	

PRODUCTION

Production of iron ore from the Acari Iron Mining District started in March, 1959, with the open pit mining of vein 1 of the Mastuerzo zone. In October, 1961, underground mining by sublevel stopping of the vein 1A of the Mastuerzo zone was begun. By August, 1964, the exploitation by small open pits and shrinkage minign of vein 10 of the Mastuerzo zone and veins 5 and 6 of Campana zone was initiated. More recently, mining of the magnetite deposits of the Pongo zone has commenced.

Since the ore is contaminated by wall rock, magnetite must be concentrated by magnetic separation and by hand picking. Production of lump ore, of open hearth and blast furnace types, for veins 1 and 1A, of the Mastuerzo zone, from March 1959 to October 1964, is tabulated in Table VIII. Crushed ore refers to the mine heads and shipped ore to the concentrates. Recovery is the ratio of concentrates to heads.

TABLE VIII.- Production of Veins 1 and 1A, Mastuerzo zone, Acari Iron Mining District, Peru (1954-1964), (long tons).

YEAR	VEIN 1			VEIN 1A		
	CRUSHED ORE	SHIPPED ORE	RECOVERY	CRUSHED ORE	SHIPPED ORE	RECOVERY
1959	700,866	464,639	66.3			
1960	1,622,224	1,168,741	72.0	111,154	70,585	61.3
1961	1,925,680	1,205,973	62.3	134,076	60,300	45.0
1962	493,467	253,845	56.8	459,470	229,554	49.8
1963	501,063	273,658	46.5	476,277	219,532	45.9
1964	62,152	31,020	49.3	429,769	210,321	44.1
TOTAL	5,305,452	3,397,876	64.0	1,610,746	790,292	49.9

YEARS	VEIN 1 + VEIN 1A		
	CRUSHED ORE	SHIPPED ORE	RECOVERY
1959-1964	6,916,198	4,188,168	60.6

RESOURCES

Based on available information and using the definitions of Blondell and Lasky (1956) the ore resources of the Acari Iron Mining District are tabulated in Table IX. The iron ore resources are subdivided into reserves (measured and indicated) and potential ore. The former consists of mineral material considered exploitable at the present and the later consist of those deposits demanding more favorable conditions for their possible exploitation. The possible grade of each deposit and the author of that tonnage estimate also are given in Table IX.

Ore tonnage estimates involve two factors: weight of the ore (sum of minerals, porosity, voids and moisture) and volume of ore. In the Acari district the conversion factor for unbroken ore in the deposit, from cubic meters to long tons is 3.9. Approximately six cubic meters of broken ore equal one long ton.

The total estimated iron ore resources in the Acari district, based upon information available in 1964, is: 9,863,200 L.T. of reserves (measured and indicated ore) for the iron deposits of the Mastuerzo, Campana and Pongo zones. The total potential is 546,870,000 L.T.; corresponding to 6,870,000 L.T. of immediate potential in the iron deposits of the Mastuerzo, Pongo and Loza zones, and 540,000,000 L.T. of the black magnetite sands in the Cerro Conchudo zone, which is latent potential.

The tabulated resources, including reserves and immediate potential, total 15,069,700 L.T., but the favorable geological and geophysical conditions of the veins: invisible, 5, 6, 10 and the

TABLE IX.- Iron ore resources* of the Acari Iron Mining District (R.A. Zevallos, 1966).

ZONE-DEPOSIT	RESERVES		POTENTIAL	RESOURCES	GRADE	AUTHOR-YEAR
	MEASURED	INDICATED				
Mastuerzo						
1A 2S	3'787,100	1'307,000		5'094,100	63.0	Varillas & Carrizales (1964)
2N		120,000		120,000	65.0	Zevallos(1964)
3		50,000		50,000	63.0	Zevallos (1964)
10	37,600	9,000		46,600	66.0	Moretti(1964)
14 16		200,000		200,000	63.0	Sadner (1962)
17			3'500,000	3'500,000	65.0	Varillas (1964)
Mancha			600,000	600,000	60.0	Zevallos(1964)
Campana						
5	268,000	38,300		306,300	61.0	Varillas & Moretti(1964)
6	236,200	192,900		429,100	57.0	Varillas & Moretti(1964)
Pongo						
4	436,800	900,000		1'336,800	65.0 60.0	Tealdo (1961) Zevallos (1964)
3E	200,000	100,000		300,000	64.0	Zevallos(1964)
2	80,000	40,000		120,000	64.0	Zevallos(1964)
9	160,800			160,800	66.0	Tealdo (1961)
1		36,000	100,000	136,000	67.0	Zevallos(1964)
Loza						
7			690,000		37.0	Zevallos(1964)
8			1'830,000	1'830,000	31.5	Zevallos(1964)
9			150,000	150,000	±48.0	Zevallos(1964)
Cerro Conchudo			$540x10^6$		6.0	Bradley(1961)
TOTAL	6'870,000	2'993,000	61970,000	15'069,700		

(*) Using definitions of Blondell and Lasky (1956).

westward extension of vein 1 of the Pongo zone, the intermediate zone between vein 5 and 6 of the Campana zone, and some possible additions from the Mastuerzo zone suggests the possibility of an additional potential of 5,000,000 L.T. Thus the total resources of the Acari Iron Mining District (1964) may be estimated at close to 20,000,000 L.T., without considering the latent potential.

PRICES

For the reader's information, published prices for iron ore in the United States includes values for certain imported ores, eastern concentrates and the Lake Erie base prices for Lake Superior ore. Lake Erie base prices are established each year by the publication of a major contract between a prominent producer and a steel corporation. According to the formula adopted in 1925, and still in use, standard Lake Erie selling values for iron ores, as quoted in trade journals and ore sale contracts, are per gross ton of 2,240 pounds (long ton), delivered by rail or vessel at lower lake ports. These are based on the following classification and guaranteed base analysis:

1. Old Range Bessemer; 51.50% Fe; less than 0.045% P.
2. Old Range Non-Bessemer; 51.50% Fe; 0.045-0.18% P.
3. Mesabi Bessemer; 51.50% Fe; less than 0.045% P.
4. Mesabi Non-Bessemer; 51.50% Fe; 0.045-0.18% P.
5. High-phosphorus; 51.50% Fe; and exceeds 0.18% P.

The type Mesabi iron ore mineral is fine-grained and earthy, and the type Old Range iron ore is coarser in structure and therefore desired more by the furnace operators.

TABLE X. . - Lake Erie iron ore prices, 1963.

GRADE	PRICE/L.T.	UNIT VALUE
Old Range Bessemer	$ 11.05	0.21456
Old Range Non-Bessemer	10.90	0.21165
Mesabi Bessemer	10.80	0.20971
Mesabi Non-Bessemer	10.65	0.20680
High Phosphorus	10.65	0.20680

The unit value is obtained by dividing the price of the base ore by 51.50. For ore with an iron content above 51.50%, the value is computed by multiplying the unit value of the particular ore by the excess percentage of iron that the ore contains above 51.50 and adding this amount to the value of the base ore.

Premiums are payed for lump structure and high manganese content. In addition to standard deductions applied to an iron content of less than 50% Fe, penalties are also levied for high silica and fine structure. Sulphur in excess of 0.025% usually is undesirable, though iron ore containing as much as 0.20% S may be marketable. Arsenic and zinc even in very small amounts, are highly objectionable. Ores up to 10% Mn and 1.5% TiO_2 usually are acceptable. Some classifications refer to "siliceous iron ore", a type which is used for special purposes in the blast furnace. This type usually contains much more than the 18% maximum silica established for the above noted grades.

Iron ore also is classified as to treatment. Direct shipping grade ore is that ore which can be used in the furnace just as it comes from the mine. Iron ore from a beneficiation plant may be shipped as concentrate, or if agglomerated, as sinter, pellets or nodules. At Acari, the finer tails (less than 1/8") derived from the crushing and screening plant are concentrated magnetically. In addition, an air current helps to eliminate the impurities. The product is referred to as fines.

CLASSIFICATION

Considering some of the classifications of mineral deposits in use today, the magnetite deposits of the Acari region would be classified in the following manner:

1. Lindgren - A magmatic deposit proper.
2. Schneiderhohn - A liquid magmatic deposit.
3. Niggli - A deep plutonic, hypabyssal, orthomagmatic, high temperature deposit.
4. Bateman - A late magmatic formed by residual liquid injection.
5. Park and MacDiarmid - Magmatic segregation deposit.
6. The present writer considers the Acari magnetite deposits to be early magmatic, dike-shaped deposits formed by magmatic injection. They exhibit an endogenetic, polyascendent, vertical zoning which originated in two stages, an early consolidation of ore fluids and a later hypogenetic alteration by barren fluids.

SIMILAR MINERAL DEPOSITS

Among the magmatic deposits which exhibit similar characteristics to the magnetite deposits of the Acari region one might include the following: Kiirunavaara, Gallivare, Grangesberg (Sweden); Lyngrot Nissedal (Norway); Vyssokaja Gora, Lebiajaja, Gora Blagodat (Ural - Soviet Union); Iron Mountain, Pea Ridge (U.S.A.); Cerro Mercado (Mexico); El Tofo, El Algarrobo (Chile); and Yaurilla (Peru).

MASTUERZO ZONE

The Mastuerzo zone consists of many individual magnetite deposits, which have been numbered 1 to 17 (including the veins 5 and 6 of the Campana zone). Of the two main ridges on the south slope that rise to the Cerro Mastuerzo, magnetite deposits occur only on the east one. Near the peak, vein 1 crops out on the south slope of Cerro Mastuerzo. La Mancha is on the north slope.

Veins 1A and 17 are situated on the west slope of the east ridge called Gordon Hill. These deposits cross the ridge to the La Mancha valley. To the north, the northward extension of vein 1A is designated as vein 2S. It crosses the La Mancha valley and extends across the next ridge, where successively the names 2N and 3 are applied. Veins 16, 14, 4, 10 and 10A occur on the east slope of Gordon Hill, while on the south slope of Gordon Hill veins 13, 12 and 11 crop out.

Because of the economic and geologic importance of veins 1 and 1A, more attention is given to these deposits in the following descriptions, but some data are given for the other veins.

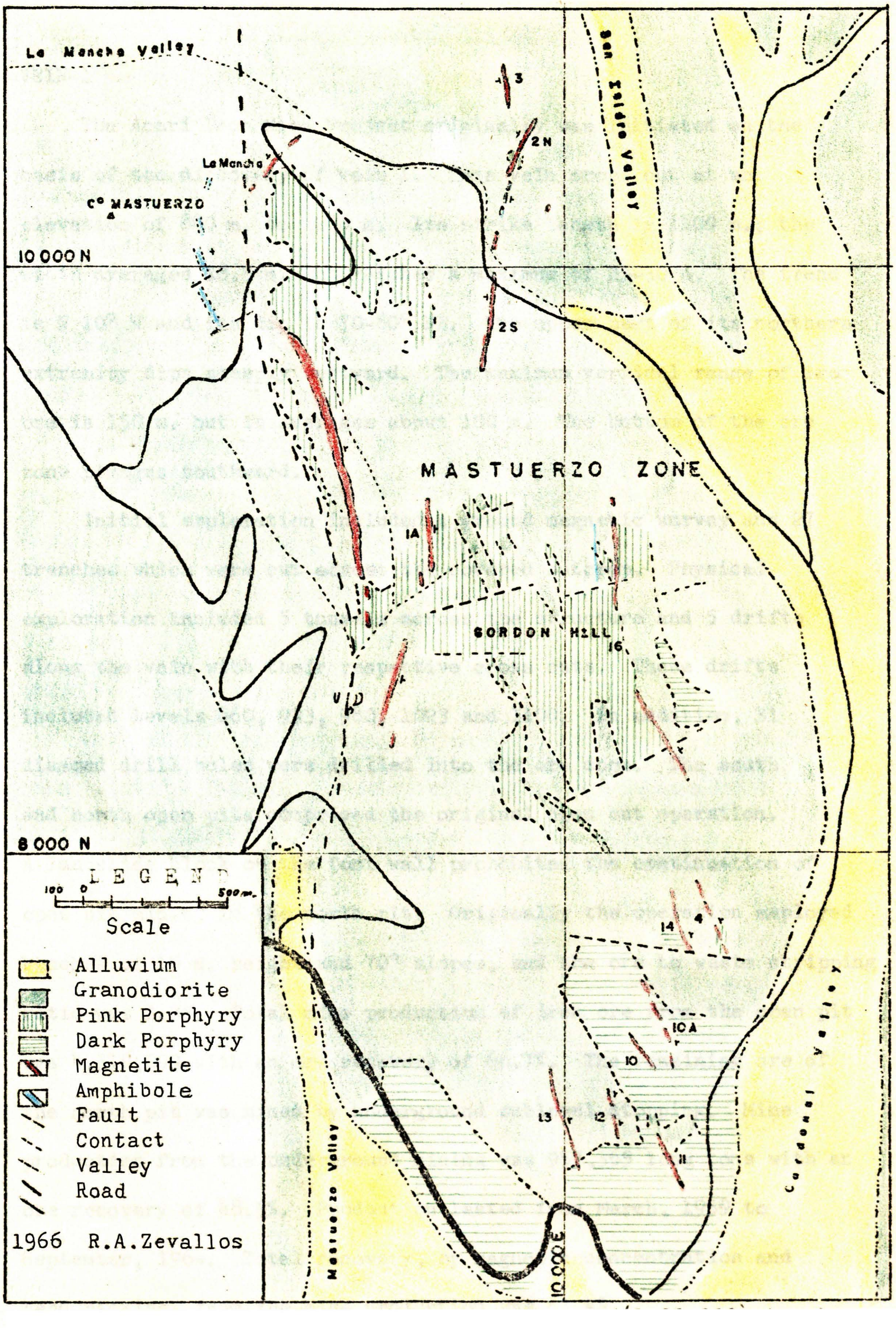


Figure 7 :- Geologic Map or the Mastuerzo Zone (1:20,000), Acari Iron Mining District

VEIN 1

The Acari Iron Mine Project originally was initiated on the basis of the discovery of vein 1. This vein crops out at an elevation of 880 m. to 1200 m. Its strike length is 1100 m.; the width averages 18.5 m. but reaches a maximum of 25-30 m. The trend is N 10° W and its dip is 70-80° NE. The upper part of its northern extremity dips steeply westward. The maximum vertical range of iron ore is 150 m. but it averages about 100 m. The bottom of the ore zone plunges southward.

Initial exploration included a ground magnetic survey and 27 trenches which were cut across the covered outcrop. Physical exploration included 5 tunnels across the structure and 5 drifts along the vein with their respective cross cuts. These drifts included levels 860, 933, 980, 1023 and 1100. In addition, 31 diamond drill holes were drilled into the ore zone. The south and north open pits comprised the original open cut operation. A landslide block on the foot wall prohibited the continuation of open pit mining in the north pit. Originally the operation employed benches of 15 m. height and 70° slopes, and the ore to waste stripping ratio was 2.35. Total mine production of iron ore from the open pit was 4,316,099 with an ore recovery of 66.7%. The remaining ore of the north pit was mined by underground sublevel stopping. Mine production from the underground mining was 957,365 long tons with an ore recovery of 48.5%. Production lasted from March, 1959 to September, 1964. Total recovery, by magnetic concentration and hand picking, from the mine production was 63.4%.

The foot wall host rock about vein 1 is a medium-grained granodiorite. The hanging wall consists of pink porphyry in the northern part and granodiorite in the southern part. Transverse faults displace the iron body both vertically and horizontally a distance of approximately 1 to 30 m. Both ends of the vein are truncated by a combination of transverse and longitudinal faults. At depth the deposit is mineralogically bottomed.

The dominant mineral of the deposit is massive compact magnetite. An exception is the northern extremity where the magnetite is pulvurulent and brittle. As depth magnetite body was cut by amphibole and amphibole-magnetite veinlets. Calcite veinlets also were found at depth within the deposit. Green andesite porphyry dikes cut the ore body.

Most of the iron ore produced contained 65% iron and less than 0.15% P. Table XII summarizes the iron and phosphorus analyses of exploration and exploitation samples from the deposit.

Possible extensions of Vein 1 includes (1) the northward extension to the La Mancha deposit as the only economic segment; (2) the southward extension is unknown because of the very complex structure and exploration to date has not produced favorable results; (3) the downward extension of the deposits is limited by a mineralogical bottoming.

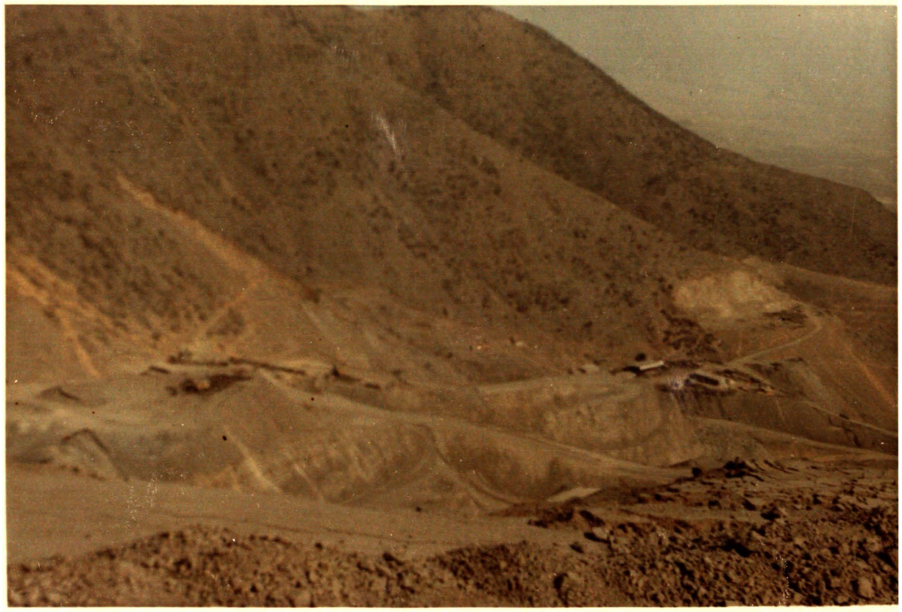


FIGURE 58.- Field photograph showing, at lest , the west slope of Gordon Hill with openings of underground workings along the outcrop of Vein 1A. Mastuerzo zone , looking northeast (R.A. Zevallos, 1963).

FIGURE 59.- Field photograph showing, at lert, the west slope or Gordon Hill with workings along the outcrop of Vein 1 Note. At the right are benches of the open pit of Vein 1 note the mine mine camp at the bottom, in the root of Gerro Batidero. Vastuerzo zone, looking southwest (R.A. Zevallos, 1963).

TABLE XI. - Iron and phosphorus content of Vein 1 of the Mastuerzo zone, Acari Iron Mining District, Peru (1964).

Location	% Fe	% P	Sampled Width	Number of Samples
A Tunnel (968)	60.10	0.081	24.5 m.	1
B Tunnel (973)	51.43		6.0	1
C Tunnel (1023)	63.94		5.5	1
D Tunnel (1071)	63.88		24.0	1
E Tunnel (1130)	62.20		29.0	1
1023 Sub-level	66.24	0.045		average
1040 Sub-level	69.10	0.011		average
1056 Sub-level	65.64	0.122	9.54	average
1069 Sub-level	63.52	0.097	13.12	average
1080 Sub-level	66.41	0.063	2.92	average

LA MANCHA

The La Mancha deposit is partly covered by soil to a depth of 6 m. It occurs on the south slope of the La Mancha Valley at an elevation of 1200 m. to 1380 m. The strike length approximates 250 m. The ore body strikes about N 40° E and dips between 60° and 75° NW. The inferred width is between 10 and 20 m. The host rock for this deposit is medium-grained granodiorite. Magnetite, some hematite and limonite are the ore minerals. Both the country rock and the ore deposit are much sheared and weathered.

Iron ore float, an outcrop in a cut at the bottom of the valley and a significant magnetic anomaly were the reasons for exploration of this area. Tunnel 1181 of S 75° W trend, which was cut in 1959, crossed a wide fault zone. Two normal horizontal diamond drill holes only traversed mixed mineral. Some percussion drill holes drilled in 1961 gave negative results. As late as 1964, four bulldozer trenches were cut in the covered south slope of the

La Mancha Valley and 16 percussion holes were drilled. The last intensive exploration outlined the newly discovered iron deposit. Assays of collected samples are shown in Table XII.

TABLE XII. - Iron and phosphorus content of La Mancha deposit, of the Mastuerzo zone, Acari Iron Mining District, Peru

Sample Location	% Fe	% P	Sampled Width	Type Sample	Number of Samples
Trench (1380 m.)	59.15	0.67	0.65 m.	Trench	1
Trench (1340 m.)					
Trench (1243 m.)	59.40	0.36	6.00	Trench	1
Trench (1250 m.)	54-62		10.00	Percussion	6
Cut road (1200 m.)	45-63		10.00	Trench	2

The weathered and broken character of the host rock in the iron ore zone favors only open pit mining. A potential of 600,000 L.T. is estimated by the present writer.

VEIN 1A-2S

Early in the exploration program of the Acari district, only outcrops on the west slope of Gordon Hill were considered part of Vein 1A. This agreed with the magnetic anomaly distribution and with the dips of the deposits. Later, Mining operation confirmed that vein 1A and 2S constituted only one vein. Possible northward extensions would be successively veins 2N and 3.

Two outdrops of Vein 1A of 250 m. length and 1-5 M. width and 100 m. length and 1-5 m. width occur in this area. Both deposits dip eastward. An iron outcrop of 160 m. length and from 2-8 m.

width occurs between 1060 m. and 1010 m. elevation on the NE slope of Gordon Hill. The deposit dips westward and is named Vein 2S. Sub-level work on the 901 and 1010 levels show that veins 1A and 2S are but one structure.

Veins 1A and 2S have been worked for a length of 1900 m. from the Alpha fault to the La Mancha Valley. The average width of the vein is 8 m., but it ranges from 4-15 m. The overall strike of the deposit is N 15° E and the dip ranges from 60-70° SE, steepening in the northern portion. The vertical range of mining on the vein 1A-2S is approximately 150 m., but mining has ceased due to mineralogical bottoming of the deposit. The plunge of the basal portion of the northern segment of the ore zone is southward, while the south segment plunges northward. Of significance is the fact that along 600 m. of the middle part of the vein 1A-2S did not reach the surface of the present bed rock.

In the northern portion of the deposit, the host rock is predominantly medium-grained granodiorite. At the south extremity granodiorite and pink porphyry are both present. Normal and reverse transverse faults, with a 70-80° northward or southward dip, cut vein 1A-2S. Displacements are horizontal and vertical and range approximately from 1-50 m. These faults have caused considerable difficulty in the mining operations.

The predominant ore mineral in this deposit is black, massive, compact, fine-grained magnetite. Some massive hematite occurs near the surface outcrops. Only small quantities of apatite were noted in the upper part of the deposit, but it increases with depth.

Magnetite with more than 0.20% P has short vertical range in the northern portion, while in the southern portion it extends much deeper. At the 810 level some magnetite occurs with both acircular and botryoidal structures. Some specularite occurs in magnetite-amphibole veinlets which cross the lower portions of the massive magnetite. At the 810 level portions of the country rock are cut by a stockwork of very thin magnetite veinlets. Locally the ore body is separated by a horst of host rock which has been partially replaced by disseminated magnetite. Vugs are uncommon and seldom exceed 4 mm. in diameter. These occur near the lower part of the ore zone.

The transitional mineralogical zone has been cut at different levels by the underground workings. Notation pertaining to this levels are given below:

1. 944 level - amphibole structure, in the northern extremity.
2. 870 level - silicified structure in the northern part.
3. 810 level - amphibole-carbonate structure in the northern part.
4. 744 level - amphibole-carbonate structure, northern extremity.
5. Several raises between the different levels have crossed the transitional zone, for example, raise 8 between 744 and 810 levels.

The results of a 1964 sampling program consisting of channel-cut samples in drifts and cross cuts and from percussion drill holes permits the construction of Figure 60, which is a longitudinal vertical projection of the deposit. Note that the ore magnetite zone is subdivided on the basis of phosphorus content, into 3 parallel bands. These sub-divisions from the upper part to the lower part are:

1. Less than 0.15% P, with a vertical range of 100-200 m. in northern segment and 50 m. in the southern segment.
2. 0.15-0.25% P band, a vertical range of 5-20 m. in the northern segment and 50 m. in the southern part.
3. 0.20-0.50% P band, vertical range 1-5 m. in the northern part and 25-60 m. in the southern part.

The bands of the northern segment plunge southward about 15°, while the bands of the southern segment plunge roughly 5° northward. Not as much is known of the early underground mined middle segment, but information based on the mining shows an average assay content of less than 0.15% P. The figure demonstrates an obvious relationship between the distribution of phosphorus, the bottoming of the magnetite and the underlying amphibole barren zone.

Exploitation of vein 1A began in October, 1961 and the 870 haulage level was developed early in the production period. Four other haulage tunnels were cut at levels 944, 810, 744 and 1010. These are shown in the longitudinal profile of the vein workings.

Production from vein 1A-2S up to October 1964 was 1,610,686 long tons of crushed ore. From this total 790,092 long tons of ore were shipped. Iron ore recovery from mined mineral was 49.1%. Estimates of positive and probable reserves on hand in February, 1964, by H. Varillas and M. Carrizales were 5,094,136 long tons with 3,780,146 considered proved and 1,307,989 probable.

Veins 2N and 3 are considered the northward extensions of

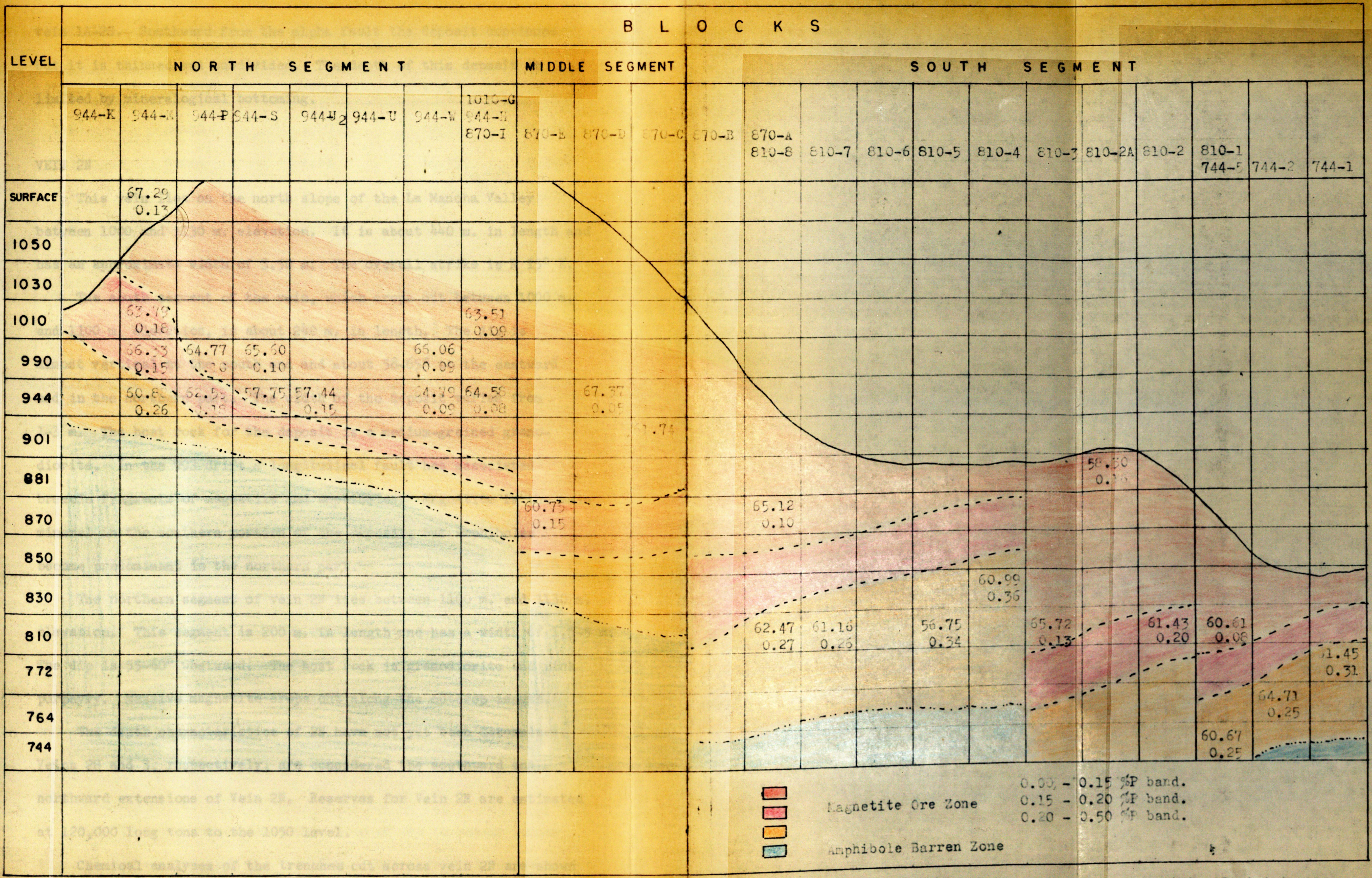


FIGURE 60.- Schematic longitudinal profile of the phosphorus banding in the magnetite Ore Zone of vein IA-2S, Mastuerzo zone, Acari Iron Mining District.

vein 1A-2S. Southward from the alpha fault the deposit continues but it is thinned and subdivided. The depth of this deposit is limited by mineralogical bottoming.

VEIN 2N

This vein lies on the north slope of the La Mancha Valley between 1000 and 1130 m. elevation. It is about 440 m. in length and has an approximate width of 3.50 m. The overall strike is N 15° E.

The south segment of the vein, which crops out between 1000 m. and 1100 m. elevation, is about 240 m. in length. The dip is almost vertical at the south end and about 58-65° to the eastward end in the northern part. The width of the deposit varies from 1-3 m. The host rock for the deposit is a medium-grained granodiorite. In the 993 drift a longitudinal fault has associated breccia fragments of magnetite and amphiboles. Magnetite is the main mineral in the southern portion of the deposit, but amphiboles become predominant in the northern part.

The northern segment of vein 2N lies between 1100 m. and 1130 m. elevation. This segment is 200 m. in length and has a width of 1.5-5 m. The dip is 55-60° westward. The host rock is granodiorite and pink porphyry. Massive magnetite crops out along the outcrop length.

The depth characteristics of 2N have not yet been determined. Veins 2S and 3, respectively, are considered the southward and northward extensions of Vein 2N. Reserves for Vein 2N are estimated at 120,000 long tons to the 1050 level.

Chemical analyses of the trenches cut across vein 2N are shown in Table XIII.

TABLE XIII.- Iron and Phosphorus content of Vein 2N, Mastuerzo zone, Acari Iron Mining District, Peru

TRENCH	SEGMENT	WIDTH	% Fe	% P
T-2	South	3.60 m.	62.03	0.202
T-3	South	1.45	66.99	0.242
T-4	South	3.15	66.95	0.092
T-9	North	2.80	63.54	0.025
T-10	North	5.20	64.12	0.212
T-11	North	1.50	64.75	0.084
T-12	North	4.20	68.55	0.064
T-13	North	3.60	68.28	0.081

VEIN 3

Vein 3 occurs on the southwest slope of the San Isidro Valley, between 1150 m. and 1170 m. elevation. The outcrop extends 240 m. in length and its width ranges from 0.5 m. to 2.0 m. The strike is N 10° W and the dip is 42-55° westward. Magnetite is the main ore mineral and it is massive in character. The host rock for the deposit is granodiorite. The grade of the deposit is 60-63% Fe. An estimate has been made that 50,000 long tons occurs in this deposit. At its northern extremity the deposit becomes very thin and finally pinches out.

VEIN 17

Vein 17 crops out on the south slope of the La Mancha Valley where it has a width from 0.3 to 0.5 m. This outcrop is correlated with the axis of a conspicuous anomaly more than 500 m. long and trending N 20° W. It also is correlated with a bifurcated split of the vein 1A found in the 944 level, which has a trend N 15° W, and a dip of 75-60° E. Several veinlets of magnetite, which strike approximately N 10° W and dip 55-60° W, crop out on the surface for more than 200 m. on the east side of the axis of the main anomaly. These veinlets range from 0.4 to 0.9 m. in width. The host rock for all of the veins is granodiorite. Massive magnetite is the important ore mineral.

Diamond drilling and drifting along the 944 level have checked the south extremity of the deposit. Varilla (1964) estimated a potential of 3 1/2 million long tons for this deposit.

Chemical analyses of vein 17, derived from surface samples, drift cut samples and diamond drill core are given in Table XIV.

TABLE XIV.- Iron and Phosphorus content of Vein 17, Mastuerzo zone, Acari Iron Mining District, Peru.

Sample	Width	% Fe	% P	Number of Samples	Elevation
Split 944 level	3.00	65.23	0.203	3	944
Core D.D.H. 163	3.00	59.69	0.236	1	1010
Surface Veinlets	0.60	64.37	0.283	3	1060

VEINS 11, 12 AND 13

Three parallel veins called 11, 12 and 13 lie on the south slope of Gordon Hill (See Figure 57). The veins are approximately 150 and 125 m. apart.

Vein 11 is 125 m. east of vein 12. The deposit is 140 m. in length; it is irregular in width but it averages less than 0.5 m. in width. The strike is N 30° W; the dip is very steep.

Vein 12 is west of vein 11, where it occurs at 750 to 780 m. elevations. The vein strikes N 20° W and dips 60° E; it is 2-5 m. in width. Exploration consisted of five percussion drill holes which extended to 20 m. below the surface. Sadner (1961) estimated 130,000 L.T. of proved ore and 20,000 long tons of probable ore.

Vein 13 is about 220 m. in length and it approximates 4 m. in width. Its elevation ranges from 670 m. to 810 m. The strike is N 15° W, and the dip is 59-60° E. Vein 13 has been explored by drill holes, by the 701 level and by four diamond drill holes. The diamond drills cut only thin veinlets in depth. A later drift (650), penetrated two ore vein splits of 2.6 and 0.6 m. in width. Northward the deposit changes to amphibole. Assays of one sample (2.00 wide) from the 650 level gave 66.45% Fe and 0.093% P. Another sample, 1.50 m. in width, from a rasied yielded 66.15% Fe and 0.040% P.

The locations of Veins 11, 12 and 13 coincide with conspicuous magnetic anomalies. The northward extension of these veins might well correspond to the positions of vein 10 and 10A, but the veins have been displaced eastward. The downward and southward extensions of these deposits are not known. The host rock is granodiorite in the northern part and dark porphyry in the southern portion.

VEINS 10 AND 10A

Parallel veins 10 and 10A occur on the east slope of Gordon Hill about 90 m. apart. The host rock is a dark porphyry.

Vein 10 is at 740-750 m. elevation. It strikes approximately N 50° E and its dip is 50-65 eastward. Fourteen percussion drill holes showed the deposit to extend at least 20 m. below the surface. The length approximates 120 m. and the width is 3-9 m. Drift 705 cuts the extreme northern part. Here the deposit consists of veinlets of magnetite and magnetite mixed with amphiboles. Surface samples from the deposit gave the following results: Sample 1, 2.00 m. wide, 64.47% Fe, 0.232% P and 3.12% SiO_2; Sample 2, 2.00 wide, 64.86% Fe, 0.494% P and 5.42% SiO_2. Moretti (1964) estimated 37,600 long tons of proved ore and 9,000 long tons of probable ore.

Vein 10A is a composite of several small veins from 0.02 m. to 0.03 m. in width. These coincide with a magnetic anomaly approximately 300 m. in length. The elevation of the deposit lies between 700-720 m. The strike is N 15° W and the veins dip 65-75° E.

The southward extension of veins 10 and 10A probably correspond to veins 11, 12 and 13. While the northward extension might well be Veins 4 and 14 (See Figure 57). The downward extension is not known.

VEINS 4 AND 14

Veins 4 and 14 occur on the east slope of Gordon Hill north of the deposits described above. Magnetic anomalies outline the bodies. The ore bodies are parallel and about 100 m. apart.

Vein 14 crops out at approximately 800 - 820 m. elevation. The strike length is 350 m. in a N 20° W direction and the width varies from 2-3 m. The body dips 50° E. A percussion drill hole and an adit explored this deposit. Sadner (1961) estimated 200,000 long tons of iron ore to be present in vein 14 and in the south segment of vein 16. Results of chemical analyses of collected samples are shown in Table XV.

TABLE XV. - Iron phosphorus and silica content of Vein 14, Mastuerzo zone, Acari Iron Mining District, Peru

Sample	% Fe	% P	% SiO_2
Trench 1	66.92	0.072	3.13
Trench 2	57.02	0.243	9.87
Tunnel 1	68.63	0.211	2.76
Tunnel 2	66.87	0.294	3.31

Vein 4 is 300 m. long, about 1 m. wide and it occurs between 780-790 m. elevation. The host rock is pink porphyry in the south part and granodiorite in the north part. Magnetite is the ore mineral.

VEIN 16

Vein 16 also crops out on the east slope of Gordon Hill between 880-1020 m. elevation. The vein is divided into two segments. The south segment strikes N 33° W and dips 50-80° E. Nineteen percussion drill holes have penetrated the body and magnetite is known to occur at least to a depth of 25 m. below the surface. The average width is 4.0 m. The host rock for the deposit is a pink porphyry.

The northern segment of vein 16 occurs between 940-950 m. elevation, where the body strikes N 5° W and dips 80° E. The strike length is 400 m. A magnetite veinlet 0.50 m. wide and a parallel amphibole vein 8.0 m. wide occur in the southern portion of this segment. At the north extremity vein 16 is 4.0 m. wide and the ore has been partly silicified. The host rock for the deposit is granodiorite and pink porphyry.

Sadner (1961) computed 200,000 long tons of probable ore for the southern extremity of Vein 16 and for vein 14. No estimate has been made for the northern portion of the vein 16.

A small outcrop of magnetite, 4.0 m. in width and approximately 150 m. east of Vein 2N, could well be part of the northward extension of Vein 16.

OTHER SMALL DEPOSITS.

On the south slope of the San Isidro Valley magnetite is exposed in an outcrop approximately 80 m. long and with a strike N 20° W, and dip of 70° SE. The width of the body ranges from 1-3 m.

The Las Leonas deposit is located on the east slope of the Leonera valley. Here two magnetite bodies of 40 and 60 m. length occur within a broad amphibole structure. The magnetite bodies range from 3.0 to 4.0 m. in width.

CAMPANA ZONE

On the west slope of Cerro Campana are four magnetite deposits. Field data suggest the possibility that they belong to one structure of 4 km. length. From north to south these deposits are: Campana Media, Vein 5, Vein 6 and Campana Redonda. These bodies occur 2 km. east of the deposits of the Mastuerzo zone. Their host rock is granodiorite (Figure 61).

CAMPANA MEDIA

The deposit of Cerro Campana Media shows two small outcrops of magnetite 5 m. long and 3 m. wide, in a 40 m. wide structure consisting mainly of amphibole.

VEIN 5

Vein 5 lies between 1220 m. and 1300 m. elevation. Here two outcrops of magnetite contain bands of amphibole and magnetite mixed with amphibole. The northwest outcrop is 70 m. long, 35 m. wide, and strikes N 30° E. The southwest outcrop is 120 m. long, 10.0 m. wide, and strikes N 10° E. Open pit mining operations show that the deposits have a dip of 30° east. The host rock is granodiorite which is highly chloritized and kaolinized.

VEIN 6

This magnetite deposit called vein 6 lies between 1230 m. and 1150 m. elevation. The outdrop is 400 m. long, ranges in width between 3 and 10 m., and strikes N 30° W. The body dips 55-75°

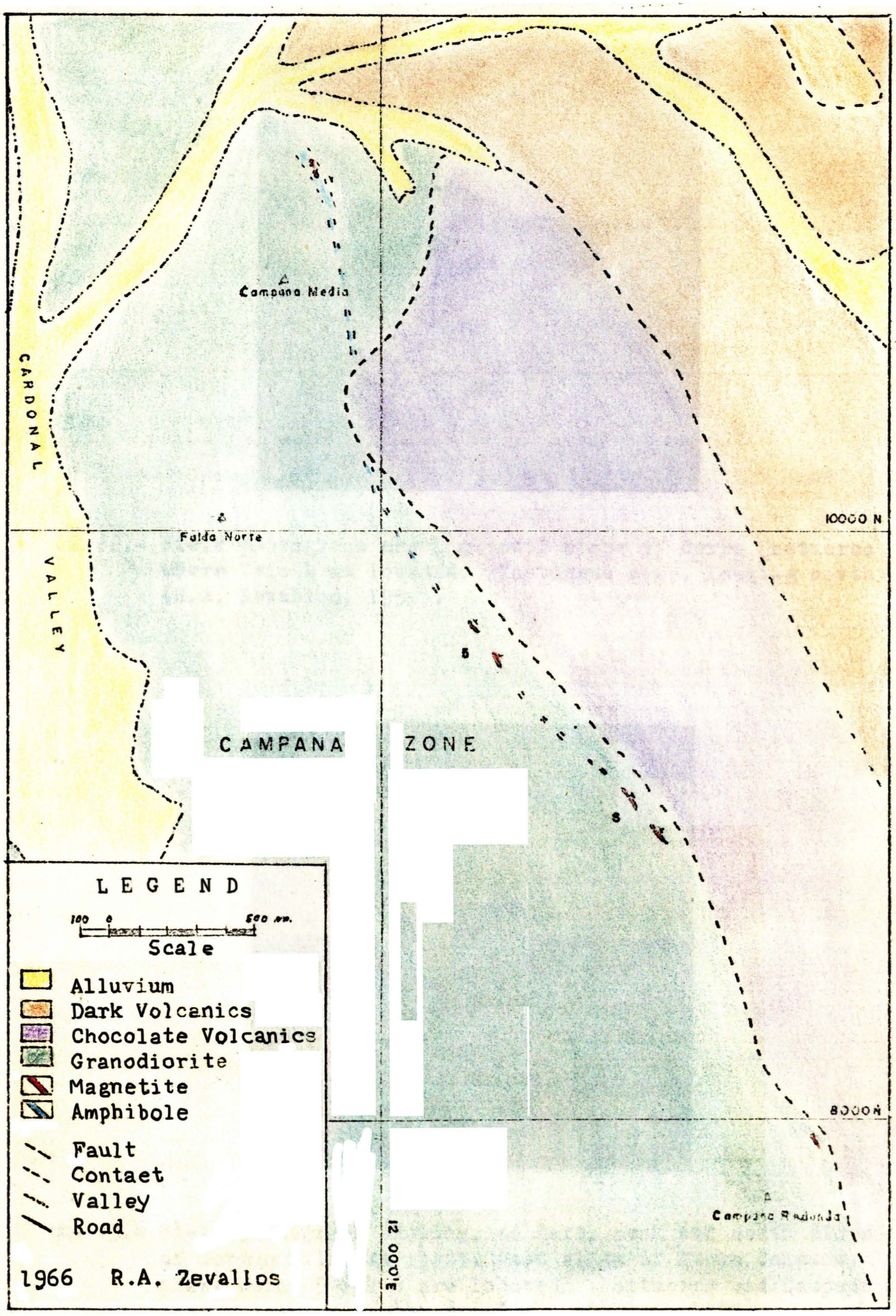


FIGURE 61.- Geologic Map of the Campana Zone, (1:20,000), Acari Iron Mining District.

FIGURE 62.- Field photograph showing south slope of Cerro Mastuerzo where Vein 1 is located. Mastuerzo zone, looking north (R.A. Zevallos, 1959).

FIGURE 63.- Field photograph showing, at left, peak and south slope of Gordon Hill. At right, west slope of Cerro Campana, where Veins 5 and 6 are located. Mastuerzo and Campana zones, looking northeast (R.A. Zevallos, 1959).

east. Levels 1205, 1155 and 1105 have been opened in this deposit. H. Varillas and J. Moretti (1964) estimated 236,200 long tons of proved ore and 192, 865 long tons of probable ore.

CAMPANA REDONDA

The iron outcrop of Cerro Campana Redonda is on the eastern slope, where it has a length of 50 m. and a width of 10 m. Hematite and magnetite are the ore minerals. Some silification has occurred. This deposit is covered by soil but its contact with the Chocolate Volcanics is very close to the surface. Assays of samples from the veins 5 and 6 are shown in Table XVI.

TABLE XVI. - Assays of the Veins 5 and 6 of the Campana zone, Acari Iron Mining District.

DEPOSIT	NUMBER SAMPLES	WIDTH	% Fe	% P	% SiO_2	DATE
Vein 5						
NW part	Average	35.0	60.40	0.17	6.1	1961
SE part	Average	10.0	61.0	0.20	5.3	1961
Vein 6						
1205 level	3	9.6	57.0	0.167	11.49	1964

PONGO ZONE

The iron deposits of the Pongo zone lie between 1300 and 1600 m. elevation, in the western part of the plateau formed by the Pajayuna, Pongo and Yuyuca hills. At Cerro Pajayuna are located veins 4, 3W, 3E, 5, 6, 7 and 8. At Cerro Pongo are Veins 2 and 10. At Cerro

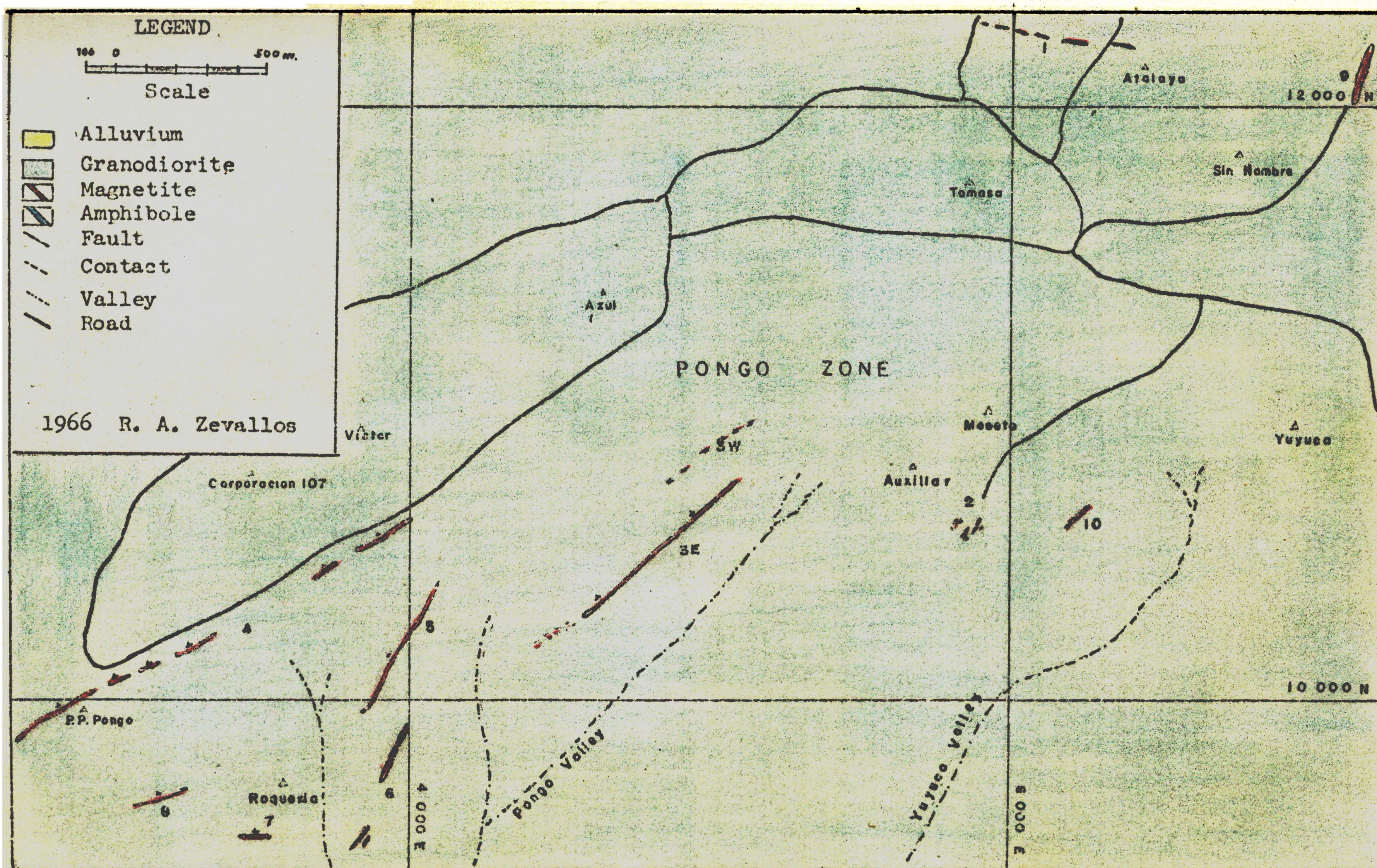


FIGURE 64. - Geologic Map of the Pongo Zone (1:20,000).

Yuyuca veins 9 and 1 crop out. Country rock for this general area is mostly granodiorite. The major veins trend northeasterly and veins 1 and 7 bear easterly.

VEIN 1

Vein 1 is located on the plateau west of the crest of Cerro Yuyuca at an elevation between 1610 and 1660m. Vein 1 crops out for 600 m., suffering small displacements due to faulting. It has a width between 1.0 and 2.0 m. The strike is N 80° W and its dip is very steep. This deposit has some of the best quality magnetite found in the Acari region. Magnetite is dominant in the deposit, but some hematite is present. Table XVII gives average assays of 10 trenches and of the stockpiles from vein 1.

The writer estimates 36,000 long tons of probable ore, but the geologic characteristics of this deposit suggest the possibility of additional potential of 100,000 long tons.

TABLE XVII. - Assays of Vein 1, Pongo zone, Acari Iron Mining District, Peru.

SAMPLE	WIDTH	% Fe	% P
Trenches	1.56	66.80	0.088
Stockpiles		67.95	0.089

VEIN 2

Vein 2, also known as "La Vibora", actually consists of three main parallel bodies. These occur on the south border of the plateau crowned by Pongo hill at an elevation between 1600 and 1630 m. The characteristics of the splits of vein 2 are tabulated in Table XVIII.

TABLE XVIII. - Characteristics of the Splits of the Vein 2, Pongo zone, Acari Iron Mining District, Peru.

VEIN	STRIKE	DIP	LENGTH	WIDTH	% Fe	% P	% SiO_2
2-W	N 30° E	50-75° SE	120 m.	4.50 m.	64.34	0.200	5.36
2-M	N 20° E	70-75° SE	50 m.	2.80	65.14	0.184	4.59
2-E	N 20° E	78-85° SE	100 m.	3.00	63.60	0.129	5.90

The writer estimates 40,000 long tons of proved ore and 80,000 of probable ore for vein 2. The northeastward extension of the zone probably was displaced eastward by a transverse fault. Vein 10 may be the faulted portion of vein 2. The downward extension has not been determined. The southwestward extension is terminated by the south cliff of the Cerro Pongo.

VEINS 3-E AND 3-W

Vein 3-E lies on the southeast slope of Cerro Pajayuna, between 1480 m. and 1530 m. elevation. The outcrop is 750 m. long, 4.00 wide, and the vein strikes N 50° E and dips 55-75° NW. The slope of the hill is 31-37° SE. The host rock is granodiorite.

The northern 400 m. of the vein exhibits good magnetite with an average grade of 64% Fe and 0.207% P. Zevallos (1964) estimated 200,000 long tons of proved ore and 100,000 of probable ore to be present in the north segment.

FIGURE 65.- Field photograph showing southeast slope of Cerro Paja-yuna with outcrop of Vein 3E in the lower part. Pongo zone, looking northwest (R.A. Zevallos, 1961).

FIGURE 66.- Field photograph showing the steep west slope of Cerro Pajayuna, with the outerop of Vein 4, dipping toward northwest. Pongo zone, looking northeast (R.A. Zevallos, 1961).

The southwestward extension of the vein 3-E would be vein 5. The northeastward and downward extensions have not yet been determined.

About 150 m. west of vein 3-E, and above the plateau, a parallel deposit is called vein 3-W. This vein is largely covered by unconsolidated material, but a series of float fragments of magnetite and amphiboles are present.

VEIN 5

Vein 5 is the probable southward extension of vein 3-E. It crops out for a distance of more than 500 m. on the SE slope of Cerro Pajayuna at an elevation between 1454 m. and 1500 m. Six trenches have revealed that the vein strikes N 30° E and dips 60-70° NW. The width ranges from 1-4 m., locally making a good grade of magnetite, but in some portions silica is abundant. The host rock is granodiorite.

VEIN 6

Vein 6 crops out on the southeast slope of Cerro Roqueria at an elevation between 1430 and 1527 m. It is about 500 m. long and 1-5 m. wide. Six trenches have revealed that the vein strikes N 35° E and dips 60-75° NW. The northern part of the deposit is silicified and the southern part, which exhibits good magnetite, forms several splits. The host rock is granodiorite. Vein 6 probably is the southwesterly extension of vein 5.

VEIN 4

Vein 4 is the principal deposit in the Pongo zone. It occurs on a small plateau southeastward from the crest of Cerro Pajayuna at an elevation between 1450 m. and 1580 m. The body is 1500 m. long and 1 to 7 m. wide. It strikes N 60° E and dips 55-65° NW. The dominant mineral is massive magnetite, which is associated with massive hematite and martite. Granodiorite is the country rock.

Exploration of this deposit began with a ground magnetic survey which showed two main parallel anomalies, one along Vein 4, and a larger one located 200 m. to the northwest of Vein 4. The latter anomaly was called the "Invisible Vein". Subsequent physical exploration in the southwestern portion of the deposit comprised 20 trenches and 25 percussion drill holes along 4 sections, 200 m. equi-distant from each other. Chemical analyses of the chip samples from the trenches and from the percussion drill cuttings are shown in Table XIX.

M. Tealdo (1961) estimated 436,800 long tons of open pit ore to a depth of 30 m. in the southwestern part of Vein 4. The present writer estimates 900,000 long tons of proved ore and 600,000 long tons of probable ore for this body.

The southwestward extension of Vein 4 is terminated by the cliff of Cerro Pajayuna (where it descends to the coastal plain). The iron deposit crops out 150 m. below the plateau. The northeastward extension of the body has not yet been explored. The downward extension has not yet been determined, though the characteristics of the deposit suggest it may lie 50 to 120 m. below the surface.

TABLE XIX. - Chemical analyses Vein 4, Pongo zone, Acari Mining District, Peru.

SAMPLES	WIDTH	% FE	% P	% SiO_2	OBSERVATIONS
T-1	4.25 m.	63.65	0.308	3.19	Trench (SW enc)
T-2	2.40	65.11	0.305	2.88	Trench
T-3	2.90	62.40	0.137	4.84	Trench
T-4		68.02	0.208	2.71	Trench
178 M.L.		58.87	0.324		Average percussion drill
T-5	2.20	67.93	0.175	2.12	Trench
T-7	0.20	67.03	0.200	1.56	Trench
168 M.L.		38.21	0.413		Average percussion drill
T-8	1.00	66.87	0.087	1.53	Trench
T-9	7.00	66.02	0.202	2.82	Trench
T-10	4.50	65.62	0.370	3.31	Trench
T-11	3.10	66.98	0.186	1.78	Trench
158 M.L.		52.23	0.264		Average percussion drill
148 M.L.		48.11	0.135		Average percussion drill
T-14	0.30	66.12	0.240	3.45	Trench
T-15	1.20	63.50	0.023	7.68	Trench
T-16	3.80	64.75	0.010	4.02	Trench
T-17	2.50	67.51	0.075	3.72	Trench
T-18	1.80	65.01	0.072	5.66	Trench
T-19	1.60	66.29	0.271	4.07	Trench
T-20	2.40	67.31	0.156	2.45	Trench
T-21	2.40	66.39	0.303	4.03	Trench
T-22	1.40	65.42	0.339	4.18	Trench (split vein)
T-23	0.60	62.71	0.579	5.49	Trench (split vein) (NE end)

VEIN 9

Vein 9 is in that portion of the plateau east of the crest of Cerro Yuyuca which is at anelevation between 1575 and 1590 m. Because of its special shape it was called "Media Luna". It crosses the saddle which joins the hills Atalaya and San Isidro. Media Luna Valley is toward the north, and the San Isidro valley to the south of the saddle.

The deposit has an oval-shape, 200 m. long and 12 m. wide. At both ends it splits into branches from 2 to 4 m. in width. The oval portion is formed by intercalations of bands of magnetite and magnetite mixed with amphibole. This deposit strikes N 15° E and dips 70-80° NW.

A ground magnetic survey, trenches, and 25 percussion holes in 4 parallel lines 100m. - 40 m. - and 60 m. apart respectively from south to north indicate mineralization, 50-70 m. below the surface.

M. Tealdo (1961) estimated 160,800 long tons of proved iron ore in his open pit mining project which was presented to a depth of 30 m. This yeilds a stripping-ore ratio of 2.57. Approximately 3,000 long tons were extracted from vein 9 in a small operation by J. Salinas (1962).

The southward extension of vein 9 is constituted by veinlets 0.3 to 0.5 m. in width which outcrop for a distance of 300 m. The northward extension is composed principally by two splits, about 50 m. apart. The west branch is formed by amphiboles. The east branch, which is located 600 m. to the north of the Media Luna body, is 70 m. long and 2-3 m. wide. The downward extension of Vein 9 would be about 50 m. below the surface.

In Table XX below, are assays of the average of the stockpiles and of the outcrop.

TABLE XX. Assays of Vein 9, Pongo zone, Acari Iron Mining District, Peru.

SAMPLE	% Fe	% P	WIDTH
Outcrop	67.88	0.032	12.00 m.
Stockpile	66.15	0.062	

OTHER SMALL DEPOSITS

Vein 7 lies on the south slope of Roqueria Hill at an elevation between 1490 m. and 1512 m. The bands of magnetite and magnetite mixed with amphibole are 50 m. long and 15-20 wide. They strike N 80° W and have a steep dip.

Vein 8 is located close of vein 7 on the southwest slope of Cerro Pajayuna at an elevation between 1484 m. and 1543 m. It is 200 m. long, 0.3-0.1 wide and it strikes N 80° E and dips 60-70° NW. Magnetite of good quality is the main mineral.

Vein 10 is probably the northeastward extension of Vein 2. It crops out for 100 m. at an elevation between 1547 and 1569 m. on the steep southwestern slope of Cerro Pongo. The strike is N 50° E and the dip is 70° NW. The width ranges from 1-3 m. Massive magnetite and hematite are the component minerals.

STRATIFORM HEMATITE DEPOSITS OF LOZA ZONE

On the east slope of the headwater area of Loza Valley an anticline composed of metasedimentary rocks plunges northeastward. The structure includes three stratiform hematite deposits, located at altitudes of 1500 m. to 1300 m. These are named 7, 8 and 9 (Fig. 67). They conform to the bedding of the enclosing rocks which consist principally of pink quartzite and less metamorphosed sandstones.

DEPOSIT 9

Deposit 9, which is located on the west flank of the gold, has an outcrop length of 70 m. and a width of 8 m. It strikes N 40° W and dips 50-30° NE. A northwestward prolongation of 70 m. length and 1.0-1.7 m. width exhibits a dip of 79° NE. The deposit occurs at an elevation between 1440 m. and 1490 m. It consists of hematite, magnetite and quartz, and its iron content is about 48%. The writer estimates a potential of 150,000 long tons for this deposit.

DEPOSIT 8

Deposit 8 is the longest and most important iron ore body in the Loza zone. It forms an almost continuous hematite bed on both flanks of the fold and has an approximate length of 950 m. The author estimates a potential of 1,830,000 L.T. in this deposit.

The segment on the west flank is 400 m. long and varies in width from 4 to 8 m. This deposit is located between 1380 m. and 1540 m. in elevation. It strikes N 55° E and it dips 50-60° NW in the southwest part, and 25-30° NW in the northeast part. The

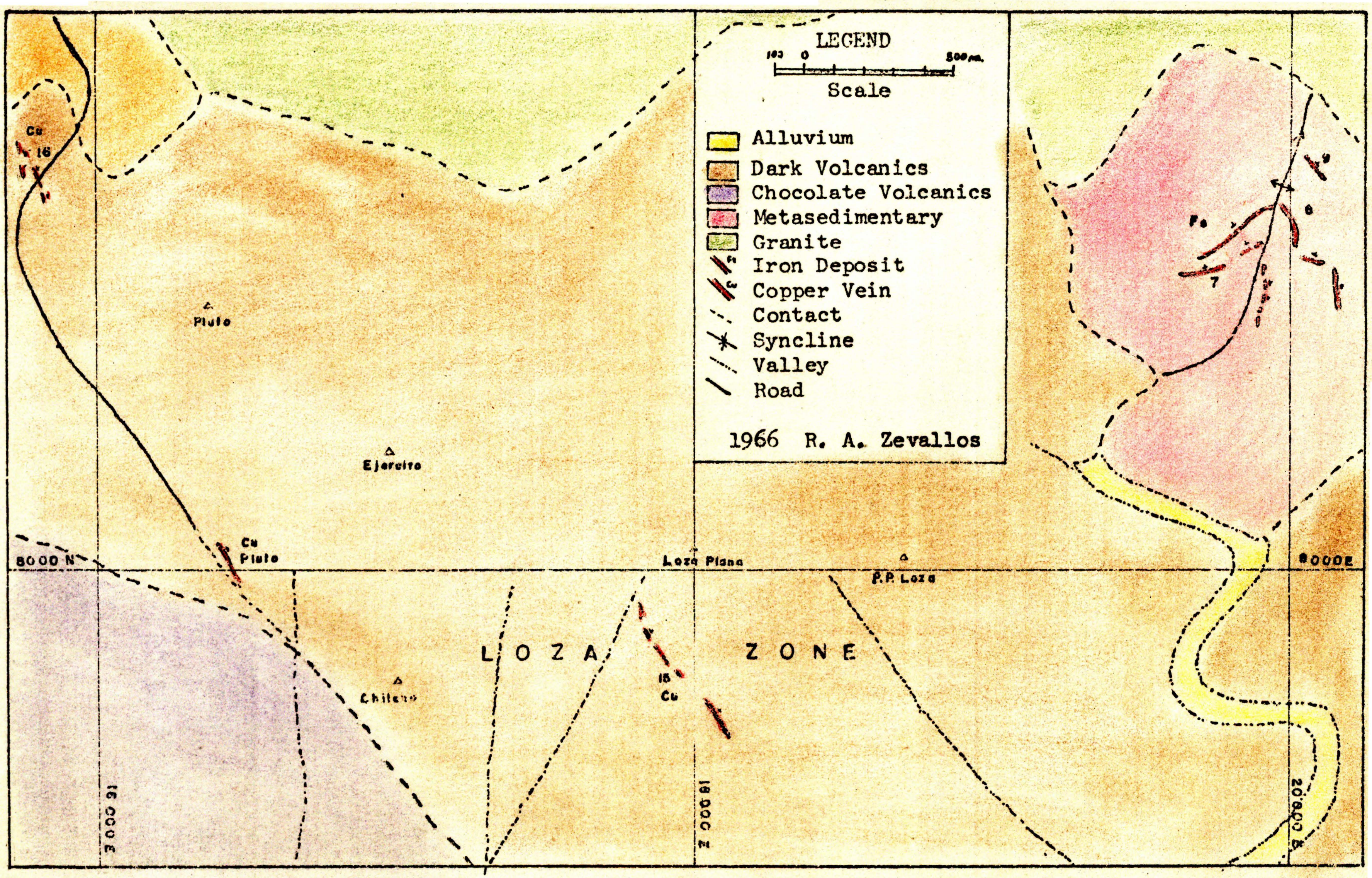


FIGURE 67. - Geologic Map of the Loza Zone (1:20,000).

ore mineral is massive hematite which is mixed with grains of quartz. Both minerals exhibit medium to fine-grained equigranular texture. Locally the hematite is intergrown with quartz to form a dense texture.

The segment on the east flank has an outcrop length of 550 m. Its width varies from 6 to 12 m., but at the northwest extremity it forms an oval-shape body 30 m. wide. The east segment strikes N 65° W and dips 38-40° NE. It is positioned between an elevation of 1380 m. on the NW. to 1540 m. on the SE. The northwestern extremity exhibits hematite mixed with quartz in a medium-grained equigranular texture. The southeastern extremity exhibits dense texture. Rich and barren zones are very irregularly distributed and the changes between them are transitional.

DEPOSIT 7

Deposit 7 is discontinuous but it is located on both flanks of the fold. The author estimates a potential of 690,000 long tons.

The segment on the west flank lies between an elevation of 1370 m. at the northeast to 1430 m. in the southwest. This segment, which is 220 m. long, is oval-shaped with a 12 m. width in the middle partion and a 2 to 3 m. width at the ends. The body strikes N 60° E and it dips from 55-60° NW. In this segment the hematite is intergrown with quartz forming a dense texture. The deposit has very sharp contacts with the enclosing quartzite.

The east flank segment presents 3 irregular and discontinuous bodies between an elevation of 1380 and 1400 m., and dip from 50-60° NE. The body of the north extremity exhibits an outcrop 80 m. long and 2-3 m. wide. The ore body of the middle part is a folded body of 70 m. long and 4-8 m. wide. The ore body of the south extremity exhibits 40 m. in length and 8 m. in width. The ore mineral is a mixture of hematite and quartz with dense texture.

The writer has estimated a potential of 690,000 L.T. in the deposit 7.

The writer estimates a potential of 2,670,000 long tons to occur in deposits 7, 8 and 9 of the Loza Zone. Table XXI gives representative assays of the three iron deposits in the Loza zone.

TABLE XXI. - Assays of iron deposits in the Loza Zone, Acari Iron Mining District, Peru.

DEPOSIT	WIDTH	% FE	% P	% SiO_2	% S	Number Samples
9	8.00	±48.00				
8						
West segment	6.00	29.98	0.017	41.20	0.810	1
East Segment	6.00	33.25	0.029	34.18	0.717	2
7						
West segment	6.00					
East segment	5.00	37.03	0.026	30.90	0.395	1

MAGNETITE BLACK SANDS OF CERRO CONCHUDO

A sand containing magnetite as a fairly abundant accessory forms the upper part of Cerro Conchudo, at northeastern border of the plateau.

Cerro Conchudo is a hill 4 km. long and 1 km. wide which reaches an elevation of 1400 m. to 1700 m. It is formed by fairly consolidated sands overlying the granite intrusive. The sands consist principally of medium grained magnetite and quartz.

D. Bradley (1962) has estimated the resources in two groups of black sands. The first is a fairly consolidated cross-bedded sand which consists of beds 2-3 mm. in thickness and which contains magnetite concentrations. Assays of this sand yielded 6% Fe and 0.1% TiO_2. He estimated the deposit to be 4 km. long, 1 km. wide and 100 m. thick. He considered 2.7 to be the conversion factor from cubic meters to long tons. He calculated 540,000,000 cubic meters and 32,400,000 long tons of iron for this deposit. The second deposit considered by Bradley was a dune sand which assayed 6% Fe and 0.3% TiO_2. He considered this deposit to be 4 km. long, 1.3 km. wide and 7 m. thick. He estimated 98,000,000 cubic meters and 5,896,800 long tons of iron to occur in the magnetite black dune sand.

HYDROTHERMAL COPPER VEINS

The copper veins of the Acari region are enclosed principally in granite intrusive but to a lesser extent in Dark Volcanics and granodiorite intrusive. Outcrops and shallow mining operations on the veins within the "Acari" claims reveal only oxidized minerals. These are principally malachite and chrysocolla.

Three main zones of copper veins are present, based on their geographical position and host rock type.

1. Plateau zone - granite intrusive.

2. Loza zone - dark volcanics

3. Loma Alta zone - granodiorite intrusive

PLATEAU ZONE

The copper veins of the Plateau zone characteristically fill very long structures from 1 to 4 km. in length within the granite intrusive, their width ranges from 1.0-0.3 m. The strike is predominantly N 65° W to N 80° E and the dip is 70-80° north. Mineralization occurs in discontinuous ore-shoots of oxidized copper minerals which pinch-out both along their length and at depth. The oxidized minerals consist principally of malachite and chrysocolla.

In the southeastern part of the Plateau zone in the Acari XV area small underground workings begun about 1953 are located in veins numbered: 1, 2, 3, X1, X2, 9, 10, 11, 12 and 14. Kleiman (oral communication, 1964) notes that for hand picked concentrates (80%) of ore shoots the assay grade was 19% Cu, while the tails retained 5% Cu. The writer (1964) sampled several mine dumps from vein 10. Assays of these dumps and a selected composite sample are given in Table XXII.

TABLE XXII. - Assays of mine dumps of Vein 10, Acari XV area, Acari Iron Mining District, Peru.

METAL	10-1	10-2	10-3	10-4	SELECTED COMPOSITE
% Cu	3.90	1.60	1.61	2.84	15.96

In the northwestern part of the plateau zone there are several parallel veins. They include the veins of Acari VIII and the veins of the Aeromagnetic anomaly No. 1. The veins of the first group cross an aeromagnetic anomaly in a northwesterly direction. They outcrop over a vertical range of more than 100 m. from the hilltops to the bottom of the vallies. The veins are 1 km. long and 0.30-0.50 wide. They consist predominantly of calcite, specularite and discontinuous spots of malachite. The veins of Acari VIII may be the northwest extension of the veins at the Genova mine, which occur outside the claim area. These veins strike about N 80° W and dip 70-80° N. The fracture fillings are principally malachite in the oreshoots and gouge in the barren zones. Two veins were drilled by percussion drill holes to a depth of 190 feet. Assays of the copper veins ranged from 0.32-1.58% Cu.

LOZA ZONE

The veins of the Loza zone are located on the southwest slope of Cerro Loza where they are enclosed in the Dark Volcanics. They include the copper veins 15 and 16 and the Pluto gold-copper vein. These veins generally parallel felsic dike contacts, or they have filled fractures transverse to the dikes. The mineralized fissures strike between N 10° W and N 30° W. and dip northeastward. They consist principally of malachite, chysocolla and cuprite in a gangue of carbonates and quartz.

VEIN 16

The deposit called vein 16 consists of several veins occurring at an elevation of 1600 m., principally on the south slope and summit of a hill across from the Cerro Pluto, in the southeastern border of the plateau. Three main veins 30-50 m. apart are known. The first vein, which crosses the road is 80 m. long and 1 m. wide. It strikes N 30° W and dips 80° NE. The ore mineral is principally malachite and chrysocolla. In the middle part of the southwest slope of the north hill are two veins. One vein strikes N 16° W and dips 86° NE. It is 60 m. long and 1 m. wide. Milky quartz, malachite, chrysocola, specularite and 0.15 m. wide parallel bands of barite which are the main constituants in this vein. About 50 m. to the west another vein 20 m. long and 0.20-0.30 m. wide contains malachite and barite. At the top of the hill two veins, 40-50 m. long and 0.3-0.5 m. wide, strike N 10° W and dip eastward. They contain malachite and specularite.

VEIN 15

Vein 15 is located on the Loma Plana range of the south slope of Cerro Loza. Oxidized copper minerals fill transverse and contact fractures, but locally they occur disseminated throughout a vein consisting principally of milky quartz. The quartz vein in 1400 m. long and 1-4 m. wide, but the width of the copper mineralization is only about 0.30-0.50 m. The vein strikes N 30° W and it dips 50° NE. The most important southern segment of the vein exhibits a blackish red crest with scattered green spots. Tealdo's (1962) analyses of samples from vein 15 are given in Table XXIII.

TABLE XXIII. - Average assays of Copper Vein 15, Loza zone, Acari Iron Mining District, Peru.

SEGMENT	LENGTH	WIDTH	% Cu
North	150 m.	1.50 m.	2.03
Middle	1000 m.	2.00 m.	0.29
South	200 m.	3.60 m.	3.90

PLUTO VEIN

The Pluto vein lies on the south slope of Cerro Pluto at an elevation of 1500 m. to 1550 m. Mineralization is confined to the transverse and contact fractures of a felsic dike 150 m. long and 3 m. wide, which strikes N 30° W and dips almost vertical. The 0.01 to 0.15 m. wide fractures are predominantly filled by chysocolla and calcite. G. Hoffmann (1959) found native gold in this vein. Average assays of 14 samples were 0.3-0.5 ounces Au and 6-10% Cu. From another small structure on the southwest side of the hill, he obtained 0.02-0.03 ounces Au and 1.5-4.0% Cu.

LOMA ALTA ZONE

The veins of the Loma Alta zone, which are enclosed in the granodiorite intrusive are located in the Cerro Loma Alta, a range which is bounded by the Media Luna and San Isidro vallies. Two veins are known and they strike almost north-south.

One of these veins is located 200 m. eastward from vein 9 of the Pongo zone. It is 0.3-0.5 m. wide and it consists of malachite and quartz. One sample analyzed 1.26% Cu and 0.04 ounces Au.

The other vein called vein 20, is located on the south slope of the Cerro Loma Alta, about 100 m. west from the triangulation station at Loma Alta. This vein, which is 300 m. long and 3 m. wide, consists principally of milky quartz. A parallel 0.10 m. wide band in the hanging wall border contains oxidized copper minerals (dominantly crysocolla). One sample from the latter vein gave 12.04% Cu.

Chapter VIII

GEOPHYSICAL EXPLORATION

INTRODUCTION

The magnetic method of exploration was applied in the region of Acari, due to the high magnetic susceptibility of the magnetite which is the principal ore mineral in the iron deposits, and due to its high susceptibility contrast to the granodioritic host rock.

Magnetic geophysical exploration attempts to outline the magnetic response of the subsurface rocks. The method is complicated in principle and practice because the response depends upon both magnetic susceptibility variations and remanent magnetism. These factors vary over a wide range, and small traces of certain ferromagnetic minerals can greatly influence the response.

An aeromagnetic survey by Aero Service Corporation of Philadelphia was initiated over part of the Acari region in 1952. It covered most of the plateau, but unfortunately the southern slope was omitted. As a result the iron deposits of the Mastuerzo and Campana zones and the west portion of the Pongo zone were not included in this survey.

From August, 1958 to March, 1962 there was an intensive program of ground magnetic surveys included almost all of the area of the Mastuerzo zone, that of the main iron deposits of the Campana and Pongo zones, and even a field check of the aeromagnetic anomalies found by earlier survey.

AEROMAGNETIC SURVEY

The aeromagnetic total intensity survey was made with a fluxgate magnetometer mounted in an aircraft. The survey was flown at an altitude of 5000 ft. above the ground level. Aerial photographs served as a base and the height of flight was controlled through a radio altimeter.

After compilation the aeromagnetic contour map showed nine main aeromagnetic anomalies. These are shown on the general geologic map as anomalies A-1, A-2, A-3, A-4, A-5, A-6, A-7, A-8 and A-9.

The anomaly A-1 exhibits a high of 16,500 and a low of -12,000 gammas. It is on the northwest part of the claim area. It has a N 10° W trend and it occurs over an area of acid and basic facies of the granite intrusive, which is here crossed by several mafic dikes. This area was drilled about 250 ft. by five percussion drill holes with negative results.

Anomalies A-2, A-3 and A-4 with high values of 1850 gammas and lows of -1600 gammas occupy an elongate area 5 km. long with a trend of N 10° W. The area is largely covered by the Dark Volcanics. This elongated area would correspond to the inferred contact between the granodiorite and granite intrusives, now covered by the Dark Volcanics. In this case, one of the probable causes would be the larger thickness of the Dark Volcanics in this area.

Anomaly A-5 trends N 30° W and is located over the granodiorite intrusive. It has a high of 1800 gammas and a low of -1200 gammas. This area was later drilled by 5 percussion drill holes. The deepest hole attained 382 ft. Rock with disseminated magnetite gave 12% Fe.

Anomaly A-6 coincides with an area of black magnetite sands at Cerro Conchudo. The magnetic readings showed highs of 1250 and 1620 gammas.

Anomaly A-7, which has a magnetic high of 1850 gammas, coincides with Vein 9 of the Pongo zone, in an area of granodiorite intrusive.

Anomaly A-8 trends N 30° E over the Dark volcanics. It has a magnetic high of 1850 gammas and a magnetic low of -1700 gammas. Anomaly A-9 also occurs over the Dark Volcanics exhibiting a magnetic low of -1550 gammas. Considering the lesser thickness of the Dark Volcanics in this area, and the possibility of the displaced northward continuity of the fracture system of trend N 50° W to N 15° E, the anomalies A-7 and A-8 could be related to magnetite deposits.

GROUND MAGNETIC SURVEYS

The initial ground magnetic surveys utilized a dip needle. Later in the systematic ground magnetic surveying two vertical magnetometers were used. They were an Arvela T-7 and a Levanto vertically balanced torque type. The Arvela had a 40 gamma sensitivity and a range from -7100 gammas to 32,200 gammas. The Levanto OY (A.R.M. 911) was less sensitive and had a range from -100,000 gammas to 100,000 gammas. The iron deposits of the Mastuerzo, Campana and Pongo zones were surveyed with the Arvela instruments. The Levanto was used principally over the Vein 1 of the Mastuerzo zone.

A Varian Precession Nuclear Magnetometer, and a Hotchkiss Dip Needle also were used. Both of these measure variations in the earth's total magnetic field. The Varian was utilized principally on the east slope of Gordon Hill and on the coastal plain. The Hotchkiss Superdip Needle was employed to check the areas of the aeromagnetic anomalies.

The ground magnetic survey of the principal areas generally utilized a spacing between lines of 20 m. and a station interval of 5 m. In areas which were considered to be less important the respective spacings were 100 m. and 20 m.

In summary, the magnetic results of the survey suggest the following:

1. The highest magnetic values were over bedrock outcrops of Vein 1 of the Mastuerzo zone. They were of 100,000 and -100,000 gammas response.
2. The magnetic anomalies coincide with the position of exposed magnetite deposits, but if the top of the magnetite body is deeper than 80 m. the response was not certain. As an example, the middle part of Vein 1A of the Mastuerzo zone did not yield an anomaly, although in this part a large vertical thickness of good magnetite was buried more than 80 m. below the surface.
3. The survey shows an important anomaly which is parallel to the northwest of, and larger than that of vein 4, in the Pongo zone. This occurs over an area where outcrops are absent.
4. Deposit La Mancha of the Mastuerzo zone gave an important anomaly, though it was almost completely covered by soil.
5. An important anomaly largely over unexposed Vein 17 of the Mastuerzo zone has helped to outline this deposit.

Chapter IX

GENESIS OF THE MAGNETITE DEPOSITS

INTRODUCTION

To begin a discussion of the genesis of the magnetite deposits in the Acari District it is helpful to concisely review information dealing with genetic processes which are related to the type of deposits occurring in the Acari Mining District. Based upon that background, one can then more adequately explain and interpret data derived from the field and laboratory studies in the Acari Mining District.

Genetic classifications generally separate, in a somewhat arbitrary manner, the different processes related to the formation of mineral deposits. The genesis of a specific ore deposit can best be understood, however, when the various processes and their interrelationships are considered together.

Considering the fact that the main difference between rocks and mineral deposits is the content of metal-bearing minerals, the present writer agrees with Niggli (1954, p. 492) who subdivided rock and mineral deposit-forming processes in the following way:

> 1) Exogenetic - processes taking place in the boundary region in which the lithosphere, atmosphere, and hydrosphere impinge upon one another, and depending on the reciprocal action of the masses.
>
> 2) Endogenetic - processes taking place within the lithosphere itself or at least depending on factors governed by conditions within the lithosphere and not specifically produced by the action of the atmosphere or hydrosphere on the rock shell.

In accord with Niggli we can divide the endogenetic processes into: magmatic, derived from magmas, and metamorphic, which involve transformations of solid portions of the lithosphere and are not associated with any considerable degree of liquefaction.

The most important for the economic geologist probably are the endogenetic magmatic processes. A broadly accepted belief is that residual fluids from a crystallizing rock magma are the source of a great majority of mineral deposits. That many geologists support this concept is shown by the following quotations:

> It is held that hypothermal and mesothermal deposits are formed by emanations from intrusive rocks, generally batholiths. (W. Lindgren, 1933).

> Probably most geologists would agree that ore deposits are generally derived from large bodies of igneous material. (C. N. Fenner, 1940).

> (Magmatic) waters and vapors have become almost universally accepted as the causative agents of most epigenetic ore deposits. (A. M. Bateman, 1942).

> There is an ample support, from chemistry of rock magmas, for the claim that ores of tin, tungsten, tantalum, and other lithophile elements (iron) are derived from bodies of eruptive magma. But in the case of the thiophile elements, evidence of this nature is scanty and unconvincing. (Shand, 1947).

> The view that predominates among economic geologists in the United States is that ore deposits of igneous affiliation are differentiated at depth, and that ore constituents are transported in the uncrys-allized fraction. (C. F. Park and R. A. MacDiarmid, 1963).

> The hydrothermal solutions are genetically related to the cooling intrusives under hypabyssal conditions at depths under 11-12 km. and pressure below 3,000 atm. (Betekhtin, 1955).

It is evident that the content of metals must vary with the different igneous magmatic processes. Some processes yield barren bodies, such as rocks, dikes and barren veins. Others produce ore bodies. We may further subdivide the magmatic processes into low-metal producers and high-metal producers.

A cooling magma gradually passes through several stages from its initial molten stage to its consolidation. The principal factors which affect these stages are the general composition, pressure, temperature and water content.

The four stages as proposed by Shand (1947) are given in Figure 69; as shown by this diagram, any magmatic process, either of high-metal content or low-metal content, before its consolidation, should pass through one or more of the following four stages.

(1) Early magmatic stage of high temperature and very low water content. Here only anhydrous minerals crystallize from the magma. In this stage the minerals formed frequently are: olivine, pyroxene, plagioclase, oxidic and sulphidic ore.

(2) Late magmatic stage of high temperature and low water content (less than 5%) in which both anhydrous and hydroxyl-bearing minerals crystallize. Typical hydroxyl-bearing minerals of this stage are hornblende and biotite.

(3) The deuteric or high temperature hydrothermal stage, with more than 5% water and 300-500°C temperature. The general tendency during this stage is to replace anhydrous species by hydrous ones. The most common minerals present are: tourmaline, wollastonite, scapolite, apatite, gold, casiterite, wolframite, scheelite, pyrrhotite, pentlandite, arsenopyrite, carbonates, chlorite, epidote, and quartz. Small amounts of magnetite, ilmentie, specularite, actinolite, tremolite, sillimanite and kyanite also may develop.

(4) The low-temperature hydrothermal stage with high content of

water and 50-300°C temperature. Here moderately hydrous species are replaced by still more hydrous ones. Minerals characteristic of this stage include: the clay minerals, kaolinite, montmorillonite, etc., zeolite, chalcedony, adularia, alunite, sulphoantimonides and sulphoarsenides of silver, gold and silver tellurides, stibnite, argentite, cinnabar, native mercury, carbonates, such as rhodochrosite, epidote, quartz, etc.

It is important to keep in mind that most rocks and mineral deposits are the result of more than one process, whether it be endogenetic or exogenetic. These bodies can even be acted on by both kinds of processes. The combinations of the different processes and their different stages result in reactions or changes which often produce modifications in previously formed rock or ore bodies. Thus, for example in the case of reactions and changes produced by endogenetic processes, the fugitive constituents of an igneous intrusion can yield deuteric alterations in the intrusive rocks, or they can produce zoning in the mineral deposits due to the successive action of ore or barren fluids or both. The zoning of the magnetite deposits of the Acari region belong to the latter case.

POSSIBLE HYPOTHESIS OF GENESIS

The intrusive enclosing rock, host rock alteration, and the structural, mineralogical and textural characteristics of the magnetite deposits of the Acari region strongly support an endogenetic origin for these deposits.

Three main types of endogenetic origin could be considered for these magnetite deposits: magmatic, hydrothermal and igneous metamorphic. However, an igneous metamorphic genesis seems unlikely because of the following facts:

1. No magnetite deposits in contact with limestone or dolomite are known.
2. Some magnetite deposits do not crop out in the intrusive bed rock.
3. The magnetite deposits generally tend to split or thin upward.

Table XXIV is a summary of the characteristics of the magmatic versus hydrothermal deposits, and the facts which support a magmatic origin for the Acari magnetite deposits.

MAGMATIC HYPOTHESIS

Magmatic deposits can be subdivided into three main structural types: (1) disseminated, (2) segregated, and (3) injected. Each is characterized by its own structural, textural and, to a certain degree, mineralogical nature. The Acari magnetite deposits appear to belong to the injected class.

In terms of time we may consider the processes forming magmatic injection deposits in the following groups:

1. Pre-metallization processes.
2. Syn-metallization processes.
3. Post-metallization processes.

For the magnetite deposits of the Acari region, the pre-metallization processes involve: (1) those of the primary magma from which the intrusive granodiorite and the iron-rich injection fluids were derived, (2) the consolidation of the granodiorite intrusion, and (3) the

TABLE XXIV. - Summary of the main genetic hypothesis of the magnetite deposits of the Acari Iron Mining District.

A. MAGMATIC	B. HYDROTHERMAL
I. SOURCE OF ORE	
a) Characteristic. - Near source deposition. b) Facts. - Host rock contains abundant disseminated magnetite throughout.	a) Characterisitc. - Source far from site of deposition.
II. NATURE OF THE ORE-BEARING FLUIDS	
a) Magmatic fluids. b) No primary hydroxil-bearing minerals occur in the ore bodies. Narrow zones of chlorotization surround the ore bodies.	a) Hydrothermal solutions
III. TRANSPORTATION OR MIGRATION	
a) By gaseous expansion or injection. b) Microporous colloform texture in the magnetite would show colloid transport of iron in medium gaseous with scarce water, at high temperature.	a) Flow of solutions with high content water, toward area of lower pressure.
IV. CAUSES OF DEPOSITION	
a) Decrease in temperature and pressure. Neutralization of electric charges in the colloids.	a) Decrease in temperature and pressure. Neutralization of solutions.
V. STRUCTURAL CONTROL	
a) Fissures in host rock.	a) Fissures in host rock.
VI. HOST ROCK OF THE ORE BODIES	
a) Ore bodies and host rock are generally derived of the same source magma. b) Disseminated magnetite occurs in all of the host rock. Similar alteration in the magnetite in the host rock and in the ore bodies.	a) The ore bodies are epigenetic with respect to the host rock.

TABLE XXIV. - Summary of the main genetic hypothesis of the magnetite deposits of the Acari Iron Mining District.

A. MAGMATIC	B. HYDROTHERMAL
VII. POSITION OF THE ORE BODIES	
a) Mineralized dikes b) No hydroxyl-bearing primary minerals	a) Metal-bearing veins.
VIII. MINERALOGY OF THE ORE BODIES	
a) Pyrogenetic primary minerals. b) The only primary ore mineral is massive, compact, colloform magnetite.	a) Hydatogenetic primary minerals.
IX. TEXTURE OF THE ORE BODIES	
a) Texture of igneous rocks b) Colloform, microporous, fine-grained texture. The texture and the predominance of magnetite indicate that the colloids had low water content and high volatile content. Research of colloids at high temperatures and pressures is necessary.	a) Open-space filling, replacement and colloidal textures. Drusy cavities, comb structures, crustifications. b) Colloform texture.
X. HOST ROCK ALTERATION	
a) Slight host rock alteration b) Alteration consists only of narrow chloritized aureola that surround the ore bodies.	a) Strong host rock alteration.
XI. ZONING OF THE ORE BODIES	
a) Absence of monoascendent zoning b) Only polyascendent zoning produced by hypogenetic alteration is present.	a) Monoascendent zoning.
XII. PARAGENESIS OF THE ORE BODIES	
a) Magmatic sequence. b) Simple primary sequence of magnetite, a pyrogenetic mineral would indicate magmatic origin.	a) Hydrothermal sequence.

fracturing of the granodiorite intrusive. The syn-metallization processes include: the migration of the iron-rich fluids from the source to the site of deposition, the conditions of deposition, and the alteration of the host rock. Post-metallization processes include: the hypogenetic alteration of the magnetite deposits by barren high temperature hydrothermal solutions, the cource of these barren fluids, their migration, reactions, and phase relations, post-metallization faulting, supergene alteration and physiographic modification. The influence of each of these processes on the Acari magnetite deposits are discussed below.

PRE-METALLIZATION PROCESSES

Considering that in these magnetite deposits the metallization fluids are derived from a magmatic body it is convenient to define the term magma. The A.G.I. Glossary of Geology and Related Sciences (1962) defines magma as:

> A naturally occurring mobile rock material generated within the earth and capable of intrusion and extrusion, from which igneous rocks are considered to have derived by solidification.

Shand (1947, p. 61), discussing the temperature and pressure of magma, has summarized:

> There is an entire lack of evidence that any body of deep magma ever had a temperature higher than 1170°C or that it even approached that temperature, in very many cases the temperature does not seem to have exceeded 870°C.

The presence of almost uniform distribution of disseminated magnetite in all of the granodiorite intrusive, which is the only host rock for the magnetite deposits of the Acari region, supports the idea that both are derived from the same primary source magma. That source magma suffered separation into two immiscible liquids. Subsequently the lighter siliceous liquid rose, floated upon the iron-rich liquid, and later crystallized. The predominant mineral in the granodiorite is medium-grained crystalline sodic-calcic plagioclase, but regularly disseminated small crystals of magnetite are common, small crystals of quartz are irregular distributed, and generally medium-grained crystals of hornblende enclose some small magnetite crystals. The characteristics of these last two minerals suggest that their formation was by high-temperature hydrothermal alteration. In this case the separation into two immiscible liquids was in the early magmatic stage. The possibility that liquid separation is an active process in the formation of magmatic ores wad advanced by Fischer (1950), who synthesized magnetite-apatite fluid as an immiscible fraction of a silicate melt.

Later the consolidation stress environment of the solifying granodiorite intrusive caused the formation of several systems of fissures which subsequently served as the open space sites for the deposition from the iron-rich injection fluids.

SYN-METALLIZATION PROCESSES

The theories of mobilization of iron-rich fluids has been subject of much controversy, but in general they fall into one of two categories. Many geologists consider the migration to be due to the high volatility of a halide gas ($Fe_2Cl_6 \cdot FeCl_3$). Others have emphasized the importance of hydrothermal solutions in the transport of iron. The high melting point (1591°C) of magnetite makes it difficult to explain its migration in the molten state.

Two interesting theories for explaining the transportation of iron under endogenetic conditions, are (1) a theoretical consideration by S. J. Shand (1947) and (2) an experimental approach by W. T. Holser and C. J. Schnner (1961).

Shand (1947) indicated that

> In nearly all deep-seated eruptive rocks their magmas ferrous oxide is much more abundant than ferric oxide... if the residual liquid is alkaline, as any solution must be which contains strong cations and weak silica-alumina anions, then the iron can only be present as a hydrosol of ferrous hydroxide peptized by the alkali.

Concerning the oxidization of ferrous hydroxide to magnetite he said

> Atmospheric oxidization is excluded in deep magma, but another process is possible, namely self-oxidization. The hydrosol loses water and the hydroxide oxidizes itself to magnetite according to the equation:
>
> $3Fe\ (OH)_2 = Fe_3O_4 + 2H_2O + H_2$

Holser and Schnner (1961) found that:

> At 390°C, 440 bars, in 0.0002 M HCl solution, 300 ppm. ferrous iron is dissolved. In pure water at the same conditions solubility is less than 0.02 ppm...Anything less than 1 ppm iron in solution is not significant in the formation of hydrothermal iron ore deposits. HCl concentrates in the range 0.01-0.10 M are probably common in natural fluids.
>
> Our measurements show that geologically significant concentrations of iron can be mobilized at temperatures and pressures similar to those at which hydrothermal deposits were formed and in solutions two orders of magnetude more dilute in CHl than these natural fluids. Transport by HCl solutions can be therefore important in the formation of some magnetite deposits. Further high-temperature experiments is necessary to compare solubilities in CHl solutions with those in other important acids such as HF and H_2CO_3.

To obtain information on the migration of these magmatic fluids which formed the magnetite deposits of the Acari region, the writer began an examination of the portions of the deposits in which the magnetite is the predominant mineral and very small quantities of apatite are present. Here the host rock exhibits a narrow chloritization aureola surrounding the magnetite deposits. The study of thin sections, polished sections and hand-specimens with one polished flat surface, taken from the different portions of vein 1A of the Mastuerzo zone, shows that the magnetite exhibits a microporous, fine-grained, colloform texture.

The writer does not believe that transportation by hydrothermal solutions is sufficient to explain the migration of the very iron-rich fluids which have formed the magnetite deposits in the Acari region. The very high percentage of magnetite and the colloform texture suggest a concentrated colloidal system rather than a dilute hydrothermal solution. Water present as the dispersing medium or solvent is a minor quantity in a colloidal system.

In such a colloidal system the dispersed phase would be iron in form of ferrous iron (wustite) which is stable about 560°C, or perhaps in form of ferrous hydroxide as Shand (1947) indicated, but the dispersing medium would be formed by super-critical fluids due to the high pressure and temperature of the environment. The distinction between liquids or gases is lost for super-critical fluids. The dispersing medium likely contained a high content of volatile constituents and a very low water content.

Constituents such as carbon dioxide, fluorine, chlorine, hydrogen and phosphorus probably were present. These features are indicated by the following:

1. Slight host rock alteration of the magnetite deposits.

2. Dominant magnetite and very small quantity of apatite are the only primary minerals.

3. The microporous texture of the magnetite.

The release in pressure due to the formation of fissures in the overlying intrusive permitted the expanding and the upward movement of the magmatic fluids due to their high content of volatile components.

The depositional conditions which promoted the flocculation of the colloidal system were the ones of the new physical environment of the fissures, particularly a decrease in temperature and pressure. The escape of the volatile substances must have produced a larger concentration of the dispersed phase in the gels which, together with the weakening of the electric charges produced by the decrease of temperature, may have promoted the settling of the gel.

The writer known of only two other occurrences of magnetite with colloform texture. One is a magnetite vein enclosed in periodtite near Espanola in Monogowin township, Sudbury District, Ontario. E. S. Moore (1929) stated that:

> The only explanation that occurs to me, is that the iron oxide vein in the peridotite was originally in the form of hematite or goethite and an intrusion of granite that outside peridotite on its southwest side not far from the vein has metamorphosed the iron oxide to magnetite.

The other occurrence of colloform magnetite is found in the magnetite bodies on the Empire Development property at the northern end of Vancouver Island, British Columbia. Of these J. S. Stevens and W. G. Jeffery (1964) stated that:

The Empire colloform magnetite may thus be assigned to the gel metasomatism type of replacement. Although most gel replacement is thought to take place at relatively low temperatures, the associated skarn suggest that the colloform magnetite of the Empire was formed at relatively high temperatures...

As a mechanism of transportation and deposition it is suggested that the iron for the colloform magnetite was carried in HCl solution, replaced the limestone, and was precipitated as a colloid during an intermediate stage of aggregation that existed between the state of ionic solution and the precipitate.

POST-METALLIZATION PROCESS

The underground geology and the megascopic and microscopic study of selected specimens show that the mineralogical bottoming of the magnetite deposits of the Acari region is the result of hypogenetic alteration produced by rising barren, high temperature, hydrothermal solutions.

The underground geology shows that a polyascendent zoning has produced 3 zones in the magnetite deposits. The upper ore zone consists of primary magnetite, small quantities of primary apatite, and the secondary minerals hematite, specularite and martite. The upper part of the transitional zone is formed by veinlets and tongues which are constituted dominantly by amphiboles and amphiboles mixed with secondary magnetite, and which cut the magnetite bodies. The lower barren zone is constituted predominantly by amphiboles along with carbonates, apatite and quartz.

The megascopic and microscopic study of specimens from the transitional zone, especially those from the lower part, exhibit textures in which the magnetite or remnants of magnetite are surrounded or cut by veinlets consisting mainly of carbonates, apatite, and a very small quantity of quartz. Some of the amphibole crystals enclose some irregularly shaped grains of magnetite. The carbonates, quartz and amphiboles in some specimens replace portions of the scalloped layers of the colloform magnetite. Where quartz is predominant in the replacement front, it appears that the metasomatic changes were slow, because the amphiboles begin to appear at a greater depth. There carbonates and apatite are predominant, the amphiboles appear very close to the replacement front.

Considering the proximity of the granite intrusive and that the tectonic and metallogenetic features of this intrusive indicate that its emplacement occurred after the formation of the magnetite deposits, the writer infers that the barren fluids which altered the magnetite ore bodies of the Acari region, consisted of fugitive components derived from the granite intrusion. The barren fluids were high temperature hydrothermal solutions constituted principally by carbon dioxide, silica, hydrogen, chlorine, fluorine, phosporus and a high water content.

The transportation of the barren fluids must have been through new fractures opened in the magnetite deposits, through the interlayers cavities of the colloform texture, and through the adjacent microscopic pores of the magnetite. The exchange of material must have taken place by diffusion of ions or molecules through the fluid phase in the fractures, interlayers cavities and microporosity of the magnetite ores. All of the metasomatic changes were produced at high temperatures and they became more intense with depth. The hypogenetic alteration reached a higher level in the wider ore bodies than in the narrower ores. For instance, such alteration is higher in vein 1 than in vein 1A of the Mastuerzo zone.

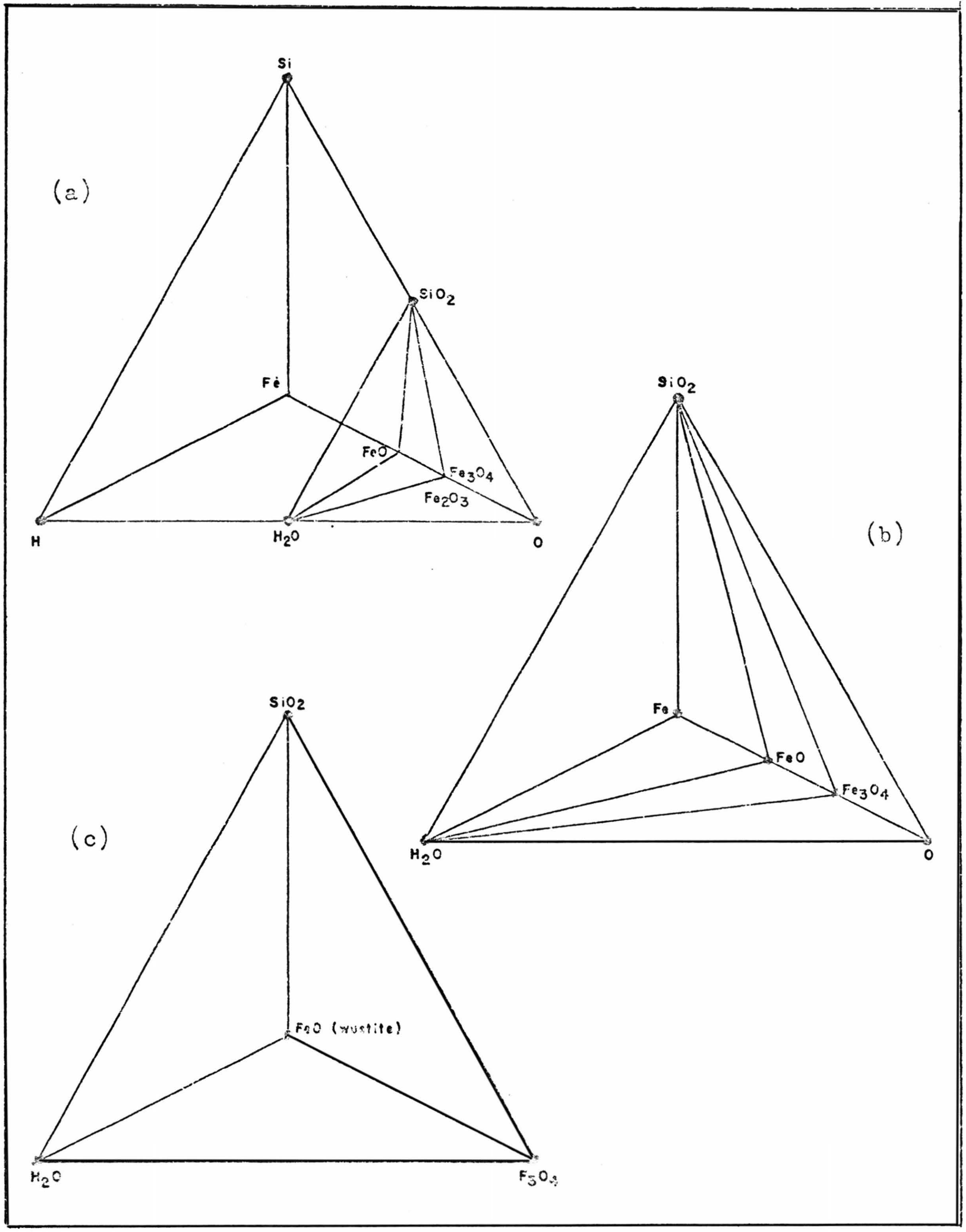
Laboratory synthesis of minerals, although the exact conditions of endogenetic processes in nature may not be reproduced, affords interesting information which may assist in a better understanding of the genesis of the mineral deposits. In order to improve our understanding of heterogeneous reactions, a first requirement is that we must be able to adequately describe the system. The thermodynamic data are strictly applicable only if all of the components have been considered which were present in that system in nature. Such information is best presented in the form of phase diagram.

The most useful laboratory information pertaining to the hypogenetic alteration of the magnetite deposits in the region of Acari are the experiments carried out by H. S. Yoder (1957) and S. S. Flascher and E. F. Osborn (1957). They have discussed the implications of the metamorphism of mineral systems containing iron oxides, silica and water as chief components.

Yoder (1957) has pointed out that:

> The various ferrous silicates can form upon metamorphism in a rock initially consisting of magnetite and quartz.

Flascher and Osborn (1957) investigated the system iron oxide-silica-water, under conditions of low oxygen partial pressures and at elevated temperatures, and with an emphasis on the temperature


Si
(a)
SiO_2
Fe
FeO
Fe_3O_4
Fe_2O_3
H
H_2O
O
SiO_2
(b)
Fe
FeO
Fe_3O_4
H_2O
O
SiO_2
(c)
FeO (wustite)
H_2O
F_3O_4

range 220°C to 600°C. They indicate that:

> In hydrothermal studies of iron oxide-silica-water mixtures at low partial pressures of oxygen, the ferrous silicates, fayalite, greenalite, and minnesotaite have been synthesized and their stability relatives investigated.

Their laboratory results show, that with any change in the physical conditions, the content of water or the number of components, there is the possibility of the formation of the different kind of amphiboles such as those found in the barren zone of the magnetite deposits of the Acari region. It is probable that the addition of CO_2, HF and P would facilitate the exchange of material in the replacement front.

ENDOGENETIC SEQUENCE

A concise review of the genesis of the magnetite deposits in the Acari region is illustrated in Figure 69. The writer considers the formation of the magnetite deposits of the Acari region to have been influenced by magmatic processes of two successive stages.

In the first stage, an early magmatic one, an original magma separated into two inmiscible liquids. One liquid was siliceous and subsequently formed the granodiorite intrusive. The other liquid was iron-rich and it formed the magnetite deposits.

In the second stage, granitic magma was intruded into the area. The fixed constituents of this granite intrusive probably crystallize in the early magmatic stage as indicated by their anhydrous nature. The barren fugitive constituents were released from the cooling magma during the high temperature hydrothermal stage. The latter process is believed to have altered the lower

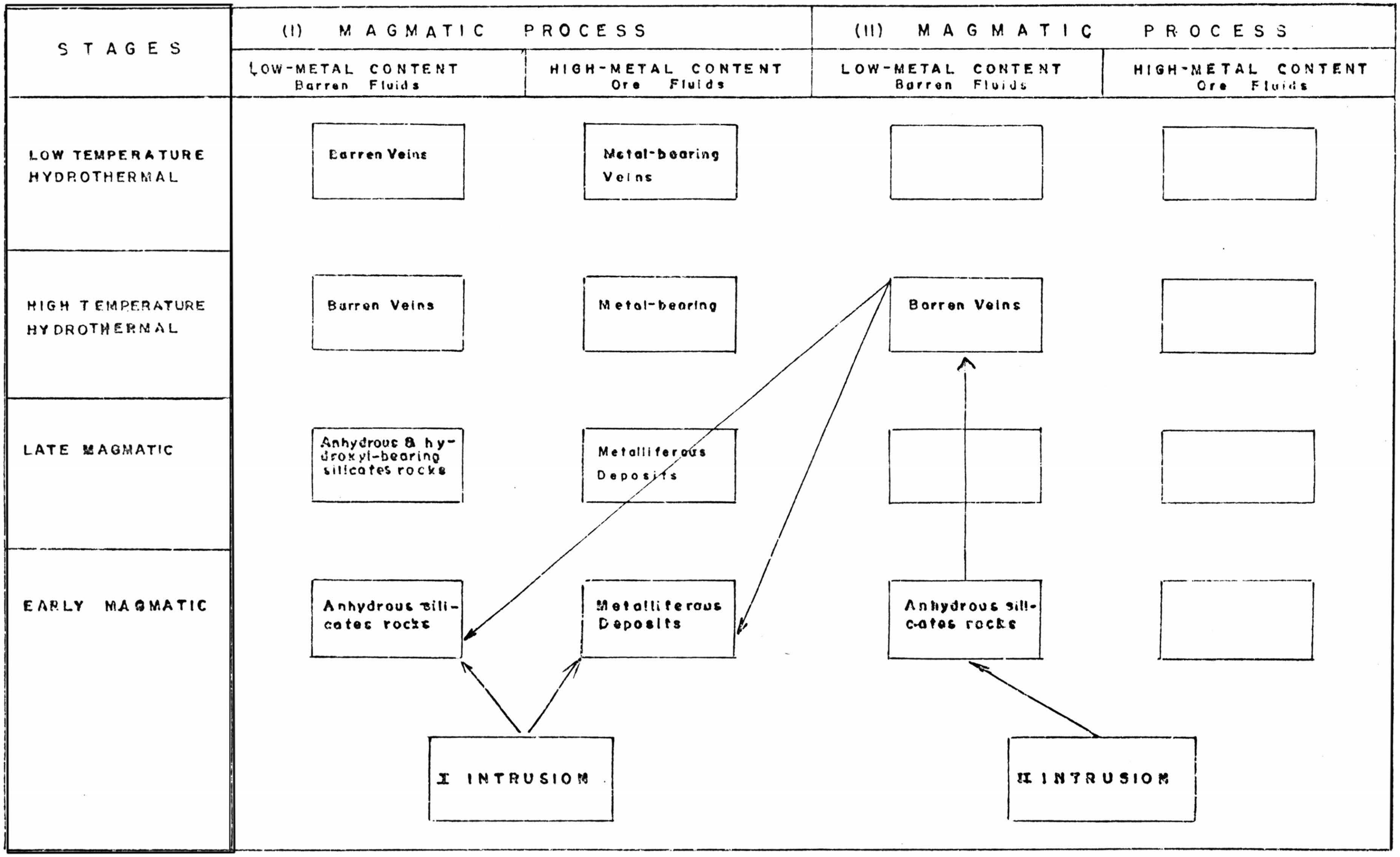


FIGURE 69. - Endogenetic sequence of the magnetite deposits of the Acari Iron Mining District.

portions of the magnetite ore bodies into amphiboles, producing their mineralogical bottoming. At the same time the disseminated magnetite in the granodiorite host rock was transformed into hornblende, which often exhibits small magnetite grains.

Chapter X

SUMMARY AND CONCLUSIONS

The principal features of the Acari Iron Mining District may be summarized by the following statements:

(1) The Acari Iron Mining District is located in the southern part of the coastal belt of Peru, in the Department of Arequipa. It occurs 30 km. inland from the coast and within the foothills of the western range of the Andes.

(2) The physiographic pattern is characteristic of the stage of late youth in an arid erosion cycle.

(3) The Acari Iron Mining District is part of an uplifted and tilted fault-block, similar to others uplifted during the process of formation of the Andean Cordilleran.

(4) The Acari tilted fault block is dominantly composed of intrusive rocks which belong to the Andean batholith of Cretaceous-Tertiary age. The intrusive rocks are overlain by a central band of metasedimentary and volcanic rocks which trend to the northwest.

(5) The intrusive rocks of the Acari region belong to two stages. The first stage consists of a granodiorite intrusion. The intrusive is located in the southwestern part of the district. It consists mainly of light medium-grained granodiorite, but lesser proportions of quartz monzonite porphyry (pink porphyry) and monzonite porphyry (dark porphyry) occur locally. The second stage was that of the granite intrusive. It is located in the northeast portion of the district, and is largely composed of light red granite.

(6) The overlying metasedimentary-volcanic rocks consist of

both pre-intrusives and post-intrusives rocks. The pre-intrusives rocks include metasedimentary rocks of probable Mississippian age and the Chocolate Volcanics of Jurassic age. The post-intrusives rocks include the Dark Volcanics, the White Tuffs of Tertiary age and Quaternary clastics. The last of these covers much of the northeastern portion of the plateau and if fills the main valleys which bisect the district.

(7) The granodiorite intrusive has been affected by three main fracturing stages. The first fracturing stage has produced two principal systems of fractures. One system strikes from N 60° E to N 40° E and dips 60-80° West, and it is called the Pongo zone. The other system strikes from N 50° W to N 15° E and dips 60-80° E and it is referred to as the Mastuerzo and Campana zones. The second fracturing stage formed a system of transverse fractures which strike from N 70° W to N 80° E and dip 75-80° southward or northward. This stage of fracturing has affected the granite intrusive as well as the granodiorite. The third stage of fracturing has produced north-south longitudinal fractures which affected all of the rocks in the district by large vertical displacements. These have formed zones of weakness along which were developed the longitudinal valleys on the south slope of the lifted fault block.

(8) In the Acari Iron Mining District four classes of mineral deposits are recognized: 1) magmatic injection magnetite deposits within the granodiorite intrusive, (Mastuerzo, Campana and Pongo zone); 2) stratiform hematite deposits in metasedimentary rocks (Loza zone);

3) magnetite black sands (Cerro Conchudo zone; and 4) hydrothermal copper veins, which are enclosed mainly in the granite intrusive (Plateau zone) but also in the Dark Volcanics (Loza zone) and granodiorite intrusive (Loma Alta zone).

(9) The magnetite deposits of the Acari region are long, dike-shaped bodies which fill the fracture systems of the first fracturing stage in the granodiorite intrusive.

(10) The magnetite deposits of the Acari region are characterized by vertical zoning. The nature of these zones, from top to bottom, is: 1) a magnetite ore zone consisting principally of magnetite with rare apatite; 2) a transitional zone in which the magnetite bodies are cut by veinlets composed of mixtures of amphiboles, carbonates, apatite, quartz and secondary magnetite; and 3) a barren zone, formed dominantly by amphiboles, but with minor quantities of apatite, carbonates and quartz. Their mineralogical bottoming is produced by hypogenetic alteration.

(11) The typical ore mineral in the magnetite deposits of the Acari region is black, compact, massive, microporous, fine-grained magnetite with colloform texture. From a commercial viewpoint the ore is classified as direct-shipping, lump, non-Bessemer (0.10-0.20% P) magnetite. The average grade is about 60-66% Fe.

(12) The nearly regular distribution of the colloform texture in the magnetite deposits suggests that the migration of the iron-rich fluids from the magmatic source to the depositional fissures was by colloidal systems and that such colloids may be stable at high temperatures. The microporous texture of the magnetite and the slight

host rock alteration suggest that the colloids had high volatile content and very low water content.

(13) The underground geology and the microscopic study support the idea that the magnetite deposits of the Acari region are closely tied in with two main endogenetic processes. The first was the injection of the iron-rich phase into the fractures in the granodiorite. The second main endogenetic process was the hypogenetic alteration of the deeper portions of the magnetite deposits by high temperature barren hydrothermal solutions which were derived from the magmatic body that later would be emplaced as the granite intrusive. This hypogenetic alteration resulted in the polyascendent, vertical, endogenetic zoning which the magnetite deposits now exhibit.

(14) The iron resources (1964) in the Acari Iron Mining District are estimated to be on the order of 20,000,000 long tons of ore largely with a grade 60-66% Fe. This is exclusive of the latent potential constituted by 638,280,000 long tons of black magnetite sands in the Cerro Conchudo zone which contains 6% Fe.

(15) The principal magnetite deposits are located in three zones. The Mastuerzo zone contains the important veins 1, 1A-2S La Mancha and 17. In the Campana zone the four known deposits belong to one structure about 4 km. long. The most favorable portion is between veins 5 and 6. In the Pongo zone the most important deposits are veins 4, 3E, 2, 5 and 1, but there are good possibilities in the invisible vein and the westward extension of the vein 1.

(16) In the outcrop of metasedimentary rocks on the east flank of upper course of the Loza valley there are three stratiform hematite

deposits: 7, 8 and 9. It is estimated that a potential of 2,670,000 long tons, with an approximate grade 31-37% Fe occurs there.

(17) Hydrothermal copper veins within the "Acari" claims show only oxidized minerals and they occur in three zones. Firstly, the copper veins of the plateau zone are enclosed in the granite intrusive. They are generally long east-west structures, 1-4 km. long and 1.0-0.3 m. wide. The mineralization occurs in discontinuous ore-shoots. Secondly, the copper veins of the La Loza zone are enclosed in the Dark Volcanics. They strike from N 10° W to N 30° W and dip northeastward. These veins generally are parallel to felsic dikes, occur along quartz vein contacts, fill transverse fractures or occur throughout bodies of quartz. An important deposit is vein 15, which is 1400 m. long and 2-3 m. wide and contains 2-4% Cu in its richer parts. The Pluto vein analyzed 0.3-0.5 ounces Au and 6-10% Cu. Thirdly in the Loma Alta zone the copper veins are enclosed by the granodiorite intrusive. An important quartz vein is number 20, which is 300 m. long. Here a single sample from a 0.1 m. wide veinlet of oxidized minerals analyzed 12.04% Cu.

(18) The aeromagnetic survey of the Acari region shows nine main magnetic anomalies: A-1, A-2, A-3, A-4, A-5, A-6, A-7, A-8 and A-9. The physical exploration program carried out to investigate the aeromagnetic anomalies A-1 and A-5 gave negative results. In the vicinity of the aeromagnetic anomalies A-7 and A-8 the geological conditions are most favorable for the occurrence of magnetite deposits.

(19) The ground magnetic surveys have been a useful aid in

outlining buried magnetite bodies where their tops are less than 80 m. deep. They were used to outline the deposits, La Mancha and Vein 17. Yet, the middle part of the Vein 1A-2S, which contained a large vertical thickness of magnetite, did not give any magnetic anomaly. It was covered by more than 80 m. of rock.

The evaluation and interpretation of the available geophysical and geological information of the Acari Iron Mining District has led to establishment of several possible relationships between the local geology and the ore deposits. These relationships are presented below as results which might prove to be useful guides for future exploration in the district.

(1) The magnetite deposits in fissure in the graniodiorite intrusive are positive topographic forms. The inclination of most of the magnetite deposits of low dip is in a direction contrary to that of the slope of the terrain over the granodiorite intrusive.

(2) Positive topographic forms of northeastern or northwestern trend in the granodiorite intrusive are favorable for the exploration for magnetite deposits. Examples are the crests of the hills of Yuyuca and Pajayuna. North-south trending positive and negative topographic forms are unfavorable. Examples are the north-south direction of the hills Mastuerzo and Huanaco, and the valleys of the south slope of the mining district. The latter are due to barren longitudinal faults.

(3) The distribution of positive and negative physiographic forms in the metasedimentary and volcanic rocks and in the granite intrusive apparently does not bear any significant relationship to mineral deposits.

(4) Since all the known magnetite deposits are enclosed in the granodiorite intrusive, it is the favorable host rock. The quartz monzonite porphyry corresponds to the peripheral portions of that intrusive body. It may be possible to find magnetite deposits in the metasedimentary and Chocolate Volcanics (pre-intrusive rocks), but none are known. There is also the possibility, especially in the northwest area, that magnetite deposits may occur in the granodiorite intrusive below the covering of Dark Volcanics.

(5) Stratiform hematite deposits are found only in the outcrop of distinctly bedded metasedimentary rocks in the upper course of the Loza valley. In contrast, in the outcrop in the Quebrada de los Chilenos valley where bedding is not evident, hematite deposits are absent.

(6) The copper veins occur principally in the granite intrusive, but some occur in the Dark Volcanics and granodiorite intrusive. The copper mineralization occurred at a later time than did the iron mineralization.

(7) The magnetite black sands of Cerro Conchudo zone are fairly consolidated sands overlying the granite intrusive. Their source probably was located to the northwestward and outside of the claims area.

(8) The structural study showed that the magnetite deposits of the Acari region fill two principal systems of shear fractures in the granodiorite intrusive. The presence of two sets of fractures (Mastuerzo and Campana zones) in the northwest-north system and one set (Pongo zone) in the northeast system, suggests the presence of another

set as the westward extension of vein 1 in the Pongo zone and north of the crest of the Cerro Pajayuna. In the area of this extension, in the west cliff of the Cerro Pajayuna, several veinlets of magnetite were found.

(9) An important system of east-west transverse shear fractures which fill the copper veins occur in the granite intrusive. These correspond to the second stage of fracturing in the granodiorite intrusive and they displace some of the magnetite deposits.

(10) Only one principal system of fractures occur in the Dark Volcanics. These trend northwesterly and they are filled by felsic dikes and milky quartz veins which, in turn, contain fractures filled with oxidized copper minerals.

(11) The metasedimentary rocks exhibit bedding but no important fracturing. The Chocolate Volcanics and the White Tuffs show no important system of Fractures.

(12) The magnetite deposits exhibit a polyascendent endogenetic vertical zoning due to hypogenetic alteration. This alteration probably was produced by barren fugitive components from the magmatic body which was the source of the granite intrusive. The plunge of the zoning is to the south. Thus, the barren amphibole zone is deeper in deposits which are further from the granite intrusive. This relationship is complex, however, by upward and rotation movements along longitudinal faults in the south part of the mining district.

(13) The downward increase in the apatite content of magnetite ore is indicative of the proximity of the barren amphibole zone of these deposits, but the distance to the zone is variable.

(14) In cross section the magnetite deposits can be seen to be wider at depth, and to thin or branch upward. The hypogenetic alteration reaches higher levels in the wider bodies than in narrow ones. The geological cross sections of vein 1 and 1A of the Mastuerzo zone show this well.

(15) Not all of the magnetite deposits have bed rock outcrops. An example is the middle part of Vein 1A in the Mastuerzo zone.

(16) The copper mineralization occurred after the iron mineralization and hypogenetic alteration. The source for the iron mineralization is believed to have been from the southwest portion of the mining district, while the source of the copper mineralization was from the northeast border of the district.

(17) A correlation of the aeromagnetic anomalies with the local geology of the Acari region show significant relationships. A-1 appears to be due to the presence of mafic dikes. Anomalies A-2, A-3 and A-4, which occupy an elongated N 10° W trending area about 5 km. long and covered by Dark Volcanics, must correspond with a greater thickness of the Dark Volcanics in this area. A-5 occurs over granite intrusive and A-6 is due to the black magnetite sands of Cerro Conchudo.

(18) The aeromagnetic anomaly A-7 coincides with the location of the vein 9 of the Pongo zone. Anomaly A-8 is in an area of granodiorite intrusive, but it lies on the northeast extension of the veins of the Pongo zone. Anomaly A-9 is in an area of the Dark Volcanics, and on the probable northwest-north extension of the deposits of the Mastuerzo zone. In the above cases, aeromagnetic anomalies are most

certainly correlated with magnetite deposits.

(19) The ground magneticsurveys also may be very useful in the determination of magnetite deposits at depths of less than 80 m. Areas which are favorable for the ground magnetic survey are: the north side of the crest of Cerro Pajayuna, the east side of the crest of Cerro Yuyuca and aeromagnetic anomalies A-8 and A-9.

Thus, the following lithologic, structural, genetic, geophysical and physiographic features comprise the best guides for the exploration magnetite deposits in the Acari region: 1) granodiorite intrusive; 2) systems of fractures with trends to the northeast and northwest-north; 3) the southern portion of the region, due to the southward plunge of the barren amphibole zone in the magnetite deposits, but this is modified by rotational movements along the longitudinal faults; 4) magnetic anomalies show the presence of buried magnetic bodies which are less than 80 m. deep; and 5) areas of the principal positive physiographic forms.

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