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"THE MARCONA IRON MINE
A POTENTIAL NEW SOURCE OF COBALT IN PERU"

(A Report Prepared for the U.S. Trade and Development Program
Under the Terms of Contract No. PDC-0000-0-00-2225-00)

Josiah Royce

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I. Introduction:

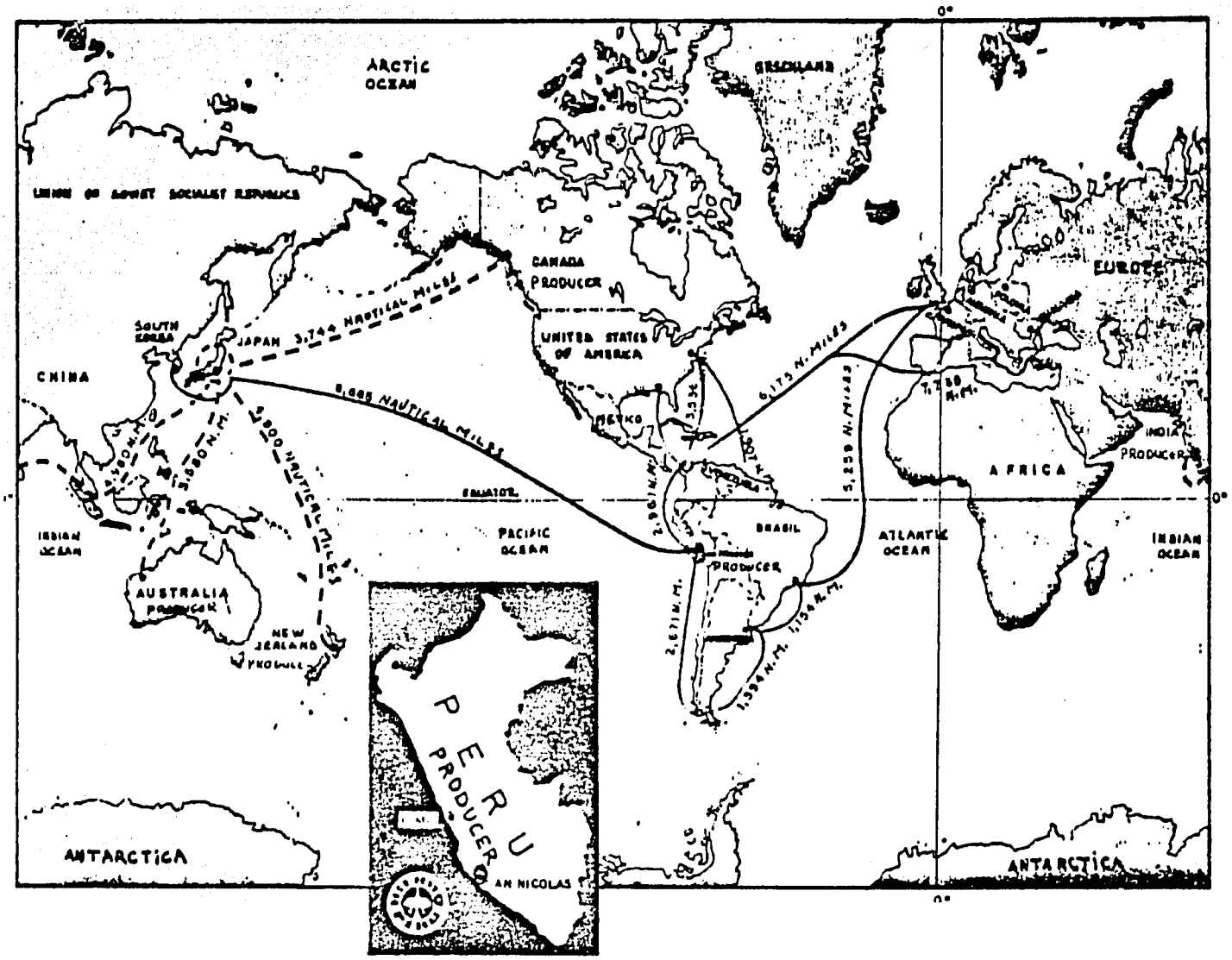
Empresa Minera del Hierro del Peru (Hierro Peru) an established Peruvian Government iron mining concern, has approached the Trade and Development Program for assistance in financing a bankable feasibility study of recovering and marketing high-grade cobalt concentrate from pyrite now being mined and disgarded in connection with their Marcona iron ore operation located 15 kilometers from the Port of Jan Nicolas. (See Figures 1 and 2). The Marcona mining area has successfully mined and marketed high-grade iron ore for nearly 30 years and has been managed by Hierro Peru since July, 1975. Present mining and milling capacity at Marcona is 7.5 million tons of high grade iron ore concentrates annually.

Hierro Peru and their predecessor, the U.S. Marcona Mining Corporation, have drilled and developed a number of outcrops and intensely magnetic areas over the years in the Marcona District some 250 miles south of Lima, Peru, in an area some 10 x 15 kilometers in extent. The magnetic iron ore they encountered is divided into three types:

(a) Oxidized (at and near surface)
(b) Transitional (of varying thickness)
(c) Primary (unoxidized ore going to undetermined but great depth)

The primary ores are the most readily processed into high-grade magnetic concentrates and contain pyrite (iron sulfide) with which is found cobalt and also copper. Hierro Peru engineers and consultants, in 1982, estimate 393,292,400 tons of measured remaining economic reserves of crude ore containing iron values varying from 46.9% to 57.7%, sulfur analyzing from 2.43% to 2.97% and copper running between 0.11 and 0.12%. Partially explored and unexplored outcrops and magnetic anomalies might reasonably be expected to double this figure. E.C. Herkenhoff, a distinguished U.S. metallurgist and a former Vice President-Technical Services of the Marcona Corporation, recently retained by Hierro Peru, estimates that, at an iron mining rate of 7.2 million tons per year, 4,158,000 pounds (2079 short tons) of cobalt could be recovered annually in a form acceptable to U.S. industry from the pyrite fraction of Marcona ore.

The U.S. Bureau of Mines gives U.S. reported consumption of cobalt varying from a maximum of 9,997 tons in 1978 to a minimum of 6,200 tons (estimated) in 1981. Cobalt superalloys (used in aircraft and industrial engines) account for about 40% of this, while metal cutting and tool bits use another 10%. Certain cobalt alloys retain a tough cutting edge even at red heat, and are corrosion-resistant.



• DISTANCE BETWEEN PRODUCERS AND BUYERS OF IRON ORE

FIGURE 1.

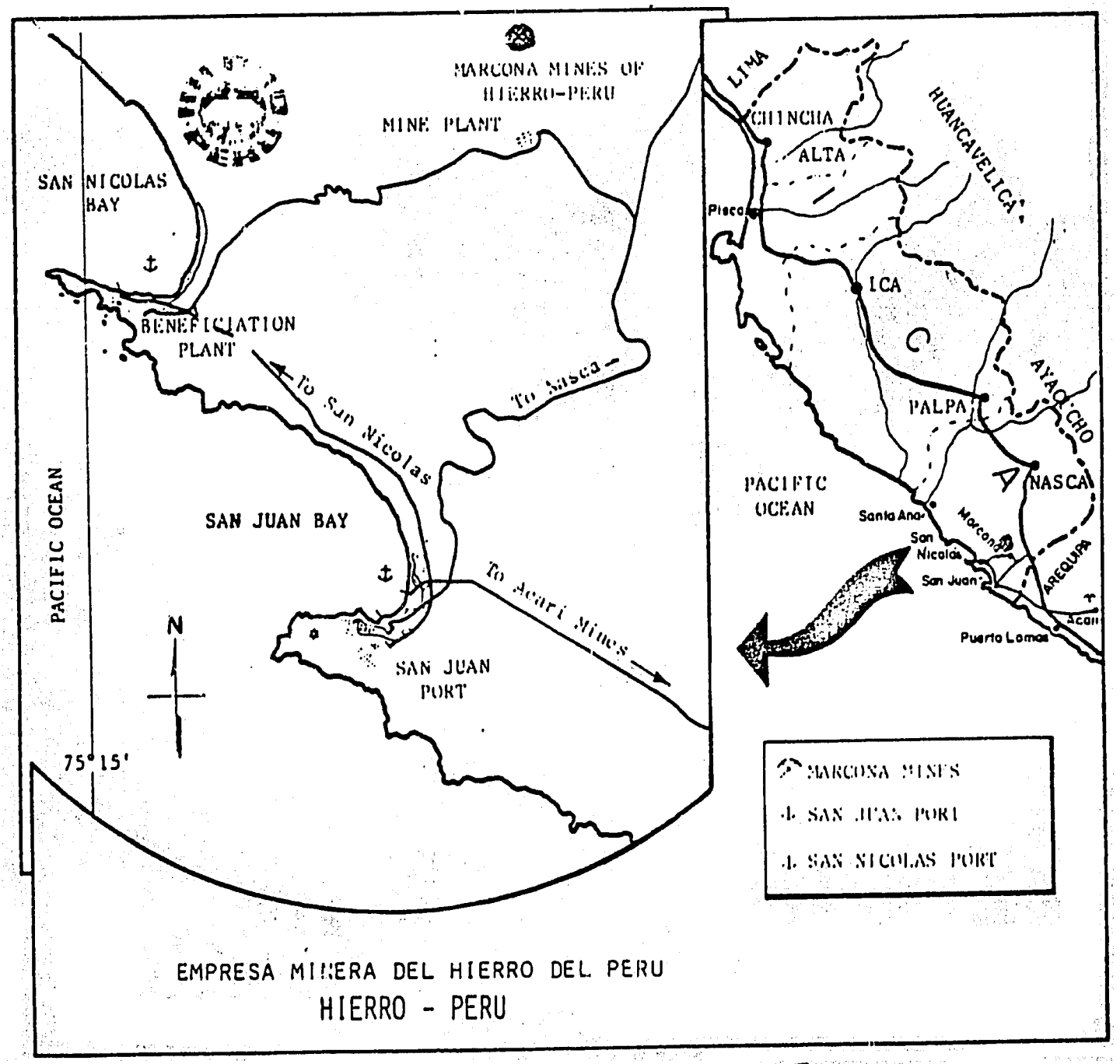

MARCONA MINES OF
HIERRO-PERU
MINE PLANT
SAN NICOLAS
BAY
BENEFICIATION
PLANT
To San Nicolas
To Nasca
SAN JUAN BAY
To Acari Mines
SAN JUAN
PORT
PACIFIC OCEAN
N
75° 15'
LIMA
CHINCHA
ALTA
HUANCAVELICA
Pisco
ICA
PALPA
AYACUCHO
NASCA
PACIFIC
OCEAN
Santa Ana
San
Nicolás
Marcona
San Juan
AREQUIPA
Puerto Lomas
MARCONA MINES
SAN JUAN PORT
SAN NICOLAS PORT
EMPRESA MINERA DEL HIERRO DEL PERU
HIERRO - PERU

FIGURE 2

Known cobalt deposits in the U.S. (See Figure 3) are generally conceded to require cobalt prices in the range of $15.00 to $30.00 per pound to become viable, while the cobalt spot market price today has tumbled to around $5.00 to $6.00 per pound from a peak of $50.00 shortly after the second invasion of Zaire in 1978.

Zaire, in 1981, mined 15,000 tons of cobalt metal and Zambia 2,700 out of a world production equal to 29,400 tons, while Central Economy countries provided 4000 tons according to the U.S. Bureau of Mines. Thus 73.8% of the world's production is located in politically volatile or potentially hostile countries. The same countries control 2,150,000 tons of the known reserve base of 3,400,000 short tons or 63.24%. Several other world cobalt suppliers are geographically remote (Finland, Australia, and the Philippines) with the attendant risk of interdiction in an emergency. Cobalt reserves in undersea nodules are very large but probably won't be mined for at least 20 years. This situation has prompted the U.S. Government to assign strategic importance to cobalt. The stockpile status is given below:

Cobalt Stockpile Status as of 10-27-82 (Short tons*)

Material	Goal	Total Inventory
Cobalt	42,700	21,896

With this background, the writer was dispatched to Peru from October 2 to October 7, 1982 to meet with Hierro Peru officials and examine the Marcona area in the field. The findings there, and researches and discussions with mining executives and earth scientists since, are summarized below.

*(Figures courtesy of W.S. Kirk, Cobalt Commodity Specialist-Bureau of Mines)

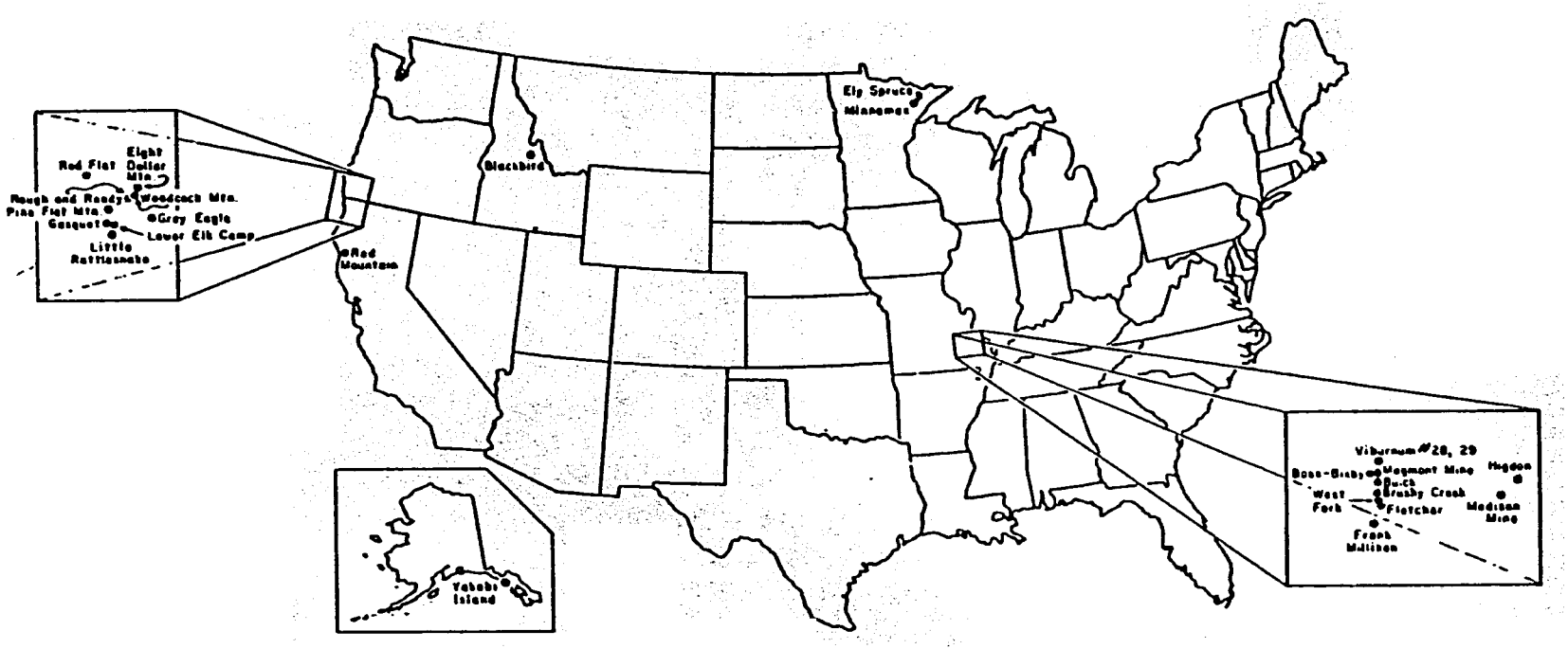


FIGURE 3. - Location of domestic cobalt properties.

II. Discussion

A. The Hierro Peru History and Organization:

Although maps of Peru exhibited at the Exposition of Paris in 1890 showed iron ore deposits, the Marcona deposits were first discovered by two mining engineers in 1945 on a Reserve created in 1923 by the Peruvian Government. By 1943 the Government had formed the Santa Corporation in order to establish a Peruvian steel industry. In 1952 the Peruvian Government and the Santa Corporation granted Utah Construction Company an option to explore the area now under consideration.

In 1953 Utah Construction entered into a joint venture with Cyprus Mines Corporation and formed the Marcona Mining Corporation to develop the iron ore, started production and construction, and made the first shipment of 10,850 tons from the port of San Juan. Marcona was awarded a 20 year lease to conduct exploration and mining operations in the area controlled by the Santa Corporation in return for royalties. An extension of 10 years to the 20 year lease was agreed on.

From 1953 until 1975 Marcona Mining Company mined the iron deposits, developed various major facilities and established a world-wide market for Peruvian iron ore. In particular, two pelletizing plants were developed in 1962 and 1966 to upgrade the iron ores and eliminate the sulfur which was increasingly encountered at depth.

However in 1972, as the time neared to activate the 10 year extension to the mining lease, controversy developed between Marcona and the Government of Peru. Eventually the Government took over all of Marcona's Peruvian property, and, in 1976, a settlement was concluded between Marcona and Peru under which $65 million was to be paid to Marcona by the Government. The last of this amount was paid in late 1980.

Since 1975, Hierro-Peru, a Company entirely owned by the Peruvian Government, has owned and operated the mines in the Marcona area. The most senior authority and policy making power of the company is vested in a 5-man General Board of Shareholders appointed through a Resolution of the Minister of Energy and Mines. Members of this Board have an indefinite term and meet at least twice each year to pass on strategy and corporate matters.

Operating management is supervised by the nine member Board of Directors. Six of these are appointed by the General Board of Shareholders, two by the Mining Community of Hierro Peru, and one by Presidential Decree. The Directors meet at least twice a month, and are responsible for maintaining executive control over Hierro-Peru's operations.

The Board of Directors also appoint the General Manager and Chief Operating Officer of the Company. (See Appendix I (A) for the names of the two Boards described above.) Appendix I (B) shows the operating organization of Hierro-Peru, and Appendix I (C) lists, with thanks, those officials who were especially helpful and informative to the writer during his visit to Lima and Marcona in October 1982.

B. The Occurrence of cobalt ores with a Description of the Marcona Deposit:

Cobalt occurs with an average abundance of 20 parts per million (ppm) in the earth's crust, but concentrates in basic igneous rock (270 ppm), being only minimally present in sediments like sandstone (6 ppm). This host rock preference has resulted in cobalt's close association with copper and nickel ores. Nearly all present cobalt production is as a byproduct or coproduct of copper or nickel. (The Bou Azzer District in Morocco is the only important active exception, being mined directly for cobalt arsenide).

Most of currently producing cobalt sources are found in strata-bound copper ores or intrusive basic igneous rocks. However the major economic reserves of the metal on land are in surficial laterites resulting from deep weathering of basic igneous rocks in tropical climates with abundant rainfall. Here meteoric waters leach out the magnesia and silica of the host rock, concentrating iron, manganese and cobalt.

Known cobalt reserves lie mainly in remote, politically unstable or potentially hostile countries and production of the abundant cobalt in sea-bed nodules may be delayed at least 20 years by legal and technical problems. See Table A reproduced from U.S. Bureau of Mines Bulletin 691 (1980):

WORLD COBALT RESOURCES
(Million Pounds)

	Reserves	Other 1/	Total
North America:			
United States	0	1,700	1,700
Canada	60	500	560
Cuba	400	2,100	2,500
Total	460	4,300	4,760
Europe:			
Finland	40	10	50
USSR	500	50	550
Total	540	60	600
Africa:			
Botswana	60	10	70
Morocco	100	50	150
South Africa	50	10	60
Zaire	2,600	500	3,100
Zambia	800	500	1,300
Total	3,610	1,070	4,680
Oceania:			
Australia	100	550	650
New Caledonia	200	650	850
Philippines	400	50	450
Total	700	1,250	1,950
World Total (land-based) 2/	5,300	6,700	12,000
World Total: Seabed Nodules 3/	0	500,000	500,000

1/ Derived in consultation with the U.S. Geological Survey.
2/ Data may not add to totals shown because of independent rounding.
3/ Based on Hosler's paramarginal resource estimate of 76 billion dry short tons of seabed nodules and the NMAB-323 estimate of average nodule composition of 1% nickel, 1% copper, 0.35% cobalt, and 24% manganese. (F. Hosler, Manganese Nodule Resource and Mine Site Availability, Ocean Mining Administration, U.S. Department of the Interior, August 1976, p. 28; National Materials Advisory Board, NMAB-323, 1976).

The iron ore deposits of the Marcona District consist of magnetite (Fe_3O_4) and pyrite (FeS_2), and occur mainly in the Paleozoic Marcona dolomite, and to a lesser extent in the more siliceous and tuffaceous Cerritos formation of Jurassic age overlying the Marcona. (See Figures 3A and 4).

The magnetite outcrops in many places, and in others, some of which are still unexplored, is inferred from zones of high magnetic intensity detected by geophysical surveys. Some 60 magnetic anomalies have been detected in an area roughly 10 by 15 kilometers in extent. Diamond drilling down to 300 (+) meters and nearly 30 years of active mining have effectively determined the grade and composition of much of the ore and its associated rocks. (See Figure 5, a typical cross section through an ore body).

Herkenhoff, in his report for Hierro Peru dated May, 1982, listed the proven and possible reserve tonnages of Marcona District iron ore available as of January 1, 1982 as in Table B below:

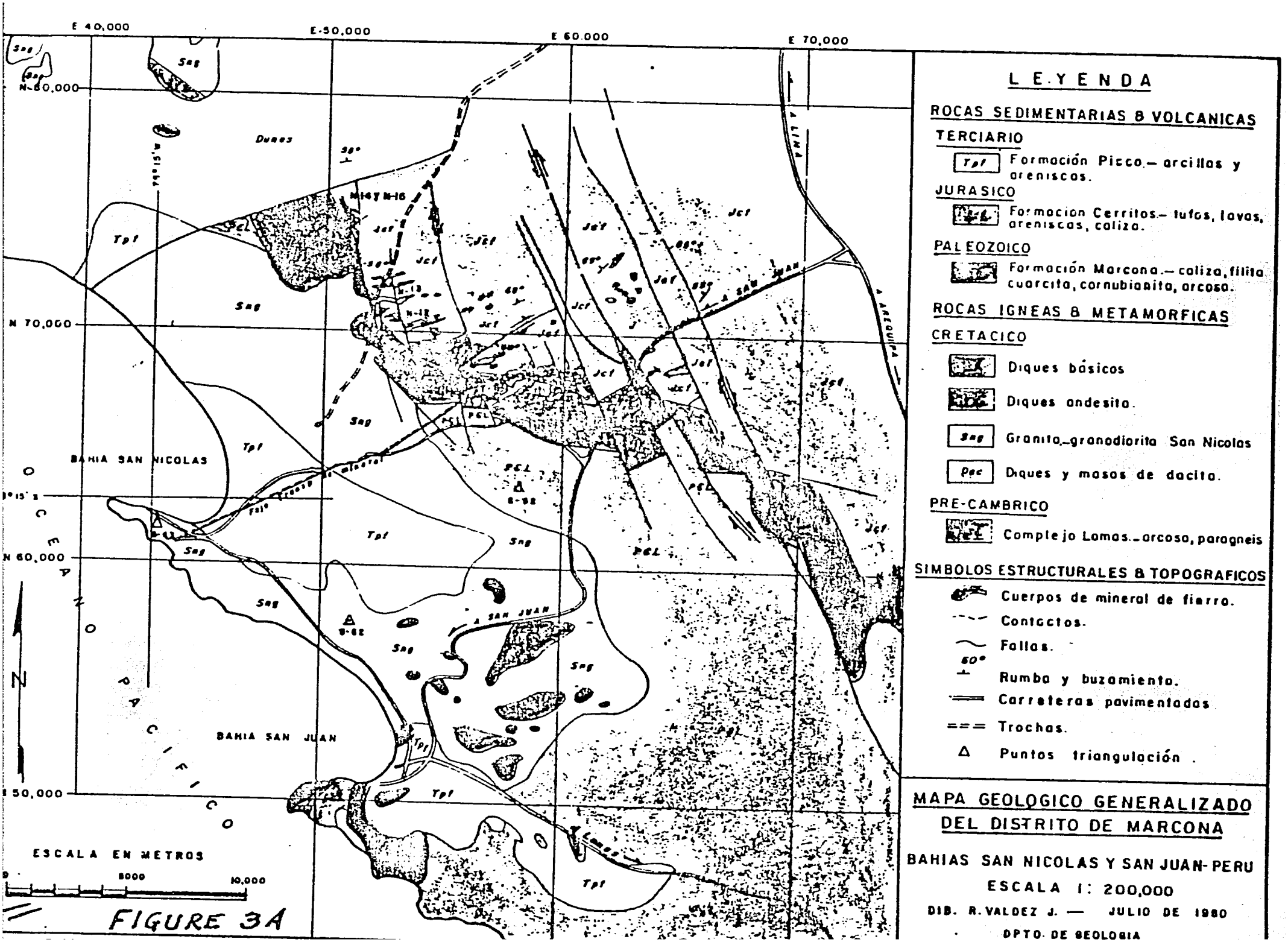

E 40,000
E 50,000
E 60,000
E 70,000
N 80,000
N 70,000
N 60,000
N 50,000
Dunas
Tpf
Sng
Jcf
PCL
BAHIA SAN NICOLAS
BAHIA SAN JUAN
OCEANO PACIFICO
A SAN JUAN
A LIMA
A AREQUIPA
N
ESCALA EN METROS
0
5000
10,000
LEYENDA
ROCAS SEDIMENTARIAS & VOLCANICAS
TERCIARIO
Tpf Formación Picco.– arcillas y areniscas.
JURASICO
Formacion Cerritos.– tufos, lavas, areniscas, caliza.
PALEOZOICO
Formación Marcona.– caliza, filita cuarcita, cornubianita, arcosa.
ROCAS IGNEAS & METAMORFICAS
CRETACICO
Diques básicos
Diques andesita.
Sng Granito.–granodiorita San Nicolas
Dac Diques y masas de dacita.
PRE-CAMBRICO
Complejo Lomas.–arcosa, paragneis
SIMBOLOS ESTRUCTURALES & TOPOGRAFICOS
Cuerpos de mineral de fierro.
Contactos.
Fallas.
60°
Rumba y buzamiento.
Carreteras pavimentadas
Trochas.
Puntos triangulación.
MAPA GEOLOGICO GENERALIZADO DEL DISTRITO DE MARCONA
BAHIAS SAN NICOLAS Y SAN JUAN-PERU
ESCALA 1: 200,000
DIB. R. VALDEZ J. — JULIO DE 1980
DPTO. DE GEOLOGIA

FIGURE 3A

COLUMNA GEOLOGICA GENERALIZADA

SECCION DEL DISTRITO MINERO DE MARCONA

PUERTO SAN JUAN, PERU

ERA	PERIODO	FORMACION	SIMBOLO	COLUMNA ESTRATIGRAFICA	POTENCIA APROX. EN METROS: MIEMBRO	POTENCIA APROX. EN METROS: TOTAL	DESCRIPCION	
CENOZOICO	CUATERNARIO		Qal		0 – 30 ±		Arena marina estratificada no consolidada, rodados heterogeneos, cenizas, cavidades rellenadas, caliche	
		DISCORDANCIA						
	TERCIARIO	FORMACION PISCO	Tpf		500 ± ?		Arcillas interestratificadas, areniscas de grano fina, arcillas laminadas, bentonita, abundante cenizas volcánicas, vetillas de yeso	
		DISCORDANCIA						
MESOZOICO	CRETACICO	FORMACION COPARA	Kcf		500 ± ?	700 ±	SUPERIOR – Miembro los Cerrillos: Areniscas blancas cuarzos pobremente estratificadas. INFERIOR – Miembro Tierra Blanca: Tufos depositados en agua, lavas, sedimentos volcánicos bien estratificados, areniscas carbonáceas.	METAMORFIZADO
					200 ± ?			
		DISCONFORMIDAD						
	JURASICO SUPERIOR Y MEDIO	FORMACION CERRITOS	Jcf		1,000 ±	6,000 ±	SUPERIOR – Miembro Tunga: Potentes flujos rojizos de andesita porfirítica, delgados calizas fosilíferas, areniscas feldespáticas y conglomerados. MEDIO – Miembro Las Tetas: Areniscas feldespáticas arcósicas, tufos, flujos rojizos de andesita porfirítica. INFERIOR – Miembro N-13: Abundantes flujos de andesita, tufos, areniscas tufáceas, areniscas feldespaticas. BASE – Brecha sedimentaria y conglomerado	
					3,000 ±			
					2,000 ±	ABUNDANTE MAGNETITA DISEMINADA		
		DISCONFORMIDAD						
PALEOZOICO	?	FORMACION MARCONA	Mf		500 ±	1,600 ±	SUPERIOR – Miembro Pompa: Pizarras siliciticadas y cornubianitas filíticas. MEDIO – Miembro San Juan: Capas de dolomita separadas por cornubianitas y arcosa local. INFERIOR – Miembro Justa: Actinolita, cuarcita, cornubianita, cornubianita arcósica (gneisítica) arcosa. BASE – Conglomerado de cornubianita (fragmentos pcL)	
					E GRID 500 ± MINA 7			
					600 ±			
		DISCORDANCIA						
PROTEROZOICO	PRECAMBRICO	COMPLEJO LOMAS	pcL ?		?		Abundante paragneises rosados, meta arcosas de grano grueso, esquistos micáceos, zonas granitizadas? Base del complejo no establecido.	

ORE

ROCAS DIQUES

- Diorita
- Granodiorito post-mineral
- Andesita Porfirítica post-mineral
- Dacita pre & post-mineral

FIGURE 4.

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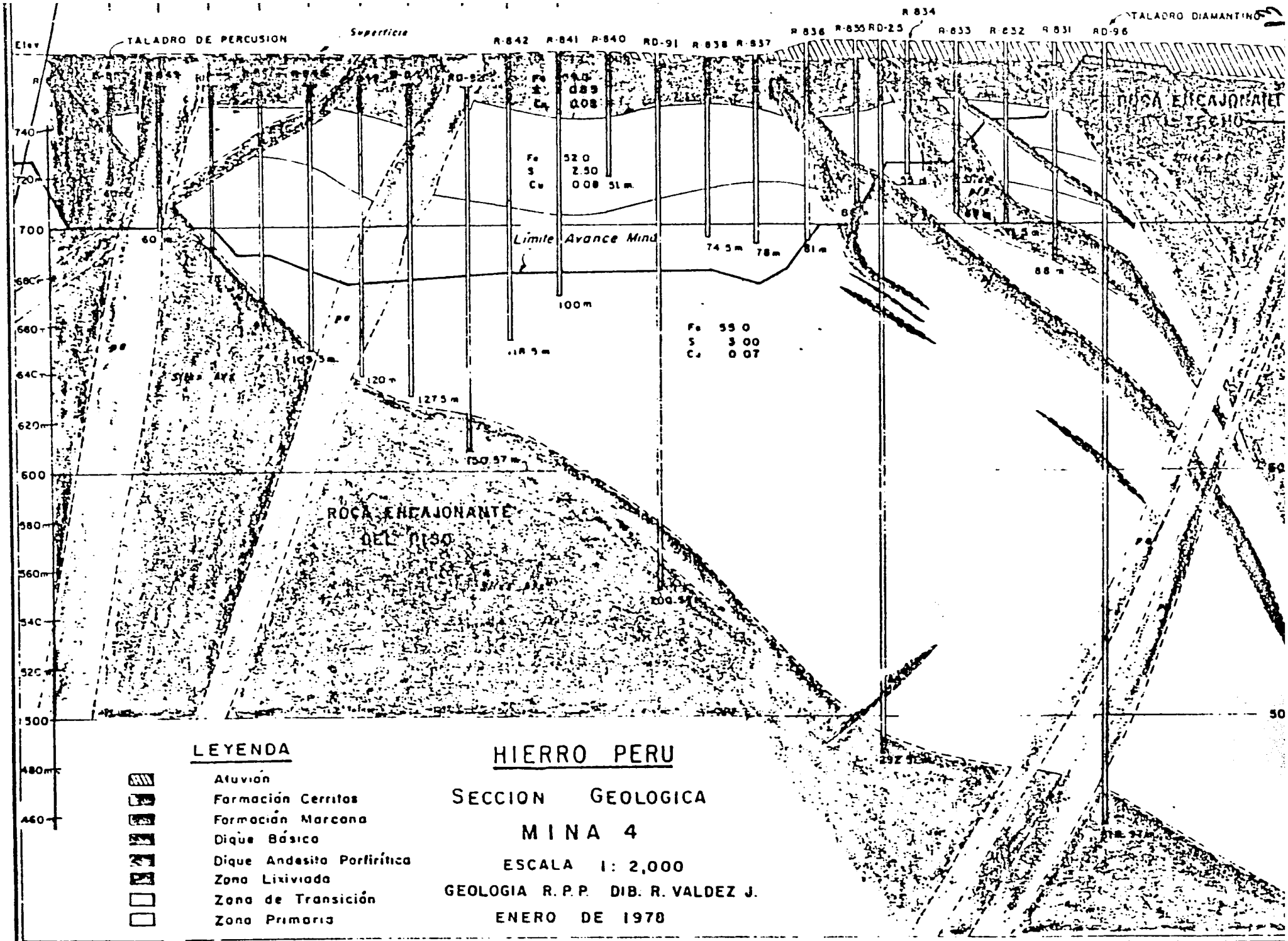

TALADRO DE PERCUSION
Superficie
TALADRO DIAMANTINO
R-842
R-841
R-840
RD-91
R-838
R-837
R-836
R-835
RD-25
R-834
R-833
R-832
R-831
RD-96
Elev
740
720
700
680
660
640
620
600
580
560
540
520
500
480
460
Fe 52.0
S 2.50
Cu 0.08
51 m
Limite Avance Mina
100m
Fe 55.0
S 3.00
Cu 0.07
ROCA ENCAJONANTE DEL PISO
ROCA ENCAJONANTE TECHO
LEYENDA
Aluvión
Formación Cerritos
Formación Marcona
Dique Básico
Dique Andesita Porfirítica
Zona Lixiviada
Zona de Transición
Zona Primaria
HIERRO PERU
SECCION GEOLOGICA
MINA 4
ESCALA 1: 2,000
GEOLOGIA R.P.P. DIB. R. VALDEZ J.
ENERO DE 1978

FIGURE 5.

PROVEN AND PROBALE RESERVE TONNAGES

GEOLOGICAL FORMATION	ORE CLASSIFICATION	DRY LONG TONS	Assay, % FE	S	Cu
1. Marcona	Oxidized	30,152,800	55.1	0.37	0.17
	Transitional	51,472,700	53.4	1.78	0.10
	Primary	367,119,200	57.7	2.97	0.11
	Probable				
	Primary	481,803,400	--	--	--
2. Cerrito	Oxidized	67,964,700	48.5	0.40	0.09
	Transitional	74,367,900	43.9	2.39	0.09
	Primary	26,173,200	46.9	2.43	0.12
	Probable				
	Oxidized	29,357,300	--	--	--
	Transitional	144,000,700	--	--	--
	Primary	207,103,500	--	--	--

TABLE B

A brief examination of maps and cross sections, supplemented by a visit to the mine site, generally supports these figures. It can be seen from the table that there is abundant crude ore with the high sulfur content which indicates the presence of pyrite, the host mineral for the cobalt.

Although Marcona has not previously been widely recognized as a potential source of cobalt, Herkenhoff reports that Utah Construction (holder of some 46% of Marcona Corporation stock) began research for that metal in the pyrite fraction in 1958, and that a 1-ton per hour pilot plant located near the port of San Juan, Peru, confirmed the findings of Utah's bench-scale tests previously done in the U.S. (It is noteworthy that all beneficiation tests utilized sea water because of the arid character of the coastal zone of Peru.) The cobalt content of pyrite concentrates recovered by flotation varied from 0.25% to 0.43% and a copper concentrate ran 0.20% cobalt. In the U.S. the pyrite concentrates were treated by a fluosolids roasting test, followed by leaching of the calcines for a cobalt-copper extraction. Recovery of cobalt and copper was 87% after sulfatizing roasting.

In 1978 a 10-ton sample of the pyrite tailings from the full-scale operating plan was sent to KHD Humboldt Wedag Ag. in Germany, who obtained a pyrite concentrate analyzing 0.70% cobalt. At that time the tailings tested were coming from mines 4 & 5, which are now operating.

In late 1980, Hierro Peru's Mining Department extensively tested cuttings from percussion holes in Mine 4 of the Marcona Group and found that cobalt in the crude ore average 0.027% cobalt with a maximum of 0.076 and a minimum of 0.008%.

Non magnetic (Pyrite-bearing) tailings from the San Nicolas beneficiation plant have been discharged into the sea making a delta on the coast from the nearly 40 million tons of rejects. In May, 1982, samples of these tailings were procured over a length of 3 kilometers. Since some of these tailings necessarily originated in the near-surface reaches of the ore bodies, rather than the high sulfur primary ore beneath, it is likely that the rejects tested represent the <u>minimum</u> average grade of cobalt in future mining.

After grinding to minus 65 mesh and flotation the results are given in Table C below.

		%			
COMPOSITE	PRODUCT	FE	S	Cu	Co
North	Bulk Conc.	46.2	47.7	1.02	0.568
	Pyrite Conc.	46.3	48.0	0.99	0.580
South	Bulk Conc.	45.5	45.6	1.45	0.664
	Pyrite Conc.		(Not completed)		

To produce its iron ore concentrates and pellets (5,973,360 long tons of pellets and sinter were produced in 1981, (and 1982 may see this figure reduced somewhat), the Hierro Peru organization must mine, grind, and beneficiate nearly 7.5 million tons of crude, removing the sulfur-bearing pyrite from the iron ore stream. Beginning in 1979, high-copper concentrates (largely chalcopyrite) were floated away from the cobalt-rich pyrite. Thus to recover the cobalt, which is left behind, merely requires treating material already mined, transported to the mill and ground; costs attributable to the first cobalt concentrate are only those for dewatering the underflow of the copper circuit.

A typical material balance showing recoveries as estimated by Hierro Peru is shown in Table D below:

Following the recovery of a cobalt concentrate, Hierro Peru will be confronted with the need to decide between the alternative procedures below:

1. Exporting the cobalt concentrate, cobalt extraction elsewere.

2. Roasting of the concentrates, leaching and precipitation of enriched copper, cobalt, and perhaps nickel products in San Nicolas and export of the precipitate for final refining elsewhere.

3. Roasting, leaching and refining for separate recovery of copper, cobalt and nickel at San Nicolas.

Although the magnitude and general extent of cobalt mineralization is known, the writer believes that cobalt occurrence patterns have not been established throughout the iron ore deposits. When the occurrence patterns of cobalt and copper are fully known, Hierro Peru can so plan their pits as to optimize values considering iron, cobalt, copper and perhaps nickel.

The organization employs three classes of people:
a. Professional and supervisory staff
b. Plant and clerical employees
c. Mine Workers

A total of 270 are employed at Lima and 3,377 at San Juan for a total of 3,647, while Marcona, in 1974 employed 3,201. Appendix IV gives a statement of profit and lost in recent years provided by Lehman Brothers Kuhn Loeb, Incorporated, Financial Advisors.

TABLE D

TYPICAL MATERIAL BALANCE TREATING PRIMARY ORE AND RECOVERING COPPER AND COBALT-BEARING PYRITE CONCENTRATES

PRODUCT	%Wt.	ASSAY % Fe	S	Cu	Co	% DISTRIBUTION Fe	S	Cu	Co
Crude Ore	100.0	54.0	2.97	.15	.037	100.0	100.0	100.0	100.0
Mag. Conc.	70.0	68.0	.30	.03	.004	88.1	7.1	14.0	7.5
Non-Mags.	30.0	21.3	9.2	.43	.113	11.9	92.9	86.0	92.5
*									
Non-Mags.	30.00	21.3	9.2	.43	.113	11.9	92.9	86.0	92.5
Copper Conc.	0.42	28.1	30.0	25.00	.15	0.2	4.1	70.0	1.7
Pyrite Conc.	4.85	46.0	49.0	.25	.60	4.2	79.8	8.1	77.8
Tailings	24.73	16.4	1.0	.05	.012	7.5	9.0	7.9	13.0
RECOVERIES BASED ON FEED TO FLOTATION									
Flot. Feed	100.0	21.3	9.2	.43	.113	100.0	100.0	100.0	100.0
Copper Conc.	1.40	28.1	30.0	25.00	.15	1.8	4.6	81.4	1.8
Pyrite Conc.	16.17	46.0	49.0	.25	.60	34.9	86.1	9.4	84.1
Tailings	82.43	16.4	1.0	.05	.012	63.3	9.3	9.2	14.1

*Feed to flotation circuit.

(B) An Interesting Provision of Peruvian Mining Regulations:
Under Peruvian mining law all workers of Hierro-Peru form the 'Mining Community" which participates in Hierro-Peru's operations as follows:

1. The Mining Community has 2 members on the Board of Directors.

2. The Mining Community receives 10% of the net income distributed as follows: 6.0 percent in cash, 3.5 in irredeemable bonds and 0.5% for administrative expenses.

3. The Mining Community has an Administrative Council of its own and forms part of an organization which includes all mining communities in Peru. It would appear possible for a local issue to lead to a nationwide strike in the mining sector.

Hierro Peru's Marcona Mines and Facilities

D. The magnetic iron ore is mined by open pit method using 12 meter benches, 9" to 10 5/8" blast holes are drilled employing metallized ANFO for the blasting agent.
Mining equipment is listed below:

2 Gardner Denver type G-100 electric drills
2 Bucyrus Erie type 40R electrict drills
6 Bucyrus Erie type 50R electric drills
2 Atlas Copco 701 Rock drills
1 Atlas Copco 601 Rock drill
5 P&H model 1600E electric shovels
2 P&H model 1900AL electric shovels
4 P&H model 2100E electric shovels
13 Haulpack Wabco trucks, 65 tons
5 Wabco trucks, 120 tons
23 Lectrahaul M100 trucks, 700HP
8 Lectrahaul M100 trucks, 1000 HP
5 Front end loaders
13 Tractors

The production rate is controlled by the capacity of the concentration facilities. Broken crude ore from the mine is trucked to one of the two crushing plants near the mines where it is crushed to minus 4" size by either a 66" x 84" primary jaw crusher or a 48" rotary crusher.

The ore is then hauled 15.4 kilometers to San Nicolas by a 36" conveyor belt with a capacity of 2000 tons per hour, (See Figure 6), where it is separated at a magnetic concentration plant, pelletized, and loaded on ships.

B. Beneficiation

When the ore arrives at San Nicolas it is stocked in a stockpiling area which has a capacity of 390,000 tons. Transition ore is then crushed to minus 3/4". The transition ore is handled in one circuit served by a 7' cone crusher and a 5 1/2' cone crusher. (500 tons per hour can be accommodated); the primary ore goes to two 7' cone crushers with a capacity of 1200 tons/hour.

The magnetic separation plant operates two circuits, a fine grind circuit to produce high grade fine concentrates for pellets and a coarse grind circuit for sinter feed. In each case magnetic separation removes the iron and leaves behind a finely ground non-magnetic tailing. (It is this which contains copper, cobalt and a minor amount of nickel.)

The finely ground magnetic material is pelletized by pelletizing discs and travelling grate furnaces.

The different products and their grades are shown in Appendix II.

Pellets and iron ore concentrates are shipped from the port of San Nicolas where a 1050 foot pier can load 170,000 dwt ore carriers at 3000 tons per hour.

Nearly 3400 employees of Hierro Peru are accomodated at the town of San Juan with a total population of 25,000. The community has a 96-bed hospital, a TV transmitting station, markets, schools, banks, and shops.

Three steam turbogenerators provide 67,000 kilowatts of electric power and electricity from the Mantaro hydroelectric plant has recently been connected to the San Nicholas grid. A 30 km pipeline provides 60 liters of fresh water per second to San Juan, and exploration for additional fresh water is underway. At present 4 desalinization modules provide 2000 cubic meters of water daily to provide industrial fresh water to the plant at San Nicolas.

Thus basically the necessary infrastructure for Hierro Peru's operations is already in place.

E. Preliminary Estimate of Goods and Services:

Over the next five years Hierro-Peru will require for the cobalt extraction project approximately $70 million of goods and services of which as much as $50 million might be obtained in the U.S. This figure is for order of magnitude only. More precise figures will be obtained in the feasibility study if one eventuates.

F. Major Sources of Funding:

Senor Luis Moran, the General Manager and Chief Operating Officer of Hierro-Peru, informed the writer that he intended to attempt to obtain a loan from the World Bank or the Exim Bank. Under the present conditions of high interest rates, it would be logical for Hierro-Peru to attempt to obtain money from international lending institutions.

G. Issues:

Geologically and chemically it is necessary to establish the pattern of cobalt and copper occurrences more precisely. There are no major mining issues. However issues are present. For example the participation of labor representatives on the mining Board of Directors might dampen the ardor of U.S. mining firms.

The question of what alternative beneficiation technique to select is an issue which must be addressed by the feasibility study. An illustrative scope of work for the feasibility study is attached as Appendix III.

However, joint mining ventures are not now proposed. What Hierro Peru apparently wants is only U.S. technology, equipment, and market.

H. Potential U.S. Firms to Perform the Feasibility Study:

The list below is brief and illustrative of U.S. firms having competence to perform the feasibility study under consideration. It does not purport to be a complete list of such firms.

1. Fluor Mining and Metals, Inc.
   177 Bovet Road
   San Mateo, CA 94402 (415) 572-3000)

This company and its associate, Fluor Engineers and Construction, Inc., of Irvine, CA 92730, designed and procured the equipment for the existing Marcona plant and have worked on copper projects in Peru as well as mineral enterprises of large magnitude and great complexity throughout the world. Fluor Engineers have performed satisfactorily on contracts for TDP.

2. Bethlehem International Engineering Corporation
   (Subdivision of Bethlehem Steel Corporation)
   Bethlehem, PA 18016

Bethlehem Mines Corporation at its Grace and Cornwall Mines have the only U.S. experience in actually commerically removing cobalt from a magnetite iron ore like that at Marcona. The Bethlehem Engineering group can draw on this experience and avail themselves of Bethlehem's diverse talents in mining, steel-making, and shipbuilding for the benefit of their clients.

3. Bechtel Power Corporation
   Fifty Beale Street
   P.O. Box 3965
   San Francisco, CA 94119

This organization has undertaken more than 30 projects in Peru since 1960 and like Fluor, has world-wide mining experience. They offer, among others for the project, Mr. Darryl Marshall, formerly General Supervisor and Analyst of Operations Research for Marcona. They have provided engineering, procurement and construction management services for a nickel refinery with a cobalt byproduct in Western Australia. Bechtel has also performed satisfactorily on contracts for TDP.

III. Conclusions:

In the field of strategic metals the Marcona deposit has the following advantages over most other sources:

1. The deposit is being mined now for iron ore and does not require long and costly geological and geophysical activities, followed by time-consuming diamond drilling to outline favorable areas for mining development The cobalt is in pyrite intimately intermixed with the magnetic ore.

2. A competent mining organization and extensive infrastructure are in place.

3. The deposit could be prepared to produce cobalt concentrates compatible with the only active U.S. cobalt ore refinery operation at Port Nickel, Louisiana.

The most vexing problem confronting Hierro Peru and the contractor who will conduct the feasibility study is whether the low-cost cobalt obtainable can justify the investment in these times of depressed cobalt prices, and high interest rates.

It is the view of the writer that the study will provide a positive answer and it is recommended that TDP finance a portion of the feasibility study by a U.S. contractor, if mutually satisfactory terms can be arranged with Hierro Peru.

APPENDIX I (A)

General Board of Shareholders

Eng. Antonio Tarnawiecki Chairman	Chairman of the Board of Directors Empresa Minera del Peru Age:60
Eng. Carlos Bellatin	Advisor Ministry of Energy & Mines Age: 55
Dr. Sergia Leon	Vice Minister Ministry of Energy & Mines Age: 38
Dr. Fernando Montero	Advisor Ministry of Energy & Mines Age: 34

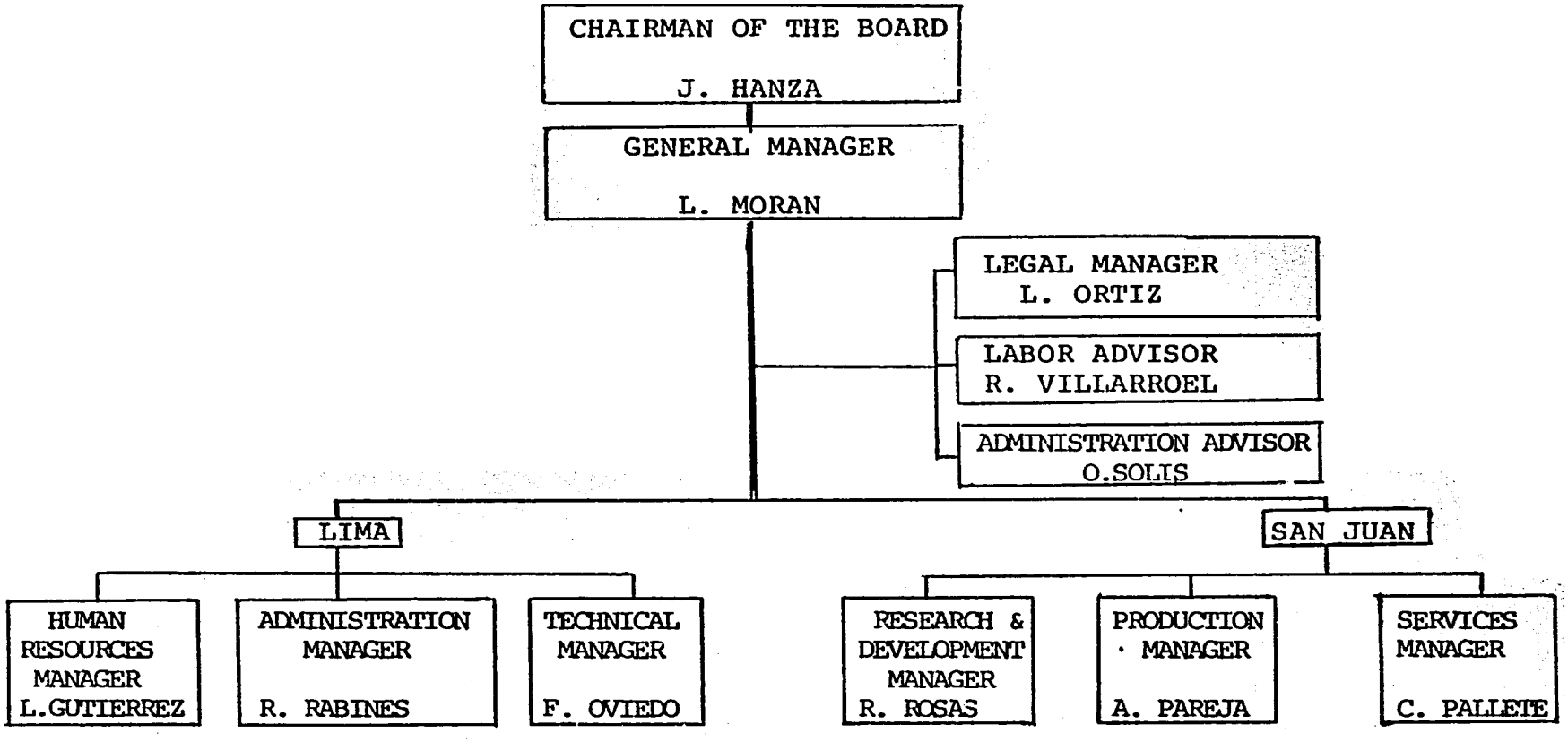
Board of Directors

Eng. Jaime Hanza Chairman	General Manager Cabana, Hanza, Leigh S.A. Age: 36
Dr. Martin Belaunde Vice Chairman	Manager Iron Ore Marketing Minero Peru Comercial Age: 42
Eng. Abel Carriquiry	Manager Refractarios Peruanos S.A. Age: 36
Mr. Fausto Cortez	Representative of Mining Community Age 47
Eng. Amilcar Gil Pareja	Chairman of the Board Vilcanota S.A. Age: 52
Mr. Salomon Guevara	Representative of Mining Community Age: 47
Dr. Luis Gutierrez	Attorney at Law Age: 46
Dr. Jose Miguel Morales Dasso	General Counsel Cia de Minas Buenaventura Age: 35
Eng. Alfredo Santistevan	Controller General Cia de Seguros "La Vitalicia" S.A. Age: 34

Management

Eng. Luis Moran	Gen. Mgr & Chief Operating Officer Age: 54

HIERRO-PERU-MANAGEMENT ORGANIGRAM



APPENDIX I (B)

APPENDIX I (C)

Officer of Hierro-Peru who were particularly helpful to the writer in Peru:

a) In Lima:

Senor Luis F. Moran G.
General Manager
Hierro-Peru
Paseo de La Republica 3587
Lima 27, Peru
Apartado 1229 - Lima 1
(Telephone- 412473)

Senor Roberto Rabines Palacios
Central Management
Hiero-Peru
(Same address as Moran above)

b) In San Juan de Marcona:

Senor Jorge La Cruz Rodriguez
General Superintendant of Mines
(Same address as Moran)

Senor Diego Lama Rios
Assistant General Superintendant of Mines
(Same address)

Senor Plutarco Huaita Bernaola
Chief Geologist
Hierro-Peru
San Juan de Marcona
Peru

APPENDIX II

ORE QUALITY

a) HIGH GRADE SINTER FEED (HGSF)

Chemical			Physical		
Fe (tot.)	:	65.0	—1/4"	:	100%
S (tot.)	:	0.900	—100	:	30%
Cu	:	0.050	Apparent Density	:	3,120 Kgs/m³
FeO	:	20.0	H_2O	:	6.0%
SiO_2	:	4.0			
Al_2O_3	:	0.60			
CaO	:	1.00			
MgO	:	1.50/1.40			
Na_2O	:	0.20			
K_2O	:	0.15			
P	:	0.03			
Otros	:	0.07			

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APPENDIX II

b) BLAST FURNACE PELLETS

Chemical			Physical		
Fe (tot.)	:	65.5	H_2O	:	0.6%
S (tot.)	:	0.02	—5 mm	:	5.0%
Cu	:	0.02	+9 −16 mm	:	85.0%
FeO	:	1.2	+16 mm	:	3.0%
SiO_2	:	4.0	Tumbler ASTM + 1/4	:	93.0% min.
Al_2O_3	:	0.6	Tumbler JIS − 28 M	:	6.0%
CaO	:	0.6	Average Compression	:	220 Kgs
MgO	:	1.0	Apparent Density	:	2,160 Kgs/m³
Na_2O	:	0.160			
K_2O	:	0.090			
P	:	0.02			
Mn	:	0.02			

APPENDIX II

c) DIRECT REDUCTION PELLETS

Chemical			Physical		
Fe (tot.)	:	67.5	H_2O	:	0.5%
S (tot.)	:	0.008	—5 mm	:	5.0%
Cu	:	0.01	+9 —16mm	:	85.0%
FeO	:	0.8	+16 mm	:	3.0%
SiO_2	:	1.50	Tumbler Test		
Al_2O_3	:	0.40	ASTM — 1/4"	:	93.0% Min.
CaO	:	0.40	Compression	:	250 Kgs
MgO	:	0.70	Apparent		
Na_2O	:	0.090	Density	:	2,160 Kgs/m³
K_2O	:	0.050			
P	:	0.02			
Mn	:	0.02			

APPENDIX II

d) PELLET FEED
(in Filtercake form)

Chemical			Physical		
Fe (tot.)	:	68.5	H_2O	:	8.5%
S (tot.)	:	0.25 Max.	—100	:	93.0% Min.
Cu	:	0.02	—325	:	65.0%
FeO	:	25.0 Min.	BSA	:	1,450 cm^2/gr
SiO_2	:	1.8	Apparent Density	:	2,560 Kgs/m^3
Al_2O_3	:	0.5			
CaO	:	0.5			
MgO	:	1.0			
K_2O	:	0.08			
P	:	0.02			
Mn	:	0.02			

APPENDIX III

The contractor will conduct a study for Hierro Peru to determine the feasibility of recovering and marketing a cobalt concentrate, cobalt metal, or other cobalt-rich marketable product from the non-magnetic tailings of its iron ore mining and concentrating operation tributary to the port of San Nicolas, Peru. The study will be in sufficient detail, and in accordance with accepted financial, engineering and metallurgical practice that, if its findings should indicate the economic viability of a cobalt recovery project, it may serve as the recognized basis for approaching financial institutions to fund the project:

The study should include the following tasks:

1. (a) Establish the extent, marketability and expected production rate of the iron ore reserves which form the basis of Hierro-Peru's operation.

(b) Determine the pattern of distribution and recoverability of the cobalt-rich fraction of the pyrite which lies in the iron ore. The location of the cobalt-bearing pyrites may dictate changes in the present mining plans of Hierro-Peru. If so these changes and their cost implications should be set forth.

2. Perform mining and beneficiation studies which:

(a) Define changes in mining methods and equipment emphasizing any new procedures which may be required to maximize financial return to Hierro-Peru from the cobalt, and itemize equipment and costs required

(b) Outline appropriate beneficiation procedures including mill modifications to optimize recovery of cobalt and any other potentially economic elements or minerals present.

Equipment, construction and operating costs should be itemized and a procurement and installation schedule specified. Maximum use should be made of existing plant facilities and costs should give a breakdown between Peruvian and U.S. currency

(c)Choose the appropriate combination of roasting, leaching, precipitation or other chemical/metallurgical treatment of either the whole sulfide offtake or the cobalt/pyrite underflow and show the financial construction, and manpower requirements of each alternative to indicate the reasons for the choice.

F. Detailed equipment requirements, construction of facilities (including reasons for selection of major items), procurement schedule, installation requirements and any new infrastructure needed. (Most critical are fresh water and electric power consumption of each unit and the entire system.)

G. Total project costs will be provided including:

1. Procurement
2. Freight
3. Customs duties
4. Installation
5. Required consumables such as lime and other chemicals
6. Plant run-in costs
7. Costs of additional infrastructure such as power, water, townsite etc.
8. Total capital requirements and cash flow

H. Based on unit costs plus a reasonable rate of return, a market study and economic analysis should determine what targets might be selected for a market and whether the project is financially viable.

I. If the above indicates viability, detailed cash flow and capital requirements from project inception through plant run-in and the first years of operation should be prepared as background for Hierro-Peru's requests for financing, with breakdown showing which costs are necessarily in U.S. dollars and which require Peruvian currency.

HIERRO-PERU

STATEMENT OF PROFIT AND LOSS
1977 - 1981

(Millions of Soles)*

	1977	1978	1979	1980	1981
EXPORT SALES	8,335.5	12,271.2	19,455.1	27,749.2	40,498.8
DOMESTIC SALES	606.7	705.4	2,132.2	2,714.6	4,233.9
TOTAL SALES	8,942.2	12,976.6	21,587.3	30,463.8	44,732.7
PRODUCTION COSTS	4,011.7	6,702.2	11,795.9	19,026.1	32,704.0
DEPRECIATION	822.0	1,423.9	1,963.3	2,642.5	3,839.7
INVENTORY VARIATION	(31.0)	(1,059.1)	(36.9)	(222.3)	(6,134.2)
COST OF GOODS SOLD	4,802.7	7,067.0	13,722.3	21,446.3	30,409.5
OPERATING PROFIT	4,139.5	5,909.6	7,865.0	9,017.5	14,323.2
SALES TAX	1,631.9	2,578.0	4,481.8	5,201.8	1,475.2
MARKETING COMMISSIONS	155.9	236.9	419.8	544.1	787.8
OTHER SALES EXPENSES	136.6	209.0	309.4	707.8	1,081.5
ADMINISTRATIVE EXPENSES	341.3	587.0	1,087.5	1,543.0	2,631.2
DEDUCTIONS UNDER THE MINING LAW	106.4	177.7	138.3	44.0	652.2
SALES, GENERAL AND ADMINISTRATIVE EXPENSES	2,371.1	3,788.6	6,436.8	8,040.7	6,627.9
INTEREST ON LOANS AND OVERDRAFT FACILITIES	200.1	247.0	217.5	469.0	(743.9)
FOREIGN EXCHANGE LOSS (GAIN)	632.4	548.3	60.4	(273.6)	(786.1)
DEFERRED LIBAILITY AMORTIZATION	(246.8)	(161.3)	(106.4)	(403.5)	--
NET WORTH TAX	--	--	--	557.3	763.0
OTHER	(32.4	(124.4)	(456.9)	(419.1)	(264.8)
FINANCE AND MISCELLANEOUS EXPENSES	553.3	509.6	285.4	(69.7)	(1,031.8)
NET PROFIT BEFORE INCOME TAX	1,215.1	1,611.4	1,713.6	1,046.5	8,727.1
INCOME TAX	193.4	276.5	318.4	104.7	2,283.1
NET PROFIT	1,021.7	1,334.9	1,395.2	941.8	6,444.0

*-(As of 11-15-82 a thousand soles approximate one U.S. dollar, but the rate of exchange varies