REPUBLIC OF PERU

REPORT ON GEOLOGICAL SURVEY

OF

THE OYON AREA

PHASE II

FEBRUARY 1981

METAL MINING AGENCY OF JAPAN
JAPAN INTERNATIONAL COOPERATION AGENCY

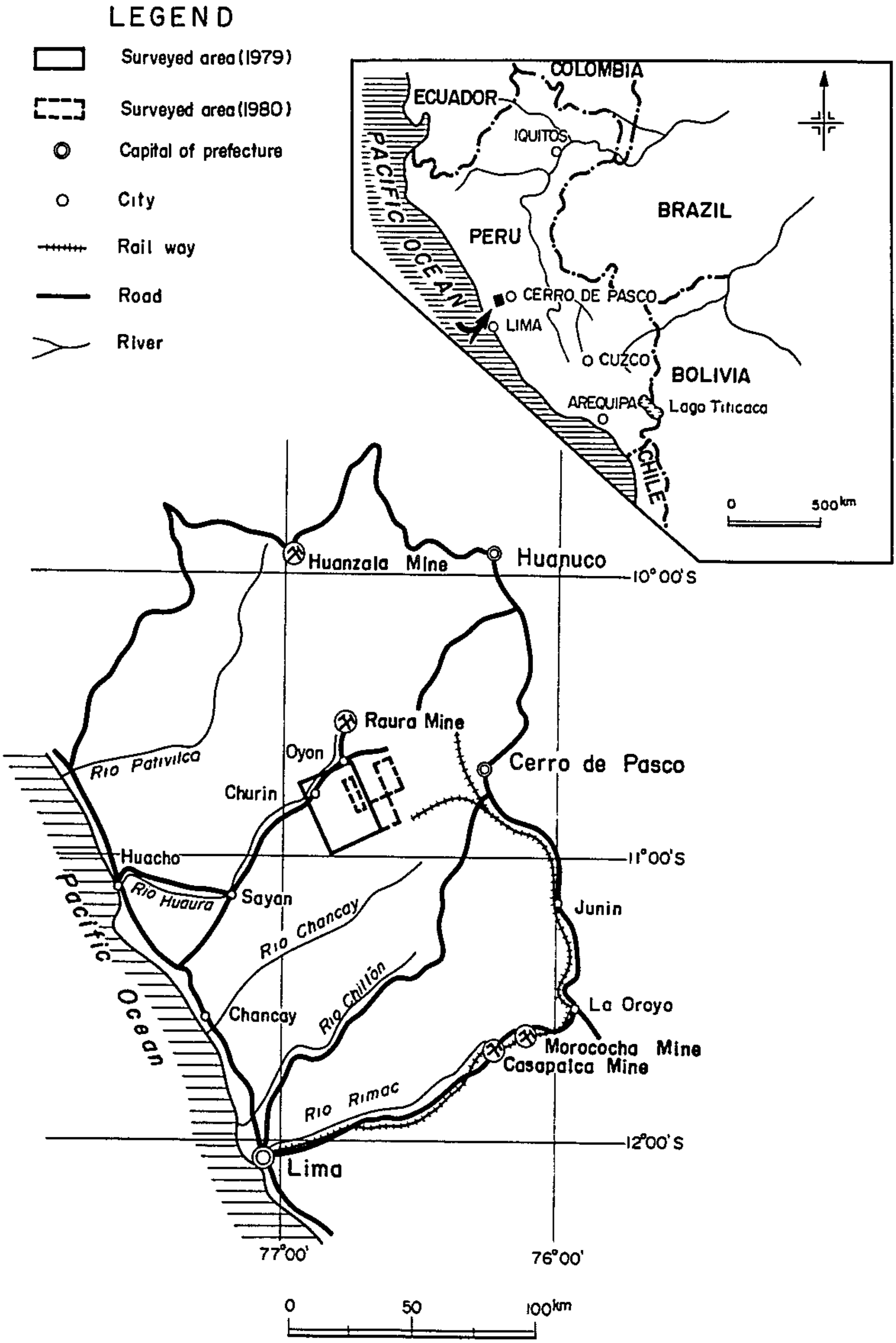


Fig. 1. Index Map

PREFACE

The Government of Japan, in response to the request of the Government of the Republic of Peru, decided to conduct collaborative mineral exploration in the Oyon area and entrusted its execution to Japan International Cooperation Agency (JICA) and Metal Mining Agency of Japan (MMAJ).

Between 1 June and 7 November, 1980, Metal Mining Agency of Japan dispatched a survey team headed by Mr. Jinichi Nakamura to conduct the Phase II of the project.

The survey had been accomplished under close cooperation with the Government of the Republic of Peru and its various authorities.

This report is a compilation of the survey of the Phase II, and after the completion of the project the consolidated report will be submitted to the Government of the Republic of Peru.

We wish to express our appreciation to all of the organizations and members who bore the responsibility for the project, the Government of the Republic of Peru, Instituto de Geología, Minería y Metalurgia, and other authorities and the Embassy of Japan in Peru.

February 1981

Keisuke Arita
President
Japan International Cooperation Agency

Masayuki Nishiie
President
Metal Mining Agency of Japan

INTEGRATED CONTENTS

ABSTRACT

This report describes the results of the Phase II geological studies in the Oyon area of the Republic of Peru, which are basic survey for the collaborative mineral exploration between Peru and Japan.

After the geological survey in C-area of the first year (Phase I study), Iscay Cruz area was selected as a prosperous area for further exploration. In this fiscal year therefore detailed geological survey, geophysical prospecting and diamond drilling were carried out in the Iscay Cruz area for about 40 km^2. Regional geological survey was made in A-area and B-area for totaling 160 km^2. Purpose of these surveys is to identify the relationship between geological structure and mineralization, and to look for another target area in future prospecting.

The field works were commenced on June 1 and ended on November 7, 1980, spending 49 days for road construction, 74 days for geophysical prospecting, 87 days for geological survey, and 111 days for diamond drilling. The geophysical prospecting consists of IP method with 8 measurement lines totaling 25.4 km and EM method with 2 measurement lines totaling 3 km. Three holes were drilled at two places; the total length was 564 m.

The Oyon area is situated at steep mountain slope in the western Andes near the continental divide. This area is underlain by Cretaceous sedimentary rocks which are strongly folded in a NNW-SSE, Andean direction. These Cretaceous rocks are covered unconformably by Tertiary volcanic rocks; both intruded by post-Cretaceous intrusive rocks.

In the Iscay Cruz area, mineralization is seen for about 12 km along calcareous rocks of Santa formation whose thickness is 40 to 80 m. The mineralization is composed of skarn type carrying copper and zinc, massive sulfide type concentrating lead and zinc, and disseminated type of lead and

zinc occurring in siderite mass. These three types show a zonation around acidic intrusive body; thus are considered to belong to the same series of mineralization.

IP prospecting of this year, which inspected the whole horizon of the Iscay Cruz mineralized area, picked up conspicuous anomalies in the central and southern parts. The diamond drilling in the northern part near the Cumbre de Iscay Cruz penetrates through disseminated lead-zinc orebody occurring in siderite mass. By another drilling at north of the Cumbre de Limpe in the central part, massive sulfide ore was discovered along 14 m, this sulfide ore contains abundant galena and sphalerite.

In addition, mineral showing was found in B-area by geological survey. This showing extends about 20 km in the strike and the width is approximately 5 km.

The following exploration program is suggested for the coming year's activity.

(1) At Limpe, Cunsha Punta and Antapampa of the Iscay Cruz area, more drillings are necessary in order to clarify size and details of the mineralization and its relationship to the geologic structure.

(2) Detailed geological mapping has to be done in the same area, this makes more precise evaluation of the surface anomaly and gives preparation for the future project. Geophysical prospecting should be continued in some part of the Iscay Cruz area.

(3) Detailed geological survey should also be done in Cochaquillo and Chagapata area of the B-area.

GENERAL REMARKS

GENERAL REMARKS

CONTENTS

LIST OF ILLUSTRATIONS

Chapter 1 Introduction

1-1 Purpose of the Survey

In the Oyon area, the geological survey, geophysical prospecting and drilling exploration had been carried out for the purpose of clarifing the geological structure and finding the geological environment, in which the ore deposits are expected, and the indications of mineralization as a clue to the further surveys.

These surveys had been performed in cooperation with Instituto de Geología, Minería y Metalurgia (INGEMMET). The data of the operated mines in the neighboring areas were also examined in the analyses of the data obtained in the survey.

1-2 Outline of the Survey

1) Circumstances of the Survey

The Oyon area surveyed is situated at steep mountain slope in the western Andes near the continental divide. The area is divided into three areas, A-, B-, and C-areas. As the first year survey, geological and geochemical surveys were carried out in the C-area for about 700 km^2 (refer to Fig. 1). As the result of the surveys, a remarkable mineralization indication has been found in the Iscay Cruz area located about 8 km south-south-east of Oyon.

This year survey is the second phase and detailed geological survey, geophysical prospecting and diamond drilling had been carried out in the Iscay Cruz area and regional geological survey in the A- and B-areas (refer to Fig. 2).

2) Geological Survey

Mineralization indication found in the Iscay Cruz area extends about

12 km in the direction of north to south. The area for about 40 km^2 covering all outcrops of the indications was selected and detailed geological survey including trenching was conducted. In the A-area for about 71 km^2 and B-area for about 89 km^2, regional geological survey was carried out.

Special emphasis was laid on clarifing general conditions and features of mineralization indication, relationship between mineralization and alteration, fracture system and igneous activity in the detailed survey. The emphasis was laid on the analysis of geological structure and finding of mineralization indications in the regional survey.

Various kinds of geochemical samples, i.e. ore, gossan, rock and stream sediments, were collected and chemical analysis were executed on these samples. Various studies by means of microscopy, X-ray diffraction, electron probe microanalysis, isotopic dating and etc. were performed for the important samples. All survey data were synthesized through the above mentioned studies, moreover, referring aerophotographs, published geological maps and various literatures.

3) Geophysical Prospecting

Geophysical prospecting by means of IP (induced polarization) method and EM (electromagnetic) method was carried out in the Iscay Cruz area for the purpose of inferring the existence of massive sulphide orebody and concentration degree of sulphide minerals underground.

Extension of the measurement lines by IP method totals 25.4 km, that is, main line along the outcrops in the Santa formation being 13 km, subordinate line established on the gossan outcrop being 2.5 km and 6 cross lines oblique to the main line totaling 9.9 km.

In the Iscay Cruz surveyed area, thick talus and glacial deposits are widely distributed on the surface covering outcrops of the mineralized parts of the Santa formation in many places. Since measurement by IP method was difficult in such places, EM method was employeed tentatively on two cross lines totaling 3 km.

Simultaneously with measurement, rock samples were collected nearby the measurement lines and electric physical properties were determined. All of these data were in-put in computer and simulation analysis was carried out on them.

4) Drilling Exploration

Three drill holes totaling 564 m was executed at two places, the northern and central parts of the Iscay Cruz area, in order to determine the subsurface geological structure and ocurrence of mineralization. All cores obtained by drilling was logged and for the mineralized portion, halves or one-quarters were collected and sent to assay. Microscopic studies and X-ray diffraction test were done on them as needed.

As the preparation for drilling, an access road of 20 km distance was constructed to transport machineries and supplies.

1-3 Organization of Survey Team

Japan Side Planning and Negotiation

Ken	Saito	MMAJ*
Kenji	Sawada	MMAJ
Kazuhiro	Yoneda	JICA**

Peru Side Planning and Negotiation

Benjamin	Morales	INGEMMET
Edgardo	Ponzoni	INGEMMET
Gregorio	Flores	INGEMMET

Japanese Survey Team

Leader	Jinichi	Nakamura	MESCO. INC.
Geological survey	Yukichi	Tagami	"
"	Kazuyasu	Sugawara	"
Geophysical prospecting	Takashi	Aoyama	"
"	Toshimasa	Tajima	"
"	Saburo	Tachikawa	"
Drilling work	Nobuhiko	Yamamoto	"
"	Koichi	Yamashita	"
"	Shigeo	Sekiguchi	"
"	Takayuki	Tsuda	"
"	Yoshio	Terashita	"

Peruvian Survey Team

Leader	Fernando	Llosa	INGEMMET
Geological survey	Cesar	Vilca	"
"	Guillermo	Diaz	"
Geophysical prospecting	Emilio	Rojas	"

* Metal Mining Agency of Japan

** Japan International Cooperation Agency

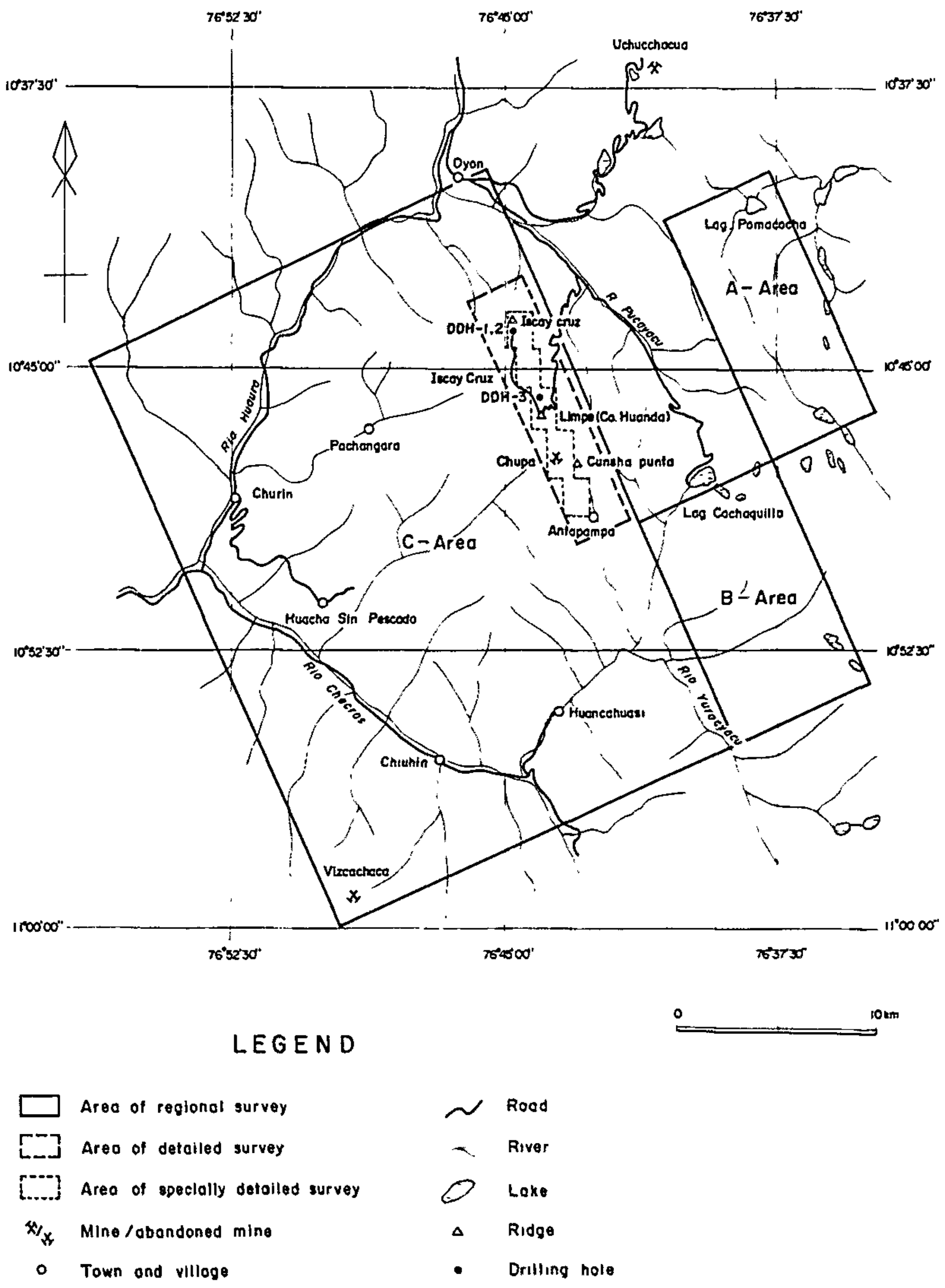


Fig. 2. Location Map of the Surveyed Area

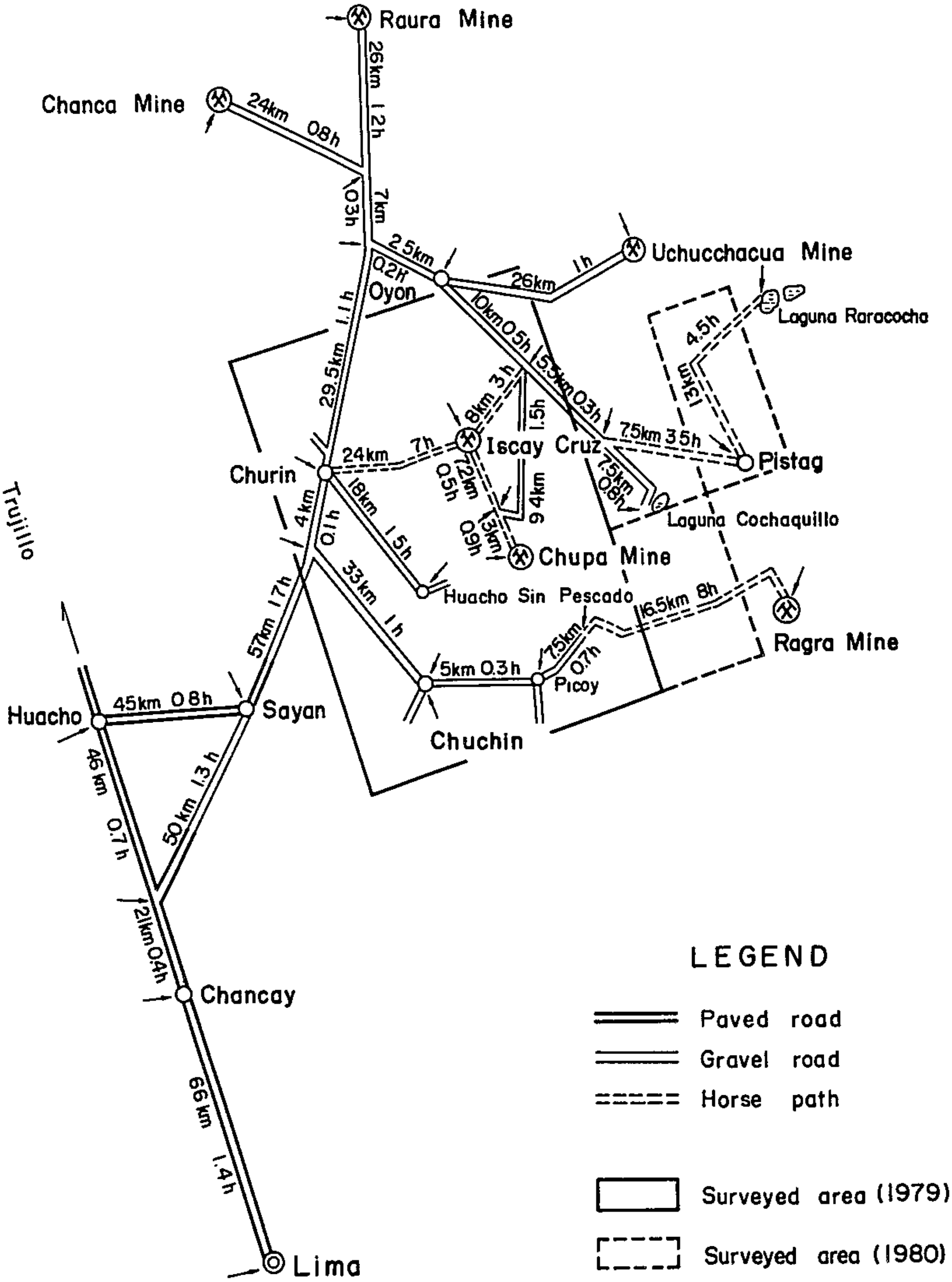


Fig. 3. Access Map of the Surveyed Area

Chapter 2 General Circumstances of the Surveyed Area

2-1 Location and Accessibility

The surveyed area lies 100 km north of Lima, the capital of the Republic of Peru.

There are 2 routes leading to the surveyed area from Lima, one is to pass through Huacho, and the other is a shortcut to attain directly Sayan through Chancay (Fig. 3). The two-lane pavement road, the Pan-American High Way, is available from Lima to Huacho, and the road from Huacho beyond 15 km of Sayan is paved. The shortcut from Chancay, however, is not all paved. From Lima to Sayan, it is 178 km by the former route and 137 km by the latter. However, it takes almost same times, 3 hours and 10 to 20 minutes, by the both routes.

From Sayan to Churin the road along Rio Huaura is rough and it takes about 2 hours to drive 61 km. From Churin to Oyon, it is 32 km and takes 1 hour and 20 minutes. To attain the Iscay Cruz area, on which the detailed surveys were carried out, the route from Oyon via Pampahuay is easiest. From Oyon to Pampahuay, it is 10 km and takes 30 minutes. From Pampahuay to Iscay Cruz, a new access road of 20 km distance passing through a pass about 5,000 m above sea level has been constructed, and it takes about 1 hour and 30 minutes by car, though it is dangerous because the road is not yet stable and it requires repair all the time.

2-2 Topography

The surveyed area lies in the Cordillera Occidental, a main range of the western Andes, and is situated in the source of Rio Huaura which belongs to the drainage system of the Pacific coast. The area forms steep mountainous topographical feature.

The sea level ranges from 2,300 m at the lowest part of the valleys to 5,300 m at the summit of the highest mountain, attaining 3,000 m in the difference. Relatively flat plane named the Puna surface is developed from 4,200 m to 4,800 m, and the difference in topography is clearly observed bounded by this plane. The glacial topography consisting of steep peaks is formed above 4,800 m and the plane shows the stage of maturity, being deeply cut by valleys below 4,200 m (see Fig. 4).

The detailed surveyed Iscay Cruz area is located at an upland of 4,600 m to 5,000 m above sea level. A-area is located in the continental divide and its elevation is 4,600 m even at the lowest place. All places above 4,800 m are covered by snow and glacier. B-area is located on the west side of the divide and the elevations range from 4,200 m along valleys to higher than 5,000 m along ridges.

The topography and drainage system in this area reflect the geological structure: the Jumasha formation consisting of massive limestone forms the highest peaks stretching in the NNW-SSE direction, then the Chimu formation of quartzite forms the mountains of indermediate height, and the Carhuaz formation composed of shale and sandstone forms lower cols. The drainage systems of NNW-SSE and ENE-WSW directions are well developed and crosses to each other. The drainage system of NNW-SSE reflects the folding structure, distribution trend of the formations and thrust faults developing in parallel with the folding axes, while that of NNE-SSW reflects the fracture system.

2-3 Climatic Conditions

The climate in the highland is so-called Andean highland climate. The temperature variation within a day is conspicuous. It rises over 20°C in the daytime and falls below 0°C at night.

The climate during a year is controlled by the seasonal wind from Amazon side and is devided into two seasons: the dry season from June to September and the rainy season from October to March. In the rainy season rainfall, which turns to snowfall above 4,000 m, attains considerable amounts near the continental devide. As the height decreases toward west, the climate becomes dry and mild.

2-4 Inhabitants and Industries

1) Inhabitants and Their Lives

The area belongs to Provincia Cajatambo in Departamento Lima in the administrative organization. The inhabitants are mainly indio. They have settled villages in the basins along the valleys since Inca time, and living in selfsuficient by old-fasioned farming and cattel breeding. The transportations between villages depend on horse and foot.

The area is steep in topography and has cold climate in the higher places and dry climate in the lower places, and therefore the lands suitable for farming are restricted. Small scale farming is engaged on the slops with water channels, which is limited by the elevation of 4,000 m. Grazing is only carried on the plateaus above 4,000 m.

2) Industries

Although there are no operating mines in the Oyon area, mordern metal mines such as Raura mine, Uchucchacua mine and Chanca mine are operating in the neighboring area. Production rates of these mines are 1,100 t/d, 200 t/d, and 200 t/d and numbers of employees are 800, 450, and 200 persons, respectively. Each production scale is small and moderate but more than 10,000 people including employees families are depending their lives on these mines.

Development of these mines is a core of industrial activity and brings a great impact and the most stable earnings to the communities

which are located in the steep mountain range and depend on old-fasioned farming and grazing.

Coal mining has been carried since long time ago, but the scale is small remained a handicraft and the weight in the local economy is not high. There are hot springs at Churin and Chiuchin, and tourism is prospecting at these places as resort zone.

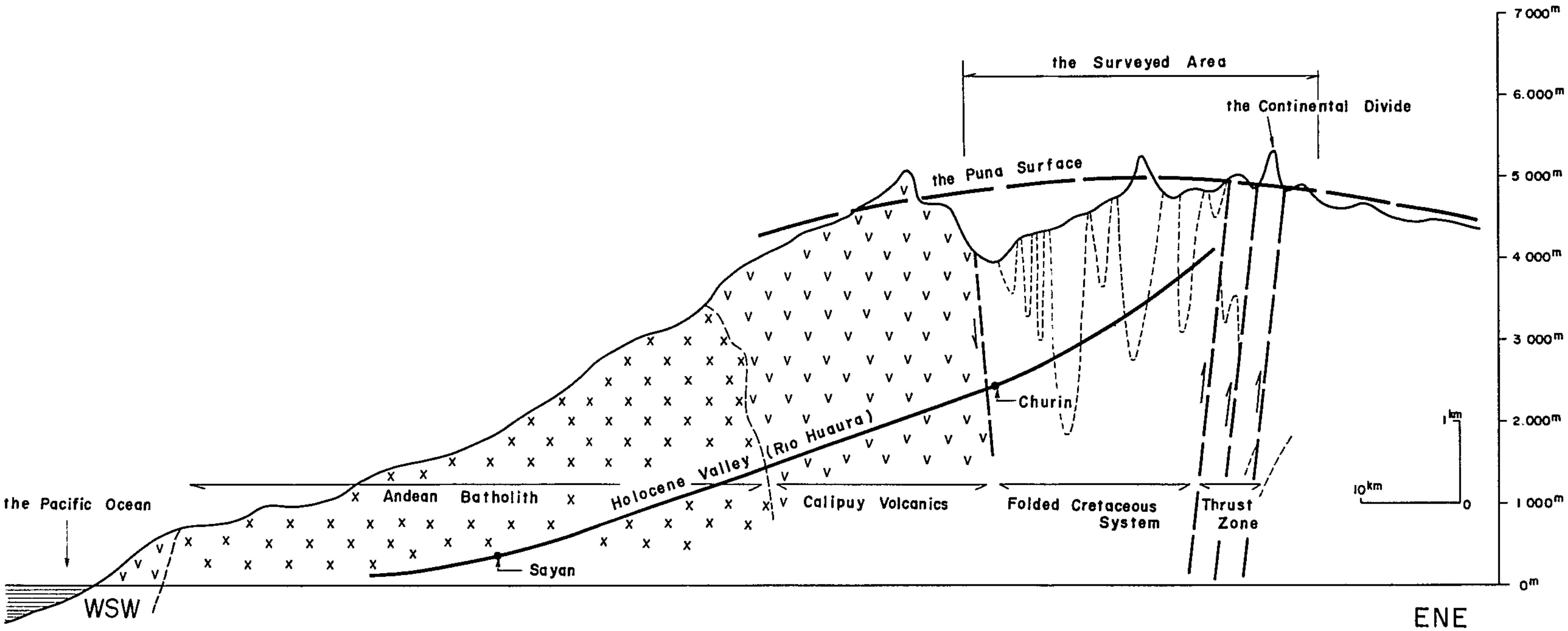


Fig. 4. Schematic Profile of Topography and Geology

Chapter 3 The Situation of Mining Industry in Peru

Peru is endowed with many mineral resources such as gold, silver, copper, lead, zinc and iron ore. Mining industry is one of the important industries of Peru. The ratio of mining industry occupys slightly less than 10% of GDP (gross domestic production) in the economy of Peru, though it depends on international prices of metals and demands of consumer countries. Workers for mining industry is about 2% of total work force.

Participation of mining industry in the economy of Peru looks low from the points of GDP and employment but from the point of international balance of payment, mining industry plays very important part in the economy of Peru. For example, export of mineral products including oil occupies 50% of total export and lately percentage reaches about 60%. The income thus obtained in foreign exchange is used in the purchase of machineries and capital goods needed for the domestic development and is an important source of funds for the modernization of Peru (see next tables).

Balance of Payment of Peru and Export-Import by Items

(Unit $1 million)

	1974	1975	1976	1977	1978	1979
Export						
Marine products	259	208	201	215	238	331
Agriculture products	330	387	282	337	281	362
Mineral products	723	547	690	901	912	1,458
Oil products	28	44	53	52	180	646
Others	165	105	133	221	330	677
Total	1,505	1,291	1,359	1,726	1,941	3,474
Import						
Consumer goods	155	199	176	173	104	170
Raw material semi-finish	919	1,172	1,032	1,050	734	894
Capital goods	610	782	675	469	458	744
Others	223	238	217	472	305	283
Total	1,908	2,390	2,100	2,164	1,601	2,091
Trade balance	Δ403	Δ1,099	Δ741	Δ438	340	1,383

(From data of Banco Central de Reserva del Peru)

Export of Peru by Items

(Unit $1 million)

	1974	1975	1976	1977	1978	1979
Fish meal	201	156	178	179	192	237
Fish oil, etc.	58	52	23	36	46	94
Cotton	96	53	71	48	38	49
Sugar	193	269	91	74	52	34
Coffee	34	53	101	197	168	245
Wool	7	11	19	18	23	34
Total, Agri. and Marine Products	589	595	483	552	519	693
Copper	301	156	227	392	408	668
Iron ore	75	52	63	90	74	85
Lead	57	42	64	173	207	389
Silver	140	146	145	82	90	145
Zinc	150	151	191	164	133	171
Total, Mineral Products	723	547	690	901	912	1,458
Oil products	28	44	53	52	180	646
Others	165	105	133	221	330	677
Grand total	1,505	1,291	1,359	1,726	1,941	3,474

(From data of Banco Central de Reserva del Peru)

Quantity of Mineral Products Exported from Peru

	Unit	1977	1978	1979
Copper	1,000 MT	331	344	373
Iron ore	1,000 LT	6,122	4,778	5,749
Silver	1,000 OZ	39,910	41,628	41,880
Lead	1,000 MT	172	176	164
Zinc	1,000 MT	434	437	418
Oil	1,000 BL	4,104	13,775	23,570

(From data of Banco Central del Reserva del Peru)

International balance of payment of Peru, as seen from foregoing tables, since 1974 is in a deficit due to world wide recession, in turn reduction in export, specially mineral export, due to low metals prices. However, improvement of metal prices since 1978, contributed to rapid improvement of the balance of payment. Mining industry of Peru is a source of mineral products for the western industrial countries including Japan and at the same time, it is a source of funds for capital goods and technology for the domestic development. In this manner, the importance of mining industry of Peru is becoming stronger from now on.

Chapter 4 Outline of the Survey Results

4-1 Geological Survey

1) Regional Survey of A-Area

A-area is located to the east of the thrust fault zone and is underlain by upper Cretaceous limestones of Jumasha and Celendin formations. Locally, the uppermost Cretaceous, Casapalca red formation is present. These formations strike in NNW-SSE and dip westwards. Some parts of the formations may be overturned, because many NNW-SSE faults cut through these formations and the faults have the same trends as that of the thrust faults. About mineralization, stibnite vein is only observed in Jumasha limestone.

2) Regional Survey of B-Area

B-area occupies the western part of the thrust fault zone. Rocks form lower Cretaceous Oyon formation to upper Cretaceous Jumasha formation, trending to NNW-SSE direction, form a complexed folded structure in this area. Tertiary Calipuy volcanics cover unconformably these Cretaceous formations at geographically high portions. Reverse faults with NNW-SSE direction, which are parallel to the thrust faults, and ENE-WSW faults are also seen. Many stocks and dikes of diorite, granodiorite and granite compositions, intrude into the Cretaceous sedimentary rocks. The intrusives are generally altered and pyritized, and accompany Cu-Pb-Zn-Fe skarn deposits (e.g. Cochaquillo) and Ag-Pb-Zn-Fe veins around the margin. (refer to Fig. I-1).

3) Detailed Survey of Iscay Cruz Area

It was found by this survey that Iscay Cruz mineralized zone extends about 12 km along the distribution trend of Santa formation. The mineralization is distinct in particular at the southern side of the Cumbre de

Cunsha Punta where pyrite gossan containing sphalerite- and pyrite-concentrated lenses is seen in 100 m long and 20 m wide zone (refer to Fig. I-6).

More than ten acidic intrusive bodies intrude as sheet into sandstones of Oyon formation and quartzite of Chimu formation which are distributed to the east of Cumbre de Cunsha Punta. Intensive alteration, brecciation and pyrite dissemination are seen in the intrusives and in the surrounding rocks. Thus the mineralizations in this area are considered to have been brought by the intrusive activity.

The Iscay Cruz mineralization is characterized by (1) manganiferous siderite disseminated with very fine crystals of galena and sphalerite and its oxidized black gossan, (2) massive pyrite-pyrrhotite orebody having galena and sphalerite concentration, (3) skarn orebody containing chalcopyrite, sphalerite, pyrite, pyrrhotite and magnetite, (4) galena-sphalerite disseminated dolostone and limestone. Copper-zinc skarn orebodies (e.g. Chupa) are distributed close to the intrusives in the area to the east of Cumbre de Cunsha Punta, whereas lead-zinc bearing massive sulfide orebodies are located in much outer zone, at the southern side of the Cumbre de Cunsha Punta and around Cumbre de Limpe. In the outermost zone around Cumbre de Iscay Cruz and in Antapampa area, distributed is lead-zinc disseminated, manganiferous black gossan or siderite mass.

These varieties of mineralization are considered to have been brought by the acidic intrusive activities. However, the mineralizations are influenced also by ENE-WSW faulting and intrusive center related to the mineralizations may be multiple. Thus a simple genetic model cannot be applied to these deposits. Although the mineralizations occur to follow the Santa formation, different mode of occurrence of ores and a wide variation in ore grade are expected even within a single orebody.

4) Geochemical Survey

Rock samples on which copper, lead and zinc were analyzed, are classified according to geological units and groups. Background values are different in each component; lead is high in limestone and zinc tends to be high in igneous rocks; copper is constant at every rock. Santa formation is not particularly enriched in the three components.

Geochemical anomalies were seen in acidic intrusives of the Iscay Cruz area, limestone of Santa formation attached with the thrust fault zone and limestone of Santa formation in the Iscay Cruz mineralized zone. Among stream sediments, copper anomaly was found at Chagapata in B-area.

A factor analysis among Cu, Pb and Zn of three groups of the samples (rock, gossan and stream sediments) indicate that copper-lead has a high correlation in the rock samples, while lead and zinc are correlated in the gossan samples. Thus the metal concentration is different depending upon the genetic history of the analyzed materials.

4-2 Geophysical Prospecting

High FE (frequency effect) anomaly and low AR (apparent resistivity) anomaly confirmed through IP method are limited to the south of Lag. Quellaycocha in the central and southern parts of the Iscay Cruz area. Specially distinct anomalies are discovered in (1) vicinity of Cumbre de Limpe, (2) Chupa ore deposit and skarn outcrop to the south of Lags. Tinyag, and (3) Antapampa area.

(1) Strongest FE anomaly obtained by IP method in the Iscay Cruz area is located at the Cumbre de Limpe where FE-values of 5 ∿ 6.5% and AR-values of 10 ∿ 100 Ωm encircle the pass, and these anomalies extend to 600 ∿ 850 m. Rocks around the pass which are of Santa formation contain abundant disseminated hematite and magnetite. Thus the

high FE-values may be due to these oxide minerals, but sulfide orebody may also be expected at depth.

(2) High FE-values and low AR-values found in the Chupa ore deposit and skarn outcrops to the east, are 4 ∿ 6% and 2 ∿ 5 Ωm, respectively. These anomalies may be correlated to skarn deposits in the Santa formation, Chupa skarn deposit in the Pariahuanca formation and pyrite dissemination in the Carhuaz formation which occurs between the above two formations.

(3) Anomalies, FE-values between 5 and 8% and AR-value of 5 ∿ 100 Ωm, are also observed in Antapampa area, below the black gossan and its northern extension where unmineralized limestone is expected. These anomalies may be due to purely pyrite dissemination in sheared zone, but hidden sulfide orebody underneath the gossan is also considered.

(4) An intermediate FE-anomaly (FE=2∿4%) but AR-values of 200 ∿ 300 Ωm are observed in the mineralized zone to the south of Cumbre de Cunsha Punta where sphalerite and pyrite containing outcrop was discovered. These results suggest that the mineralization in this area is low in sulfide content or small in its extent.

(5) Low AR-values (AR=1∿10 Ωm) were widely recognized around the Cumbre de Cunsha Punta and its northern mountain slope. Since this area has thick talus deposits and horizon of Santa formation is not clear, detailed study to clarify the cause of the anomaly is necessary.

(6) Low FE-values (FE=1∿2%) and high AR-values (AR=150∿500 Ωm) were seen in the northern Iscay Cruz area between Canaypata and Lag. Quellaycocha. Thus large scale sulfide orebody cannot be expected here. This speculation was testified by DDH-1 and DDH-2 drilling.

(7) EM method was applied along two measuring lines located at the Cumbre de Limpe and at south of Lags. Tinyag where skarn outcrops were

known to occur. Each detected conductive body in the place of Santa formation. It was proved that EM method is useful tool in this area where electric noise is small and recent cover of sediments is thick.

4-3 Drilling Exploration

Three drill holes were made at two places, and all detected prominent mineralization in Santa formation.

(1) DDH-1 and 2 were drilled at the northernmost part of the Iscay Cruz mineralized zone near Cumbre de Iscay Cruz. It was found that the lower part of black gossan is composed of manganiferous siderite and the siderite is disseminated with minute crystals of galena and sphalerite. Lead-zinc disseminated deposits in the siderite mass are separated to a few layers being intercalated with shale and marlstone. Size of each mineralization is about 10 m long, and the grades are less than 1% lead and about 4% zinc. At one place, the length exceeds 30 m including 4 m - wide horse stone.

(2) High-grade lead-zinc containing massive sulfide orebody was detected about 80 m below the surface by DDH-3, which was located in the central part of the Iscay Cruz mineralized zone at north of Cumbre de Limpe. This massive sulfide orebody is essentially aggregates of pyrite and pyrrhotite, and has local concentration of galena and sphalerite. The maximum length in the drill hole is 14.3 m and the average grades are 48 g/t Ag, 2.8% Pb and 7.2% Zn. The highest grade part of 4 m yielded such high figures as 89 g/t Ag, 6.7% Pb and 14.2% Zn.

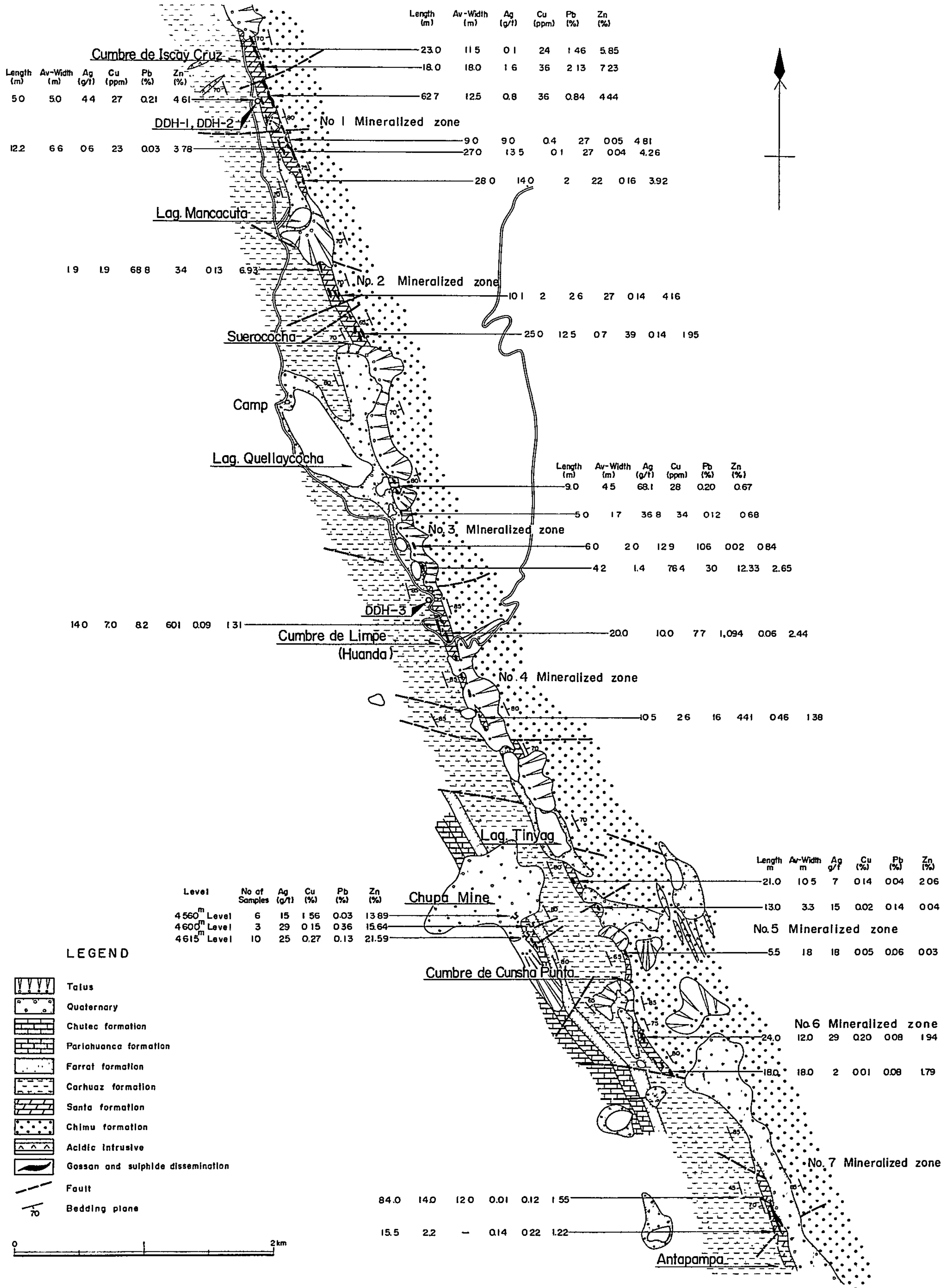


Fig. I-6. Mineralized Zone of the Iscay Cruz Area

Chapter 5 Conclusion and Outlook in Future

5-1 Conclusion

1) Iscay Cruz Area

The phase I geological survey revealed the Iscay Cruz area as a prosperous area for lead-zinc mineralization. This possibility became more promising after this year's survey including the detailed geological survey, geophysical prospecting and drilling.

The ore deposits discovered so far occur in Santa formation and are considered as a limestone replacement type related to acidic igneous activity. Copper-zinc-bearing skarn deposits occur in the central part, lead-zinc bearing massive sulfide deposits are present in the outer zone, and the outermost mineralization is shown by lead-zinc dissemination in the manganiferous siderite mass. Strong mineralizations are seen sporadically in the horizon of Santa formation, and the total length of the mineralization is 12 km.

Geologic and tectonic settings of this mineralized zone are similar to those of Huanzala mine, and ore minerals of the sulfide deposits are similar to those of the Huanzala mine and Cerro de Pasco mine.

The lead-zinc dissemination in the siderite mass is low grade and cannot thus be considered as an immediate future mineral resource. It is recommended to focus exploration in the coming years on the skarn and massive sulfide deposits.

2) B-Area

This area is located to the west and right next to the thrust fault zone. Intensive magmatism is shown in this area by many intrusive rocks which intrude the Cretaceous sedimentary rocks. Regional geological survey of this year indicates that skarns and veins prevail around the intrusive bodies. A few contain silver, copper, lead and zinc. This mineralized zone extends about 20 km from B-area to the north, and the width is about 5 km.

5-2 Outlook in Future

1) Iscay Cruz Area

More drilling is needed to be done in this area, in order to establish relationship among the geologic structure, mineralization and IP anomalies, and also to find hidden orebody. At the same time, detailed geological survey is necessary and geophysical prospecting has to be continued in some part of the area.

The following areas are suggested as target areas in the exploration of the coming years.

(1) Limpe area:

By the drilling of DDH-3 and geophysical prospecting in this year, high grade, lead-zinc bearing massive sulfide and distinct FE anomalies were discovered around the Cumbre de Limpe. Further drilling is recommended to catch up extension of the massive sulfide mineralization.

(2) Cunsha Punta area:

Sphalerite-bearing pyritic gossan is located at south of Cumbre de Cunsha Punta and sphalerite disseminated skarn crops out to the north of the pass. Thus drilling is recommended in this area. Because young sediments cover the pass and its northern slope, even location of Santa formation is not clear in this area. Yet this is considered to be center of the mineralization, since acidic intrusives are present to the east and Chupa deposit is located to the west. It is recommended therefore that EM-prospecting and trenching survey should be done in this area.

(3) Antapampa area:

This area occupies the southernmost part of the Iscay Cruz mineralized zone. Only black gossan and limestone are seen on the surface. Yet IP anomaly was found by this year's exploration. In order to know the details of the anomaly, further IP prospecting based on crossing measuring lines is needed. The anomaly has to be also checked by drilling. If an orebody were discovered in the Antapampa area, construction of a new access-route from the south, passing through Huancahuasi, is needed to be considered.

Throughout the three areas, the drilling data thus obtained are compared with surface geological data. Detailed geological mapping is necessary to evaluate properly each mineralized zone and to plan further exploration program. Systematic sampling of ores and their mineralogical studies are needed to be strengthened.

2) B-Area

In order to understand the details of the mineralization showing and its relation to geologic structure and igneous activity, detailed geological survey is needed to be done in Cochaquillo and Chagapata areas.

PARTICULARS
PART I
GEOLOGICAL SURVEY

PART I GEOLOGICAL SURVEY

CONTENTS

LIST OF ILLUSTRATIONS

LIST OF TABLES

LIST OF APPENDICES

LIST OF PLATES

Chapter 1 Outline of Survey

1-1 Purpose of Survey

Although there is no developed metal mine in the surveyed Oyon area, mineralized zones of zinc and lead such as Iscay Cruz are known.
In the adjacent area, there are several producing mines such as Raura, Uchucchacua and Chanca.

The purpose of the survey is to inquire the possibility of any mineral reserves existence in the A- and B-areas by way of regional survey and to clarify the special feature of the mineralized zone of Iscay Cruz by way of detailed survey, and consequently to establish valuable guideline for the further exploration.

1-2 Scope and Period

1) Location of Surveyed Area and Scope of Survey

The surveyed area lies 100 km north of Lima and upstream of Rio Haura including the continental divide.

Regional geological survey was carried out in the A- and B-areas which form the central part of the western Andes and the areas are 71 km^2 and 89 km^2 respectively. A-area is located at the source of Rio Huallaga and Rio Mantaro both of which are tributaries of the Amazon River, while B-area is located at the source of Rio Checras which is a upper stream of Rio Huaura. To enter the A-area, caravan is needed from Pucayacu going through a pass of 4,900 m above sea level. To reach the B-area, caravan along a valley is needed also from Huancahuasi. Detailed geological surveyed area of Iscay Cruz is located 12 km south of Oyon forming a rectangle of 40 km^2 streched to N-S direction.

In this year, from Pampahuay, which is 7 km southeast of Oyon, a new road was built, passing a pass of 5,000 m above sea level and it becomes convenient to enter the area.

2) Period of Survey

87 days have been spent for the field work and 110 days for the laboratory work.

Field work : July 9, to October 3, 1980.

Laboratory work : October 4 to February 10, 1981.

1-3 Method of Survey

A cooperative survey team consisting of three Japanese geologists and three Peruvian geologists had been formed in Lima. A field office at Churin and a base camp at Oyon were established. Three survey teams were organized at Churin and the work was divided among them. Survey team consists one of each Japanese and Peruvian geologist, 2 to 4 laborers and another horse driver.

All survey areas are located in the central part of Andes mountain range with steep topography and even the lowest part has elevation of 4,600 m. At this altitude, there is always danger of high altitude sickness with headache, loss of body strength, low appetite and lack of sleep. For this reason, to maintain good health and adaptation to high altitude, the best considerations and ample preparation period are needed. For this altitude, oxygen vessel is very necessary.

Three survey areas are far from village and isolated, connected only by horse trails and almost unexplored region. To enter the survey areas, long distance caravan is necessary and survey was conducted by mobile camp system. To move the camp and to transport supplies, and for survey activities, many horses were used. Without horse, survey is extremely difficult.

The topographical maps used are 1/25,000 scale and 1/10,000 scale for the regional survey and the detailed survey, respectively. The survey was done in the scale of 1/2,000 using the pocket compass at the outcrops of mineralization indication and its surrounding areas in the Iscay Cruz area.

In the geological survey, the lithology and structure at the outcrops are examined in detail, and thus the distribution of formations and the mutual relations between the formations were clarified. Then, the regional structure was inferred and the correlations between formations was made. Rock samples for geochemical studies were collected from each lithofacies and each formation and samples of stream sediments were also collected as much as possible. These samples were crushed and prepared at the field office for the chemical analysis, and the various studies including microscopic observation were made for the important samples.

At the outcrops of ore minerals in the Iscay Cruz and gossan areas, the channel sampling with 10 cm in width and $2 \sim 4$ m in length was attemped to obtain the samples for chemical analysis and the ore samples were also collected for the various laboratory studies.

1-4 Method of Data Analysis

Followed up the field works, the laboratory works have been carried out on the various samples, and the data obtained in the field were analysed. The laboratory works were almost performed in Japan, but a part of them was done in Peru. The main items are as follows:

(1)	Microscopic observation of thin sections:	21 samples
(2)	Microscopic observation of polished sections of ore:	11 samples
(3)	Chemical analysis of ore (Ag, Cu, Pb, Zn):	36 samples
(4)	X-ray diffraction:	30 samples
(5)	Electron probe microanalysis:	5 samples
(6)	Determination of isotopic age:	4 samples
(7)	Complete analysis of igneous rocks:	4 samples

(8) Assay of geochemical samples:	(total)	128 samples
Rock (Cu, Pb, Zn):		(30)
Gossan (Cu, Pb, Zn, Aq):		(78)
Stream sediments (Cu, Pb, Zn):		(20)
(9) Analysis of rock-forming elements (Ca, Mg, Mn, Fe, Si, Ba, Sr, Co):		10 samples

Chapter 2 Geology

2-1 Outline of Geology

2-1-1 Geologic Outline of Oyon Area

The Oyon area belongs stratigraphically to the zone of Cretaceous sedimentary basin (la zona de la cuenca cretacea) by Cobbing (1973), and is structually situated in the folding-thrusting zone (la zona de plieques y sobreescurrimientos) by Wilson (1967).

In this area thick Cretaceous sedimentary rocks are widely distributed. Their lithology is significantly different in the lower part and the upper part to each other; the lower part is composed mainly of clastic rocks such as siliceous sandstone and shale, the upper part calcareous rocks associated with dolostone and shale, and the uppermost part red formation. This sequence indicates an evolution of sedimentary basin in Cretaceous period and corresponds to a cycle in sedimentary environment, continental-marine-continental.

In the present report the stratigraphic classification and the name of the formations are referred to Cobbing (1973) and Wilson (1967). The clastic rocks of the lower part is divided into the Oyon, Chimu, Santa, Carhuaz and Farrat formations, and the calcareous rocks of the upper part into the Pariahuanca, Chulec, Pariatambo, Jumasha, Celendin and Casapalca formations in ascending order. These formations are unconformably covered by the Calipuy volcanics in Tertiary and are intruded by tonalites, dacites, granite porphyry and others (Fig. I-1).

The Cretaceous sedimentary rocks suffered intensely a structural movement in consequency of the Andean Orogeny to form composite folds with NNW-SSE trend. Anticlines and synclines appear at intervals of 2 to 3 km, sometimes several tens meters, so that the same stratum is repeatedly exposed at the surface. Usually the folds have acute angle at the axis. In many cases the upper strata are folded in between the lower strata, and the latter are interbedded in the former as plug. At the central part in the orogenic zone thrust faults parallel to the fold axis are developed. The total vertical displacement of the two main faults at intervals of about 2 km attain approximately 1,500 m. The west block thrust into the east block, and this part makes a continental divide. To the east of the thrusting fault, the faults belonging to the same system are developed at intervals of 1 to 2 km and make a imbricate structure.

2-1-2 Geologic Outline of A-Area and B-Area

1) A-Area

The A-Area covers a part of the Rumi Cruz mountains (Cordillera Rumi Cruz) forming the continental divide and its eastern flanks, and the Jumasha and Celendin formations are distributed in this area. In the both sides of the Rumi Cruz mountains, a thrust fault divides the geologic structure of this area into two parts. This area is also situated in the western part of a great anticlinal structure, and therefore the both formations mentioned above dip west. The faults with NNW-SSE trend belonging to the same system as the thrust fault are developed regularly and make a imbricate structure.

2) B-Area

The B-Area covers a part of the Rumi Cruz Mountains and the region on the west of the Callejon mountains (Cordillera Callejon) which is situated on the southern extension of the thrusting fault mentioned above. Cretaceous sediments of the Oyon and Jumasha formations are distributed, forming a composite folding structure. The Calipuy volcanics covers unconformably both formations. In the eastern half of this area complicate system of faults and fissures is developed along the thrust fault, and many stocks and dikes intrude into the formations. These intrusive rocks suffer partly mineralization.

2-1-3 Geological History of the Oyon Area

The Oyon area is situated in the central zone of the western Andes (Cordillera Occidental) is composed mainly of intensely folded Cretaceous sedimentary rocks. On the east of this area the eastern Andes consisting mainly of Paleozoic sedimentary rocks and pre-Cambrian metamorphosed rocks runs, while on the west Tertiary volcanic rocks are continuously distributed and the Andean batholith intrudes into this volcanic rocks.

In the Cretaceous period geological movements in this area reached a climax. A boat-shaped basin separated from ocean was developed at the western margin of the area, consisting of Paleozoic, Triassic and Cretaceous formations which have deposited to surround the South American Continent. In this basin the sediments with various lithology were formed. At the early stage of Cretaceous a considerable amount of clastic material were brought from the land lying to the east of the basin, and clastic sediments containing coal beds were formed. At the middle stage of Cretaceous the transgression progressed and thick strata of limestone were formed. At the later stage of Cretaceous the retrogression proceeded and red formation were formed.

At the later stage of Cretaceous the volcanic activity took place along the western margin of the basin and reached a climax in Tertiary. A large amount of andesitic lava and volcanic ash flow was erupted, and thus the volcanic arc was formed. These volcanic rocks are distributed from north to south in the Territory of Peru attaining 2,000 km. On the west of the volcanic arc, a large batholith crops out. This botholith is considered to form a spine of the western Andes and to be a base of volcanic rocks, and was exposed by later erosion.

When the magma that brought about the volcanic activity on the surface is cooled in the crust, plutonic body is formed. The violent volcanic activity in Tertiary is a characteristic feature of the Andean Orogeny, and a large amount of lava was erupted and many plutonic bodies intruded. As a result, the crust was considerably expanded and strong compression and upheaval were produced. It is thus considered that these compression and upheaval caused the strong folding and uprising in the thick sediments in the eastern and western Andes. According to plate tectonic theory, the magma was continuously supplied by partial melting of subducting plate.

2-2 Sedimentary Rocks

The details on the Cretaceous formations that are distributed in the most part of the Oyon area have been described in the first year report. In this report, therefore, a brief outline of these formations and the detail description only on the Celendin and Casapalca formations are presented.

2-2-1 Lower Clastic Group

1) Oyon Formation

The Oyon formation, the lowest formation in the Oyon area, is distributed underneath the Chimu formation in NNW-SSE trend along the axis of anticline. This formation is composed mainly of the fine alternation of dark grey sandstone and shale and carries coal beds in the upper part. The fine-grained and poorly sorted nature and presence of coal bed of this formation suggests deposition in swamps.

2) Chimu Formation

The Chimu formation is most widely distributed in this area as well as the overlying Carhuaz and Jumasha formations. This formation is exposed as a long slender zone. The thickness is from 600 m to 700 m in general. The formation consists mainly of white to pale grey and fine to medium-grained siliceous sandstone containing same intercalated blackish sandstone and sandy shale. The Chimu formation forms the rugged mountains consisting of massive and tough rocks and is easily distinguished by the topography from other formations. Cross bedding and ripple mark are recognized in the sandstone and fragments of plant fossils have been only discovered in the formation. Judging from the lithology, sedimentary structure and contained plant fossils, this formation is regarded as delta and flood plain deposit.

3) Santa Formation

The Santa formation is distributed in a long and slender zone covering the Chimu formation. This formation consists mainly of fine-stratified bluish grey limestone associated with sandy limestone and marlstone accompanied with dolostone and nodueles of chert. The formation is usually 100 m to 150 m in thickness. The Santa formation forms steep cliffs in contact with the rock wall composed of Chimu quartzite, and sometimes it is interbedded as a plug in the overlying Carhuaz formation. The abundance of fragments of shells and the absence of pelagic invertebrates suggest deposition in a near-shore environment.

4) Carhuaz Formation

The Carhuaz formation is widely distributed along the saddle part of mountain which consists of the Chimu and Jumasha formations. The formation is mainly composed of alternation of sandstone and shale and subordinate thin beds of limestone. In the uppermost and middle parts, bright red shale, which can be used as a key bed in the field survey, is remarkably developed. Because of the flexible and incompitent nature of the rocks, thickness of the formation is extremely variable depended upon the situation in the folded structure, usually 500 m to 800 m. The presence of plant fossils and coaly layers indicate a shallow marine environment of the deposition.

5) Farrat Formation

The Farrat formation is distributed in a narrow zone interbedded between the underlying red shale of the Carhuaz formation and overlying massive limestone of the Pariahuanca formation. This formation is composed of light color and medium-grained siliceous sandstone in the lower part, and pale grey and medium-grained calcareous sandstone in the upper part. Conspicuous development of cross bedding in the sandstone suggests deltaic or fluviatile conditions along the seashore. The thickness is about 100 m to 120 m.

2-2-2 Upper Carcareous Group

1) Pariahuanca Formation

The Pariahuanca formation consisting of massive limestone in contact with the underlying Farrat formation is distributed in long and slender to surround the mountain chain consisting of the Jumasha formation. This formation topographically forms the small projections distributed continuously in a narrow zone, and is able to be used as the most useful key bed in the analysis of aerial photographies. The formation becomes thin eastward and thick westward. The thickness usually ranges from 80 m to 100 m. Since the formation carries fossils mostly broken into fragments and no pelagic fossils, it may have accumulated in the neritic sea near shore. The deposition of this formation shows the beggining of the Albian transgression on a large scale.

2) Chulec Formation

The Chulec formation, together with the overlying Pariatambo formation, is distributed to surround the mountain chain made up by the Jumasha formation and forms a topographical dipression between Jumasha and Pariahuanca formations. The formation consists of pale brownish marlstone and its thickness is about 200 m. The study of fossil fauna shows that the lower part of the formation represents near-shore facies and the upper part slightly deeper water condition. This indicates that the marine transgression progressed from the west and the sea became gradually deeper toward this direction.

3) Pariatambo Formation

The Pariatambo formation is distributed surrounding the mountain chain which is composed of the upper Jumasha formation. The formation consists of thin alternation of limestone, marlstone and shale. All of these rocks are bituminous and show dark grey to black color. Limestone of several centimeters in thickness and marlstone or shale of several millimeters are alternated and rectangular cracks to bedding plane are developed in the formation showing a brisk-like structure. Near the axis of syncline intra-formational foldings are repeated. The thickness is about 150 m. The lithologic types and faunal assemblages suggest that the sea became shallower eastward and euxinic conditions prevailed at that time.

4) Jumasha Formation

The Jumasha formation is distributed along the axis of syncline with NNW-SSE trend, forming prominent steep mountain chain brightening in light grey. Thus, the mountain chain made up by this formation, being a contrast to the rugged mountains composed of the Chimu formation, makes the land-scape in this area diversified. The formation consists of grey massive limestone and embraces marlstone beds of several tens meters in thickness about 150 m above the bottom of the formation. The Jumasha formation is widely distributed on the east of the thrusting zone forming the continental divide. According to the survey results of the A-area, its thickness seems to be more than 1,400 m based on the relation between the upper Celendin and lower Pariatambo formations. The sedimentation environment is supposed to be the offing with weak currents, judging from the lithology and contained fossils.

2-2-3 Celedin Formation

(1) Distribution

The formation is distributed on the east side of the continental divide and is bounded by the thrusting fault at the west side. So far the Oyon area, the distribution of this formation is limited to the A-area, and is absent in the B- and C-areas due to erosion.

(2) Constituents and lithology

The formation consists mainly of pale yellow to pale brown dolostone and carries thin limestone seams and patches. It easily suffers weathering and is eroded at the surface. Therefore, it is distributed in the collapse and basin structure formed by fault, being surrounded by the Jumasha formation. Near the thrust fault, fractures parallel to the fault are densely developed, and bedding plane becomes obscure.

(3) Thickness

The thickness of formations varies from place to place. It attains approximately 200 m.

(4) Correlation

A typical outcrop is observed in Celendin, northern Peru. This formation covers conformably the Jumasha formation and in turn is covered by the Casapalca red formation which indicates a continental environment. This formation is correlated to the Coniacian stage or Santonian stage and the fossil founa indicates a shallow sea environment. It forms uppermost part of the limestone belt which continues to the Pariahuanca formation, and represents the final stage of marine sedimentation in the western Andes. The lithology and thickness of the formation varies from place to place and is absent in places.

2-2-4 Casapalca Formation

(1) Distribution

The distribution of the Casapalca formation is restricted to the east of the continental devide. In the Oyon area the Casapalca formation crops out on a small scale in the southernmost part of A-area, whereas it is widely distributed in the northeastern part of the A-area and the eastern part of the B-area. This formation is easily weathered and eroded. Therefore, it was completely removed at the upheaval parts of the blocks and remains at the depressed parts of the blocks, usually forming basins and planes together with the Celendin formation.

(2) Constituents and lithology

The Casapalca formation is usually characterized by red formation consisting of conglomerate, sandstone, shale and limestone. However, from the southernmost part of the A-area to the eastern part of the B-area limestone and dolostone is more than 60%.

(3) Thickness

On the basis of structural analysis, it is estimated that the thickness of the Casapalca formation attains more than 1,000 m.

(4) Correlation

The name of the Casapalca formation have been given to the red formation at the Rimac Valley by McLaughlin (1924). The red formation distributed on the east of the continental devide is called the Pocabamba formation that corresponds to the Casapalca formation. The red formations corresponding to the Casapalca formation are widely distributed in the whole western Andes area, and their lithology and thickness vary from place to place. The existence of this formation indicates the finality of marine environment and the commencement of continental environment, and that the sedimentary basin was localized.

The Casapalca formation does not carry index fossils, and is uncomformably covered by the Calipuy volcanics of Tertiary age. According to Wilson (1963), a part of this formation is in the relation of interfinger with the Celendin formation. Harrison (1960) stated that in some part the Casaplca formation directly covers the Jumasha formation uncomformably. From these facts it is estimated that the Casapalca formation has a conformable relation with the Celendin formation and represents a late stage of Cretaceous after the Santonian stage.

2-3 Calipuy Volcanic Rocks

(1) Distribution

The Calipuy volcanic rocks covering the Cretaceous sediments are distributed in the wider area along the Pacific coast of the western Andes. In the Oyon area, these volcanic rocks are restricted to the western part of the C-area and the northeastern part of the B-area. The volcanic rocks are in contact with the lower sedimentary rocks mainly by fault in the C-area and by unconformity relation in the B-area.

(2) Constituent rocks

The volcanic rocks are composed mainly of andesitic, dacitic, and rhyolitic lavas and pyroclastic rocks. The lithology of these rocks varies considerably both in the horizontal and vertical directions. The andesitic and dacitic tuffs and andesite lava are most abundant. The andesitic tuff is usually brown, but pale green in places. The phenocrysts of plagioclase, hornblende, and a small amount of biotite is observed. The matrix is usually very fine to fine-grained, and has foliated and weak welded texture. The andesitic tuff sometimes contains a large amount of essential breccias and transform to tuff breccia.

The andesite lava is usually dark green, dark grey, or dark brown, and contains the phenocrysts of plagioclase and hornblende. In general the lavas receive chloritization and partly suffer alteration such as silicification and epidotization.

The rhyolite is white to pale grey and contains the phenocrysts of biotite and quartz. The rhyolitic tuff is white to pale grey, medium to coarse-grained, and contain essential subangular breccias.

Conglomerate, consisting of the blocks of chert, silicified shale and limestone in the silicified matrix, occurs at the base of the volcanic rocks.

(3) Structure and thickness

The volcanic rocks are gently folded, contrasting with the strongly folded Cretaceous sediments. The volcanic rocks appear to incline toward west as a whole, but are nearly horizontal. The volcanic rocks have a abut relation to the Cretaceous sediments, being controlled by the eroded surface of the underneath sediments.

The upper part of the volcanic rocks has been eroded out and the thickness is estimated to be more than 900 m in the B-area. The apparent thickness in the C-area attains about 3,000 m.

(4) Correlation

The volcanic rocks cover unconformitably the Casma formation of middle to late Cretaceous, and are intruded by the Andean batholith at the Pacific coast in the western part of the area, while cover the Casapalca formation of early Tertiary to the east side of the continental devide in the eastern part.

The K-Ar age of the Andean batholith at the north of Lima is 60 to 90 m.y., corresponding to the late Cretaceous (Cobbing, 1973). The Andean batholith is a composite batholith, its activity continued for a long time, and the K-Ar ages of the batholith through whole Peru area range from 26 to 10 m.y. (Stewart & Snelling, 1971).

Assuming that the activity of the batholith corresponds to the plutonic phase of the volcanic rocks in the same epoch, the volcanic rocks are correlated to the late Cretaceous and early Tertiary, and it is estimated that the volcanic activity was most violent in the early Tertiary.

The isotopic age of the andesite lava measured in the first year survey is 17.9 ± 0.9 m.y., which is surprisingly young corresponding to the Miocene age. It is reasonable to interpret that the Calipuy volcanics consist of various rocks that were formed during the volcanic activity for a long time.

2-4 Intrusive Rocks

Intrusive rocks in the Oyon area are mainly composed of tonalite, granodiorite, quartz-porphyry, rhyolite, dacite, and porphyrite. In this report detailed description is given on the rocks of the B-area and the Iscay Cruz Area.

2-4-1 Granodiorite of Cochaquillo in the B-Area

(1) Shape and extent

The granodiorite intrudes into the Carhuaz formation and the Calipuy volcanics to the 2 km east of Cochaquillo, shows stock form, and extends 0.5 km x 1 km.

(2) Lithology

The rock is medium to fine-grained and varies from granodioritic to dioritic in lithology. Suffered alteration it become pale green. It is disseminated by pyrite. Under the microscope it shows porphyritic texture and consists mainly of plagioclase and amphibole with subordinate amount of quartz and orthoclase. The amphibole is almost replaced by chlorite and the plagioclase partly by sericite. Epidote is observed in places.

This rock is considered to have a relation to the formation of the Cochaquillo ore deposit.

(3) Bulk composition

The CIPW norms calculated from the bulk composition of NO-373 plot in the Q-Or-An diagram (Fig. I-5). The composition is plotted near the boundary between granodiorite and diorite classified by Bateman et al. (1975).

(4) Age

The K-Ar age was determined to be 11.1 $\pm$ 0.6 m.y. This corresponds to the Pliocene age. The age is coincident with that of tonalite occuring to the northeast of Churin. The age determination was made on the bulk rocks, because the rock suffers alteration and the mafic minerals are replaced by chlorite.

2-4-2 Granodiorite of Chagapata in the B-Area

(1) Shape and extent

The granodiorite intrudes in the Chimu formation as stock and extends 0.5 km x 1 km.

(2) Lithology

The rock is medium-grained, hollocrystalline, shows porphyritic texture, and consists mainly of plagioclase, quartz, orthoclase, biotite and amphibole. The phenocrysts of biotite and amphibole are observed. In places plagioclase is surrounded by orthoclase, and amphibole is replaced by chlorite. The limestone in the Santa formation surrounding this granodiorite suffers skarnization.

(3) Bulk composition

The CIPW norms calculated from the bulk composition plot on the boundary between granodiorite and quartz monzonite, and fall on the extension of the tonalite of the A-area, indicating that both rocks are in genetic relation.

(4) Age

The K-Ar age determined by using biotite separated from the granodiorite is 9.0 ± 0.5 m.y. This value is younger than that of the Cochaquillo diorite. It is generally said that the age of the Andean batholith becomes younger from west to east, suggesting the migration of igneous activity from west toward east. The age of this granodiorite is youngest among the igneous rocks in the western Andes, and this is consistent with the migration of igneous activity from west to east.

2-4-3 Granodiorite and Diorite of Jancacuta in the B-Area

(1) Shape and extent

Two composite bodies of acid igneous rocks intrude in the Chimu formation and Pariahuanca formation, and they form stock and extend 1 km x 1.5 km.

(2) Lithology

The lithology varies considerably from granodiorite to diorite. The rock is usually medium-grained and contains amphibole phenocrysts. It is strongly altered and show pale grey color. Dissemination of pyrite is observed and a large scale gossan is formed on the surface. Under the microscope the granodiorite (NO-374) shows porphyritic texture, and consists mainly of plagioclase, quartz, and amphibole which is replaced by chlorite. Lead-zinc veins occur around the intrusive bodies.

2-4-4 Acidic Dikes of the Iscay Cruz Area

(1) Shape and extent

Near Cumbre de Cunsha Punta in the southern part of the Iscay Cruz area, several tens dikes of quartz porphyry or rhyolite intrude parallel to each other in the Oyon and Chimu formations. The dikes are usually several meters to several tens meters in width and have NNW-SSE trend which coincides with the strike of formations.

(2) Lithology and alteration

The dikes are strongly altered and shows leucocratic appearance. Occassionally quartz and altered feldspar are observed. It is brecciated in places, and dissemination of limonite and hematite is observed. They have porphyritic texture, consisting of quartz and feldspar. The feldspar phenocryst is completely replaced by sericite. X-ray diffraction indicates that the dikes are composed mainly of quartz and pyrophylite, suggesting that the dikes suffered strongly hydrothermal alteration.

(3) Relation to the mineralization

The marginal parts of the dikes are usually brecciated to form brecciated dikes. The breccias consist in some case mainly of quartzite and in other case mainly of fragments of the dike itself. Recrystallization of quartz, sericitization, and dissemination of pyrite are observed around the dikes over the wide area. These dikes occur in places in the Iscay Cruz area, and they intrude in the Santa formation near Cumbre de Limpe. Juding from the locations and distances between the dikes and the mineralization, the mineralization is in close relation to the igneous activity which brought about the dikes.

(4) Bulk composition and age

The analyses of bulk composition show addition of a considerable amount of silica and almost complete leaching of alkali elements. An age determination on the dikes was attempted to estimate the age of hydrothermal alteration. The reliable value, however, was not obtained due to a small amount of residue sample of screening.

2-4-5 Dikes

Dikes of porphyrite, dacite and granite porphyry are found in addition to the quartz porphyry dikes of the Iscay Cruz.

The porphyrite is dark grey and has amphibole phenocryst. It has regular trends among which the trends of ENE-WSW, WNW-ESE and NNW-SSE are predominant.

The dacite is pale grey and contains phenocrysts of amphibole and plagioclase. At Seccha in the northern part of Iscay Cruz, many dikes with NE-SW trend meet together to form stock shape and intrude in limestone of the Jumasha formation. The dikes give weak skarnization to the surrounding limestone.

Several dikes of granite porphyry with E-W trend occur in the Chimu and Carhuaz formations at Chagapata in the B-area. The granite porphyry is leucocratic and carries biotite phenocrysts.

2-5 Geological Structure

The geological structure in this area is characterized by intrafolial fold, thrust fault parallel to the fold axis, conjugate shear faults oblique to the fold axis, and tension fault which cross with the fold axis at right angle. These are formed by the strong compressive force and emergence force of blocks produced through the Andean orogenic movement.

2-5-1 Fold Structures

The Cretaceous sediments in this area make a composite fold structure with an axis of NNW-SSE direction, and the Chimu formation forms anticlinal part, while the Jumasha formation forms synclinal part.

The cycle of folding is usually 2∿3 km, and sometimes it becomes several tens meters. The fold axis is horizontal, and according to Cobbing (1973), extends to 100 km. The dip of fold plane is usually 80° ∿ 70° to the west and accasionally 80° ∿ 70° to the east. The structure at the axial part usually show acute angle, and in such a case at the synclinal part the upper strata are folded in between the lower strata, while at the anticlinal part the lower strata are sandwiched in between the upper strata, showing plug shape.

In competent strata such as Chimu formation flexual-slip folds with faults parallel to bedding plane are developed. In this case fine-grained sandstones and sandy shales sandwiched between siliceous sandstones are considerably crushed, which may be caused by the bedding plane faults. On the other hand, in incompetent strata such as Pariatambo formation flexural-flow folds are developed and the thickness of strata varies considerably, depending on the shape of fold and the position at which the strata lie. The cycle of folding is in short range, and when the axial part has acute angle, thickness of strata varies considerably. Thickness of strata decreases usually at the wings of fold, while increases at the axial part.

2-5-2 Faults

In this area three fault systems are found: the first fault system with NNW-SSE trend is parallel to the fold axis; the second system with NE-SW and WNW-ESE trends crosses obliquely the first system; the last system with ENE-WSW trend crosses rectangularly the fold axis.

1) NNW-SSE System

In the westernmost part of the A-area and the eastern part of the B-area, two series of thrust faults, the west Rumi Cruz thrust and the east Rumi Cruz thrust, are running parallel to the Rumi Cruz and the Callejon, both of which form the continental devides. The distance between the two thrusts is about 2 km and the vertical displacement attains approximately 1,500 m. The block of the west side to the faults, consisting of lower formations such as the Chimu formation, thrusts up to the upper formations consisting of the Jumasha, Celendin and Casapalca formations. On the both sides of the thrust faults, the faults belonging to the same system of the thrust faults, such as the Ruco fault, the Cutacocha fault and the Picoy fault, are developed. In the area on the east of the east Rumi Cruz thrust, the faults of

the same system are developed, forming imbricate structure.

2) NE-SW System and WNW-ESE System

The two fault systems, which cross obliquely the fold axis, are characterized by the horizontal displacement. The Shapra fault, about 10 km northwest of Oyon and the Otuto fault, about 5 km southeast of Oyon, are typical among the faults with NE-SW system. The Viroc fault to 3 km southwest of Oyon and the Cuchpange fault to the 13 km of Oyon belong to the WNW-ESE system. These faults are mainly characterized by horizontal displacement, and the block on the east is displaced toward west. Apparent displacement attains 1 km. The faults of both systems are typical conjugate fault, and have a close relation to the formation of the fold structure in this area. The Viroc fault forms echelon shape and the drags of strata are observed.

3) ENE-WSW System

This fault system is developed in echelon shape and crosses rectangularly fold axis. It has a characteristic of tension fracture, being randomly displaced. The Cochaquillo fault is a typical one. The fracture of this system is related to the intrusion of dikes and mineralization.

4) Bedding Fault

The strata are strongly folded, and at the part where flextural-slip folds are developed many bedding faults are formed. Although the displacement in each fault is small, it is considered that the displacement as a whole attains a considerably large amount. The folds, therefore, show saw-shape at the axial part. The dips of bedding fault are horizontal or very steep, and the fractures which are nearly horizontal and cross rectangularly the bedding faults occur at intervals of several tens to several hundreds meters. The strata are displaced to several meters by these fractures.

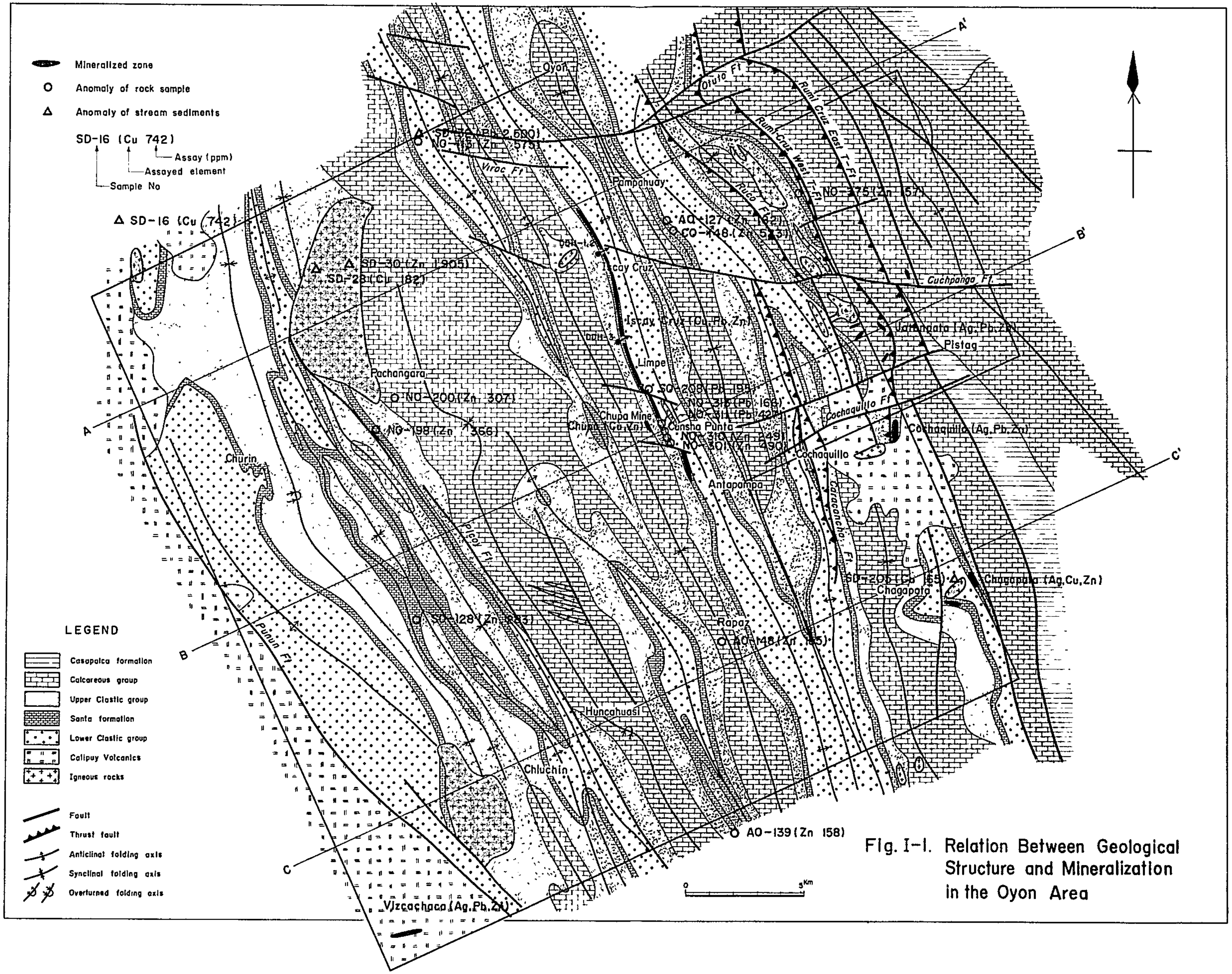


Fig. I-1. Relation Between Geological Structure and Mineralization in the Oyon Area

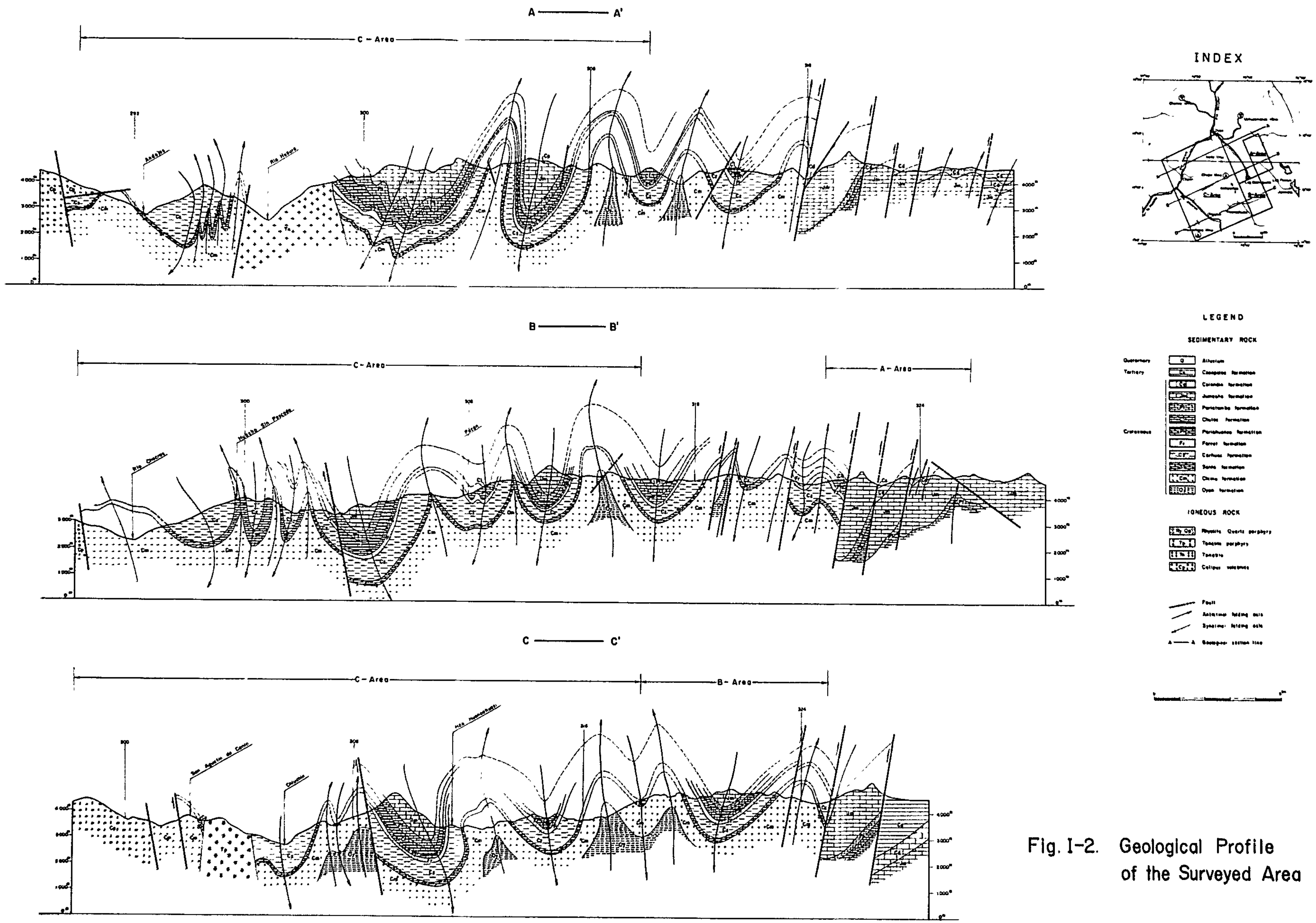


Fig. I-2. Geological Profile of the Surveyed Area

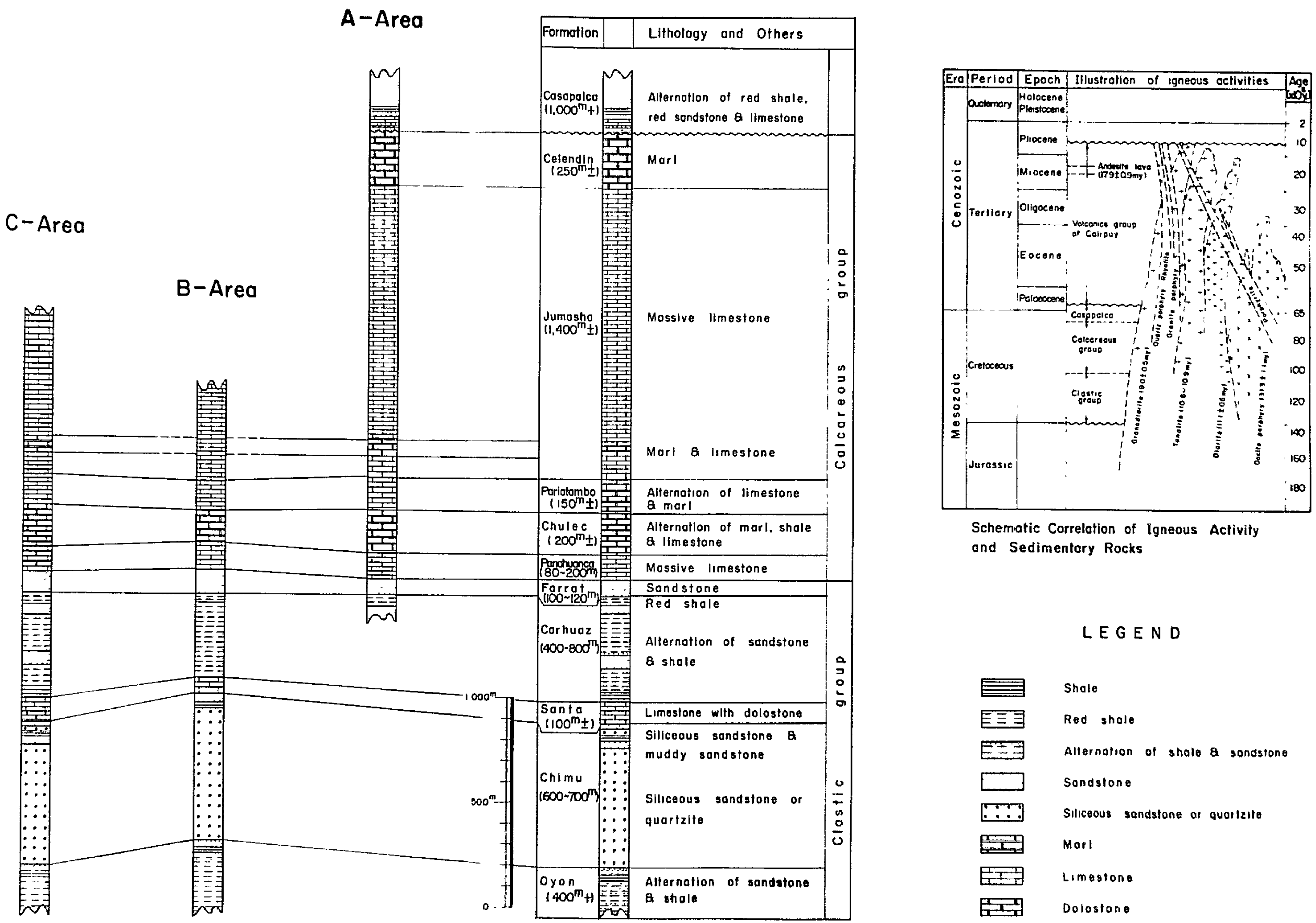


Fig. I-3. Geological Column and Igneous Activity in the Surveyed Area

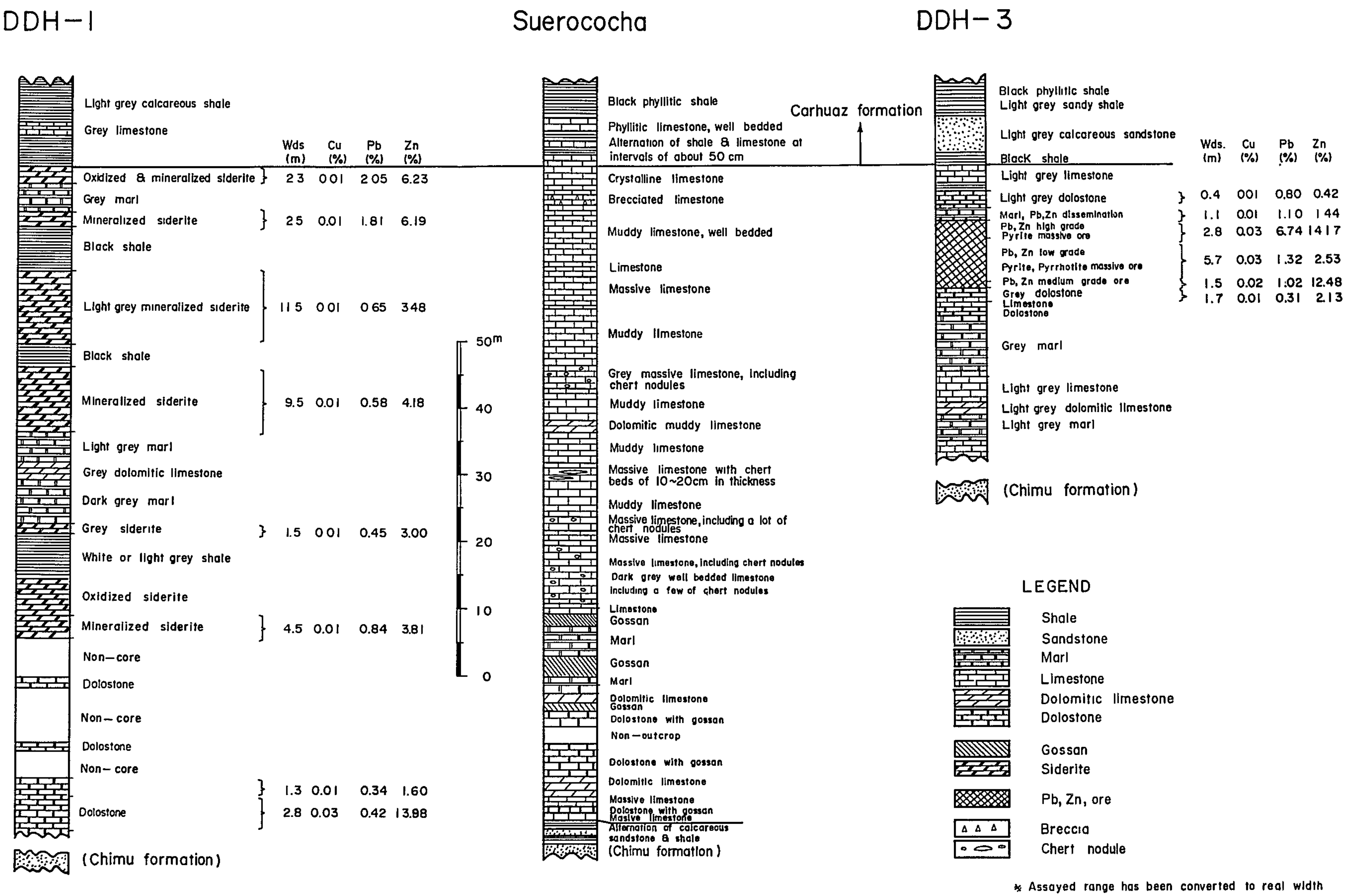


Fig. I-4. Geological Columns of the Santa Formation in the Iscay Cruz Area

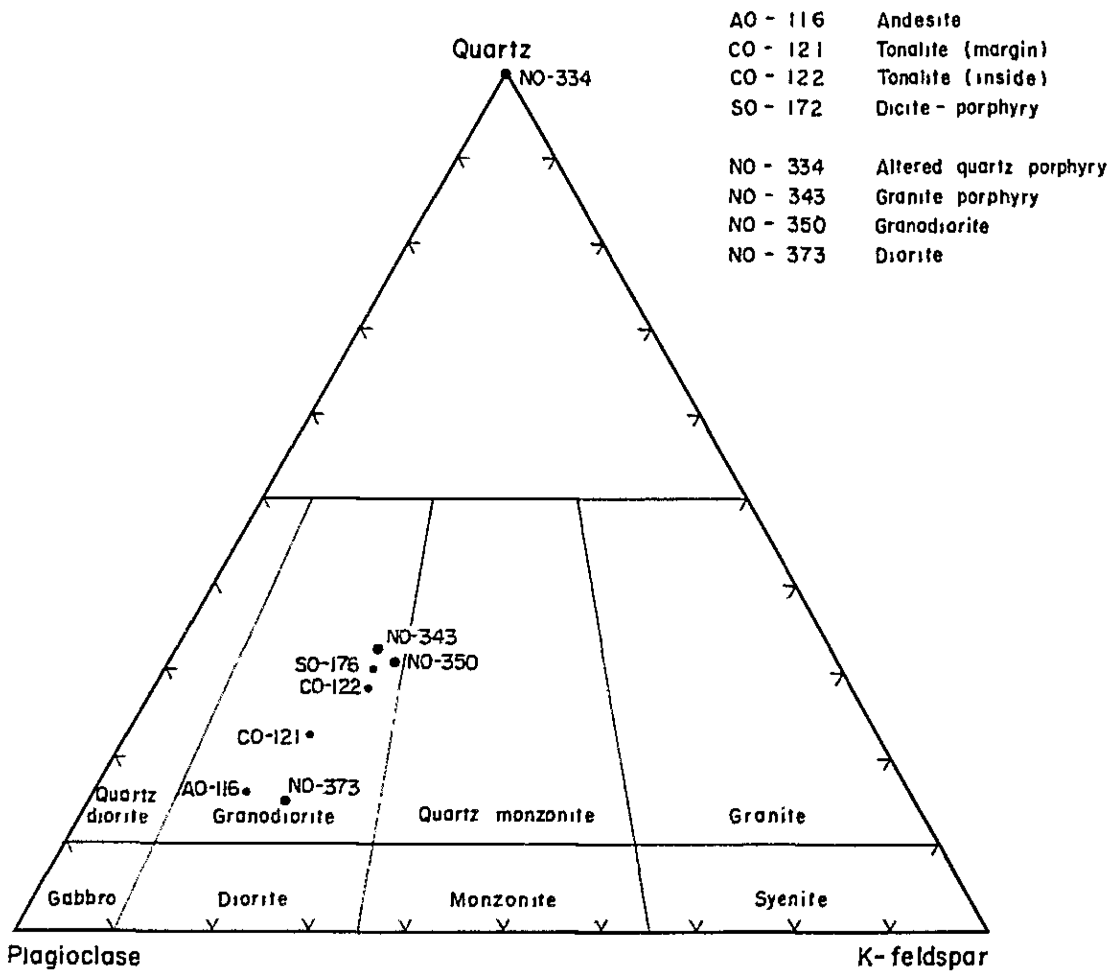


Fig I-5 Triangular Diagram of Quartz, K-Feldspar and Plagioclase for Normative Composition of Igneous Rocks

Table I-1 Assay values and normative composition of igneous rocks

	Component \ Sample No. / Rock Name	NO-334 Altered rhyolite	NO-343 Rhyolite	NO-350 Granite	NO-373 Diorite
Assay Values	SiO_2	80.27 (%)	68.90 (%)	67.58 (%)	57.49 (%)
	TiO_2	0.06	0.35	0.52	1.07
	Al_2O_3	16.39	16.51	15.57	16.62
	Fe_2O_3	0.21	1.18	1.51	2.07
	FeO	0.11	1.10	1.80	4.81
	MnO	0.00	0.07	0.01	0.13
	MgO	0.00	0.77	1.53	3.44
	CaO	0.06	2.51	3.33	6.01
	Na_2O	0.00	3.58	2.97	2.94
	K_2O	0.00	3.05	3.38	2.53
	P_2O_5	0.06	0.15	0.16	0.32
	H_2O+	1.81	1.12	0.98	1.54
	H_2O^-	0.06	0.29	0.09	0.18
	Total	99.03	99.58	99.43	99.15
Normative Composition	Q	82.62	30.59	28.32	12.03
	C	16.87	3.17	1.38	0.00
	Or	0.00	18.36	20.31	15.34
	Ab	0.00	30.86	25.55	25.53
	An	0.00	11.69	15.73	25.33
	Sub-Total	99.49	94.67	91.28	78.23
	Wo-Di	0.00	0.00	0.00	1.30
	EN-Di	0.00	0.00	0.00	0.75
	Fs-Di	0.00	0.00	0.00	0.49
	En-Hy	0.00	1.95	3.87	8.04
	Fs-Hy	0.00	0.61	1.24	5.25
	Mt	0.19	1.34	2.23	3.08
	Hm	0.09	0.00	0.00	0.00
	Il	0.12	0.68	1.00	2.09
	Ap	0.11	0.35	0.38	0.76
	Sub-Total	0.50	5.34	8.72	21.77
Ratio	Q	100.00	33.44	31.50	15.37
	Or	0.00	20.07	22.59	19.61
	Ab+An	0.00	46.50	45.92	65.01

Table I-2 Isotopic age of igneous rocks

	Field No. (Rock Name)	Location	Mineral	Isotopic Age (m.y.)	$Ar^{40}/gm \times 10^{-5}$	% Ar^{40R}	% K
1979	AO-116 (Andesite)	G3	whole rock	17.9 ± 0.9	0.113 0.108	52.1 55.3	1.57 1.59
	CO-121 (Tonalite)	G1	biotite	10.9 ± 0.5	0.215 0.225	43.8 51.0	5.17 5.16
	CO-122 (Tonalite)	G1	biotite	10.6 ± 0.5	0.267 0.258	56.6 47.8	6.36 6.32
	SO-176 (Dacite-porphyry)	G1	biotite	31.3 ± 1.6	0.133 0.129	39.2 36.2	1.09 1.04
1980	NO-350 (Granodiorite)	G4	biotite	9.0 ± 0.5	0.162 0.164	45.3 43.8	4.60 4.66
	NO-373 (Diorite)	G4	whole rock	11.1 ± 0.6	0.101 0.102	31.9 35.8	2.33 2.35
	NO-376 (Granite porphyry)	G2	whole rock	22.4 ± 1.1	0.457 0.463	75.2 72.2	5.24 5.28
	NO-334 (Rhyolite)	G4	whole rock	- *	-	-	-

Constants used

$\lambda_\beta = 4.962 \times 10^{-10}$/year

$\lambda_\varepsilon = 0.581 \times 10^{-10}$/year

$K^{40} = 1.167 \times 10^{-4}$/atom/K

Notes

Ar^{40R} : Radiogenic Ar^{40}

m.y. : million years

Analyses were performed by Teledyne Isotopes, Westwood, New Jersey, USA.

* Cleaning remains are not enough for measurement.

Chapter 3 Ore Deposits

3-1 Outline of Ore Deposits

The Oyon area belonging to polymetallic sub-province of Andean plateau (Sub-Provincia Polimetalica del Altiplane) in Metallogenetic Province of Western Andes (Provinca Metalogenica Andina Occidental) proposed by Bellido, et al. (1969), is surrounded by the following areas: the Huallanca-Oyon area, in which Huanzala and Raura mines are well known, on the north, the Cerro de Pasco area represented by Cerro de Pasco and Vinchos mines on the east, and the Huaron-Carhuacayan area, in which Huaron and Santander mines are well known, on the south. Adjoining to the north of the survey area, three operating mines are present, namely Raura, Chanca and Uchucchacua mines.

In the Oyon area, Iscay Cruz, Chupa, Cochaquillo and Vizcachaca ore deposits or mineralization indications are present but are undeveloped. The followings are present conditions of those ore deposits or mineralization indications.

(1) In the Iscay Cruz area, there is large scale mineralization indications but it is low grade. So far, no high grade portion is discovered so that survey and exploration are suspended.

(2) In the Chupa ore deposit, exploration tunnel was driven in the past and high grade part was discovered but it was abandoned due to small reserves.

(3) Small scale underground exploration was done in the Cochaquillo ore deposit but no high grade portion was discovered so exploration is suspended now. In surrounding areas, there are many mineralization indications.

(4) At the Vizcachaca mine, small scale mining was done in the past but no high grade part was encountered so it is now abandoned.

The ore deposits in the Oyon and adjoining areas are classified according to kind of ore, shape and genesis.

(1) Copper, lead and zinc contact metasomatic deposits within Cretaceous limestone.

Part of Ruaura deposit, Chupa deposit, Part of Iscay Cruz deposit, and Cochaquillo deposit.

(2) Silver, lead and zinc fissure filling-deposits within Cretaceous limestone.

Uchucchacua deposit, part of Raura deposit.

(3) Silver, lead and zinc fissure-filling deposits within Tertiary volcanics and intrusives.

Chanca deposit and part of Raura deposit.

(4) Lead and zinc bedded deposits and lead, zinc and pyrite massive hydrothermal replacement deposits within Cretaceous limestone.

Iscay Cruz deposit.

3-2 Iscay Cruz Mineralized Zone

1) Outline

Mineralization indications of the Iscay Cruz area extend discontinuously about 12 km distance from Canaypata about 6 km south of Oyon to Antapampa about 18 km south of Oyon (see Fig. I-6).

Mineralization indications occur in Santa calcareous formation occupying a west wing of anticline whose axial part consists of Oyon and Chimu formations.

Thickness of the Santa formation is from 40 m to 80 m and to the east, it contacts steep cliff of Chimu quartzite formation and extends in NNW-SSE direction in belt-like shape. Dip of the Santa formation is almost vertical. Northern and southernmost parts dip to the west steeply but central and southern parts dip steeply to the east in reverse.

Mineralization indications are black gossan containing Pb and Zn;

galena and sphalerite accompanied by massive pyrite; sphalerite within skarn; and dissemination of galena and sphalerite within dolostone. In this area, talus deposit of quartzite floats and glacial deposit are well developed. Above outcrops are exposed intermittently among these deposits.

The alterations of host rocks are silification, sideritization, dolomitization, argillization and brecciation, which are distinct. Igneous rock related to mineralization is acidic intrusive such as quartz porphyry rhyolite received much alterations. Surrounding the intrusive also received strong brecciation, pyritization, sericitization and silification and they are also much altered.

Fault system runs perpendicular to the axis of folds and well developed in WNW-ESE direction. Displacement of beds range from few meters to over 10 meters. This system of faulting is tension fault and considered to be related to mineralization. There is a possibility finding fault parallel to the bedding.

The followings are description of outcrops.

2) Northern Part of the Iscay Cruz Area

For a distance of 5.4 km from Canaypata via Cumbre de Iscay Cruz to Lag. Quellaycocha, the mineralization indications are mainly black gossan in limestone and dolostone.

(1) Canaypata-Cumbre de Iscay Cruz (distance about 1.8 km)

Santa formation in this area is mostly covered with talus and glacial deposits but on the slope of Canaypata, in the limestone, there are few beds of dolomitic gossan width of which range from one meter to two meters. Four samples were taken and assayed and the following is the result. This outcrop is located in northernmost part of Iscay Cruz area.

	No. of samples	Cu (ppm)	Pb (%)	Zn (%)
Average of 4 samples	4	3	0.06	0.51

(2) Cumbre de Iscay Cruz-Lag. Mancacuta (distance 1.4 km)

This is the No. 1 mineralization indication of the first year report. On south slope of Cumbre de Iscay Cruz, there is black gossan outcrop for a distance of 1.2 km. The gossan outcrop is in two parallel rows and on the foot wall side (east) maximum width is 25 m, average 13 m, and hanging wall side (west) maximum width is 7 m, average 6 m.

Minerals of black gossan are mainly goethite and quartz, accompanied by siderite, barite, calcite and quartz vein. The result of assay shows high grade Pb and Zn but megascopically no sulfide can be detected. By x-ray difraction, little sphalerite and chalcophanite are detected but sulfide minerals are found in very minute particles and considered to be converted to oxide minerals.

Black gossan is accompanied by dolostone and normally highly brecciated and has soft brown part which is considered to have much kaolinite.

Assay result of continuous channel sampling of black gossan shows that the high grade part is found near the top of the pass, Pb is 1% level while Zn is 6% level. Average grade of all outcrops is as follows.

Location	Total Length (m)	Ave. Width (m)	Ag (g/t)	Cu (%)	Pb (%)	Zn (%)
North FW.	103.7	13.2	5	33	1.20	5.24
South FW.	64.0	5.7	1	25	0.09	4.19
Hanging W.	17.2	5.7	2	24	0.09	4.02
Average	194.9	11.6	3	30	0.71	4.76

This year, drilling was done 150 m to the south of the pass to check about lower part of gossan outcrop. From the study of core, in the lower part of gossan, there is white carbonate rock with dissemination of galena and sphalerite.

Assay result of carbonate rock is shown as follows. By X-ray difraction, it is found out that the rock is mainly composed of silicified siderite containing a large quantity of manganese. From these data, the black gossan found on the surface is a product of oxidation of manganiferous siderite. Upon its dissolution, chemically active Mn element is considered to have played an important part.

(unit: %)

Sample No.	Ca	Mg	Mn	Fe	SiO_2
CB-01-032	1.65	1.23	12.70	19.48	19.43
CB-01-061	1.35	0.48	16.20	26.40	3.45

Assay result of black gossan is as follows. It shows that the removal of Ca element and much enrichment of Mg and Mn elements are recognized.

(unit: %)

Sample No.	Ca	Mg	Mn	Fe	SiO_2
NO-381	0.04	8.52	27.70	15.76	6.26

(3) Lag. Mancacuta-Suerococha (distance 1.1 km)

This is the No. 2 indication. Northern half of the area in extension of 0.5 km is completely covered by talus. To south of the area, a distance of about 0.6 km including a pass of Suerococha, there are exposures of black gossan and dolomitic gossan in limestone and dolostone. Scale of gossan ranges from few meters to few tens meters and their assays are as follows.

	Total Length (m)	Ave Width (m)	Ag (g/t)	Cu (ppm)	Pb (%)	Zn (%)
Average of 6 outcrops	37	6.2	5	35	0.14	2.55

In limestone and dolostone of this zone, there are white vein mainly composed of calcite and another black-brown veinlet in network composed of mainly quartz, accompanied by a small amount of sulfides. In northern tip of this zone, there is old tunnel, following clay vein with width of 0.5 m to 1.0 m which runs parallel to the bedding. In the clay vein, mainly composed of quartz and kaoline and in surrounding area, sphalerite and chalcophanite are recognized.

(4) Suerococha-Lag. Quellaycocha (distance 1.1 km)

This area is completely covered by quartzite talus derived from Cerros Quellococha located to the east and glacial deposit so that the conditions of Santa formation are unknown.

(3) Central Part of the Iscay Cruz Area

This area extends 3.3 km from Lag. Quellaycocha, via Cumbre de Limpe, to Lags. Tinyag. Its mineralization indications are characterized by concentration of hematite, massive pyrite deposit accompanied with galena and sphalerite and dissemination of galena and sphalerite in limestone and dolostone.

(1) Lag. Quellaycocha - Cumbre de Limpe (1.1 km)

This is the No. 3 indication in the first year report. In this area, mineral indications are distributed on the east bank of group of small lakes south of Lag. Quellaycocha. To the east of this area, quartzite talus from Cerros Quellococha and glacial deposit are well developed so much so that outcrops are divided into six and present as like islands among the talus and glacial deposits. Scale of outcrops range from few meters to over ten meters. In northern outcrops, there is dissemination of sphalerite in dolostone and dolomitic gossan. In southern outcrops, there is massive pyrite body and in the surrounding part, there is concentration of galena. Assay results of the mineralized parts are as follows.

	Total Length (m)	Ave. Width (m)	Ag (g/t)	Cu (ppm)	Pb (%)	Zn (%)
North, 4 places	24.2	6.1	49	53	0.12	0.73
South	4.2	4.2	76	30	12.33	2.65

In this year, drilling was done at a point 400 m north of Cumbre de Limpe which is the southernmost tip of this area. As a result, 80 m below the surface, massive pyrite-pyrrhotite deposit was encountered for a length of 14.3 m. Average grade of high grade part is 6.74% in Pb, 14.17% in Zn, and 89 g/t in Ag.

(2) Cumbre de Limpe-Lags. Tinyag (2.2 km)

This is the No. 4 indication. There are mineralization indications in northern half for a distance of 1.3 km, but in southern half, for a distance of 0.9 km, it is completely covered by talus and glacial deposits so that the condition of the Santa formation cannot be determined.

Cumbre de Limpe as center, mainly dolomitic and sideritic gossans are recognized. Outcrop of gossan is composed of two beds and their widths are about 10 m each and for a distance of 350 m, it is exposed discontinuously in Santa formation. There is dissemination of galena and sphalerite in dolostone. Special feature of sideritic gossan is that it contains a large amount hematite, accompanied by magnetite. In sideritic gossan, sometimes sphalerite is concentrated in lens-shape. Under microscope, sphalerite containing chalcopyrite dots and well developed exsolution structure are recognized. Average grades of those mineralized parts are as follows.

Location	Total Length (m)	Ave. Width (m)	Ag (g/t)	Cu %	Pb %	Zn %
FW. side	20	5.0	8	0.11	0.06	2.44
HW. side	14	7.0	8	0.06	0.08	1.31
Average	34	8.5	8	0.09	0.07	1.97

In this area, the width of Santa formation is about 70 m and dip is 80° to 90° to the east presenting reverse structure. Parallel to foot wall side of the Santa formation, there is 10 m wide sheet-like acidic dike. The alteration of this dike is strong and received brecciation and disseminated with a large amount of hematite. Original rock is not clear but rarely altered phenocrysts of feldspar are recognized so it may be either quartz porphyry or member of rhyolite, both of which are closely related to mineralization of this area.

South of this gossan, talus of quartzite is well developed so in few places only small outcrops are exposed among the talus deposit.
Part of these outcrops shows massive pyrite, pyrrhotite and marcasite, accompanied by galena and sphalerite. Average grade of four places is as follows.

	Total Length (m)	Ave. Width (m)	Ag (g/t)	Cu (%)	Pb (%)	Zn (%)
Average of 4 outcrops	10.5	2.6	16	0.04	0.46	1.38

4) Southern Part of the Iscay Cruz Area

This area extends 3.6 km from Lags. Tinyag, via Cumbre de Cunsha Punta, to Antapampa. The mineralization indications of this area are dissemination of chalcopyrite and sphalerite in skarn, south of Lags. Tinyag; dark brown gossan found on the north slope of Cumbre de Cunsha Punta; blackish-brown gossan with pyrite and sphalerite found on the south slope of the same pass; black gossan with hematite found at southernmost tip, Antapampa; etc.

(1) Lags. Tinyag-Cumbre de Cunsha Punta (1.1 km)

This is the No. 5 indication in the first year report. There is outcrop of skarn about 0.3 km south of Lags. Tinyag which is about 25m x 40m in size but surrounding area is covered with glacial deposit. The principal minerals found in the skarn are actinolite-tremolite, garnet, epidote and quartz and also dissemination of chalcopyrite, sphalerite, pyrite and magnetite. Assay results of skarn are as follows and in high grade portion, 10% level of zinc is found.

	Extent (m)	Width (m)	Ag (g/t)	Cu (%)	Pb (%)	Zn (%)
Average	21	3	7	0.14	0.04	2.06
High grade part	1	1	25	0.65	0.05	13.00

This area is on the northern slope of Cumbre de Cunsha Punta with very few exposures of bed rock because the surface is covered with glacial deposit and talus of Chimu quartzite and Carhuaz sandstone and shale. About 0.3 km south of above skarn outcrop and about 150 m just below the pass, there is only small brown gossan which is porous due to leaching and mainly consist of quartz. Assay result of this gossan is as follows.

	Total Length (m)	Ave. Width (m)	Ag (g/t)	Cu (%)	Pb (%)	Zn (%)
Average of 2 outcrops	18.8	2.4	16	0.03	0.12	0.03

West side of this area, sandstone and shale of Carhuaz formation are disseminated with pyrite which is oxidized to reddish brown color. On the east side, silification and sericitization of Chimu quartzite is advanced so much so that it became white and fracture system of WNW-ESE is densely developed. About 600 m west of skarn outcrop, the Chupa ore deposit is present. About 1 km southeast, there are more than ten acidic dikes intruded into the Oyon and Chimu formations.

(2) Cumbre de Cunsha Punta-Chinchaycocha (about 1.0 km)

This is the No. 6 indication. About 0.5 km to 0.6 km south of Cumbre de Cunsha Punta, there are many blackish-brown gossan outcrops. Extension of the outcrops is 20 m wide and slightly less than 100 m in length and covered completely with talus on northern side. In this gossan, concentration of sphalerite and pyrite is recognized. Diameter of the concentrated portion is few meters and is lens-like in shape. Observation of polished sections (NO-304 , 308) show that chalcopyrite dots in sphalerite is well developed. About 0.4 km south of this outcrop, there is strongly brecciated black gossan and its size is 20m x 50m. Between the two outcrops, there are discontinuous limestone and dolostone with small gossans. Average grade of two gossans and ore part is as follows.

	Total Length (m)	Ave. Width (m)	Ag (g/t)	Cu (%)	Pb (%)	Zn (%)
Cunsha Punta	24	12	29	0.20	0.08	1.94
Chinchaycocha	18	18	2	0.01	0.08	1.79
High grade part (NO-308)	-	-	84	0.65	0.18	32.43

In this area, there are well developed overturned structure. Dip of the Santa formation is 75° to 85° to the east, while on the east side of Santa formation, lower Chimu quartzite formation occupies apparent upper position. The thickness of the Santa formation is quite thin, ranging from 25m to 30m. On the west side, thickness of the Carhuaz formation is about 200 m which is about one half of normal thickness. From this fact, possibility of thrust fault parallel to the Santa formation is considered. In the southernmost tip of this area, there is E-W system of faulting, and it is estimated that the Santa formation is dislocated about 300m to the east.

(3) Chinchaycocha-Antapampa (1.5 km)

This is the No. 7 mineralization indication in the Iscay Cruz area. At the western slope of Antapampa, black gossan with a width of 30 m extends about 250 m, forming southernmost tip of Iscay Cruz mineralized zone. This gossan is mainly composed of quartz and goethite, accompanied by hematite. Grades on the surface are as follows.

Location	Total Length (m)	Ave. Width (m)	Ag (g/t)	Cu (%)	Pb (%)	Zn (%)
HW side	15.5	5.2	-	0.14	0.28	1.22
FW side	84.0	14.0	12	0.01	0.12	1.55
Average	99.5	11.1	12	0.03	0.14	1.50

In the northern part of this gossan, it turns to limestone with small size gossan and cut by faults parallel to bedding. Following this fault, late conglomerate is developed over the Santa formation. About 0.6 km of northern half of this area is a pampa of Chinchaycocha and equivalent bed to Santa formation is covered by lake sediments. Southern extension of Antapampa outcrop is also covered with talus and further south, non-mineralized and unaltered limestone is present.

5) Chupa Ore Deposit

Chupa ore deposit is located about 600 m west of skarn outcrop (No. 5 indication) within the Iscay Cruz mineralized zone. It is a skarn deposit formed by replacement of part of limestone belonging to the Pariahuanca formation and mainly accompanied by zinc and copper minerals. It was explored in the past with two levels of tunnels and high grade portion was encountered but due to small reserves, it was abandoned (see Fig. I-7).

The Pariahuanca formation is the host rock of deposit which is massive limestone with a thickness of about 100 m. It is located on the east wing of syncline formed by west side Jumusha formation as axis. Strike is NNW-SSE and dip is 75° to 85° to the east forming reverse structure. On the east side, Farrat sandstone occupies apparent upper position and on the west side Chulec marl and limestone occupy apparent lower position. Near the deposit, well developed fault system of ENE-WSW is present.It is in echelon formation, displacing beds few meters each. Near the deposit its strike is changed to E-W direction.

Mineralization is strongly controlled by this fault system. Ore deposit receives stratigraphical control and extends following the strike of bedding. High grade part follows fault system and formed nearby. Size of the deposit on the surface (elevation about 4,680 m a.s.l.) is about 20m x 70m, on upper level (elevation 4,615 m) is about 20m x 80m and on the lower level is about 20m x 90m. On 4,600 m level 100 m north of above main deposit, there is small deposit of about 10m x 20m.

Skarn minerals are mainly composed of tremolite, hedenbergite, and quartz, accompanied by chlorite, epidote and lievrite. Ore minerals are mainly composed of sphalerite, pyrite and minor amount of chalcopyrite, pyrrhotite and magnetite. Observation of polish section(TP-211)shows that sphalerite holds dots and lattice of chalcopyrite and presents exsolution structure. By electron probe microanalysis, existence of bismuthinite was confirmed in the sample of TP-203. Assay results of 2-meters channel samples taken at randum on three levels are as follows.

Level	No. of Samples	Length of Sampling (m)	Ag (g/t)	Cu (%)	Pb (%)	Zn (%)
4615 m	10	20	25	0.27	0.13	21.6
4600 m	3	6	29	0.15	0.36	15.6
4560 m	6	12	15	1.56	0.03	13.9

No igenous rock is found nearby but it is considered that mineralization belongs to the same type as the Iscay Cruz area, i.e. due to the activity of acidic igneous rock.

3-3 Mineralized Zone of B-Area

In the area with width of about 3 km and length of 20 km from the northeast part of the B-area, passing the southwest tip of the A-area and ending at west side to the A-area, a large scale mineralized zone is included. In this area, skarns and veins associated with pyrite gossans are widely distributed. Most salient is Cochaquillo ore deposit.

1) Cochaquillo Ore Deposit

Cochaquillo is large skarn deposit and located about 3 km west of Lag. Cochaquillo and at elevation of 4800 m a.s.l.. Outcrop measures about 200m x 400m and on the east side, it is covered by Calipuy volcanics and on south side, it comes in contact with the Calipuy volcanics due to faulting. It is estimated that what can be seen on the surface is only a part of deposit. Garnet skarn forms the central part with much magnetite and pyrite, and also chalcopyrite dissemination. On the north side, non-mineralized limestone is present but on the surrounding area of garnet skarn and in transition zone to limestone, vein type skarn with concentration of galena and sphalerite is well developed. Vein-type skarn is found in few places width of which varies but normally about 1 m to 4 m. Assay of ore sample is as follows, which is high in Ag and Pb.

Sample No.	Ag (g/t)	Cu (%)	Pb (%)	Zn (%)
NO-401	257	0.53	30.96	30.30
NO-402	145	0.28	16.72	9.20
NO-403	168	0.26	20.44	8.50
Average	190	0.36	22.71	16.00

Considering the fact that thickness of limestone is over 200 m, the host rock of this deposit is estimated to be belonging to Jumasha formation. The strike and dip of this limestone are NNW-SSE and 70° to 80°W respectively. On the west, it comes in contact with Carhuaz formation due to faulting. Carhuaz sandstone and shale near the deposit turned to hornfels due to contact metamorphism. About 1 km west of the deposit, in the Carhuaz formation as well as in the Calipuy volcanics, there are sills and dikes of quartz porphyry which is disseminated with pyrite.

2) Chagapata Area

Chagapata area is about 8 km southeast of Cochaquillo and there are granite stock and granite porphyry dikes intruded into the Chimu and Carhuaz formations. Surrounding the intruded granite, there is wide spread dissemination of pyrite among quartzite, sandstone and shale, and on the surface gossan was produced. Also in the Santa formation, skarn was developed with dissemination of chalcopyrite and pyrite. Assay of skarn is as follows.

Sample No.	Ag (g/t)	Cu (%)	Pb (%)	Zn (%)
NO-351	32	0.47	0.02	0.10
NO-352	128	0.66	0.45	0.80

3) Lag. Jutunpata Area

Lag. Jatunpata area is about 4 km east of Cochaquillo and in this area, there are intrusions of granite and diorite complex. Intrusions range from sill to dike with much alterations and dissemination of pyrite. On the surface gossan was produced. In surrounding sedimentary rocks, veins and network are developed, accompanied by Cu, Pb and Zn minerals. Principal gangue minerals are rhodochrosite and quartz.

About 1.5 km south of Jatunpata, there is a vein in the Carhuaz formation with width of 40 cm to 60 cm. Its strike and dip are N20°E and 65°S respectively. It contains galena and sphalerite and can be traced for 50 m. About 1.2 km east of Jatunpata, there are many veinlets and network with galena and sphalerite in the Pariahuanca limestone. Width of veinlets ranges from few millimeters to over 10 cm and overall strike is N60°E and dip is 75°S and covers an area of 150 m square. In the network in the limestone, silver is abnormally concentrated. Observation of the polish section (NO-369) shows that in galena, silver mineral is recognized. By electron probe microanalysis, this silver mineral is determined to be tetrahedrite. Assay result of veins is as follows.

Sample No.	Ag (g/t)	Cu (%)	Pb (%)	Zn (%)
TO-227	52	0.06	4.20	5.35
NO.-369	672	0.03	2.85	11.80

3-4 Mineralization Indication of A-Area

In the A-area which is located to the east of the thrusting zone, thick limestone and marl belonging to the Jumasha and Celendin formations are widely distributed. About 2 km north of Pistag, there is brecciated vein containing stibnite in Jumasha limestone. It is just outside of the mineralized zone including Cochaquillo to the west. Aside of stibnite, no other distinct mineralization indication is found. Southwestern corner of the A-area located to the west of the thrusting zone, there are gossans and lead-zinc veins which are already mentioned in the report before.

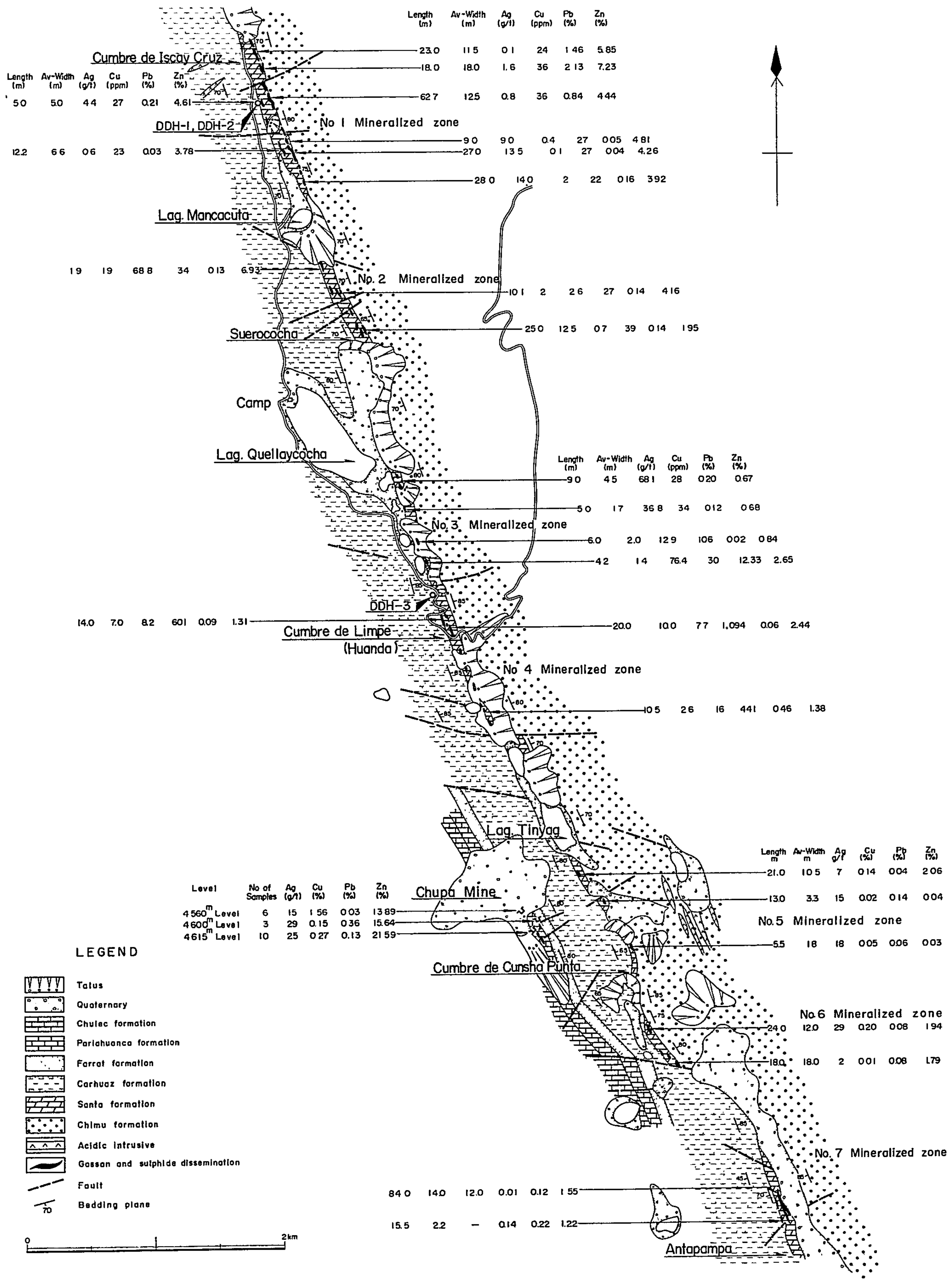


Fig. I-6. Mineralized Zone of the Iscay Cruz Area

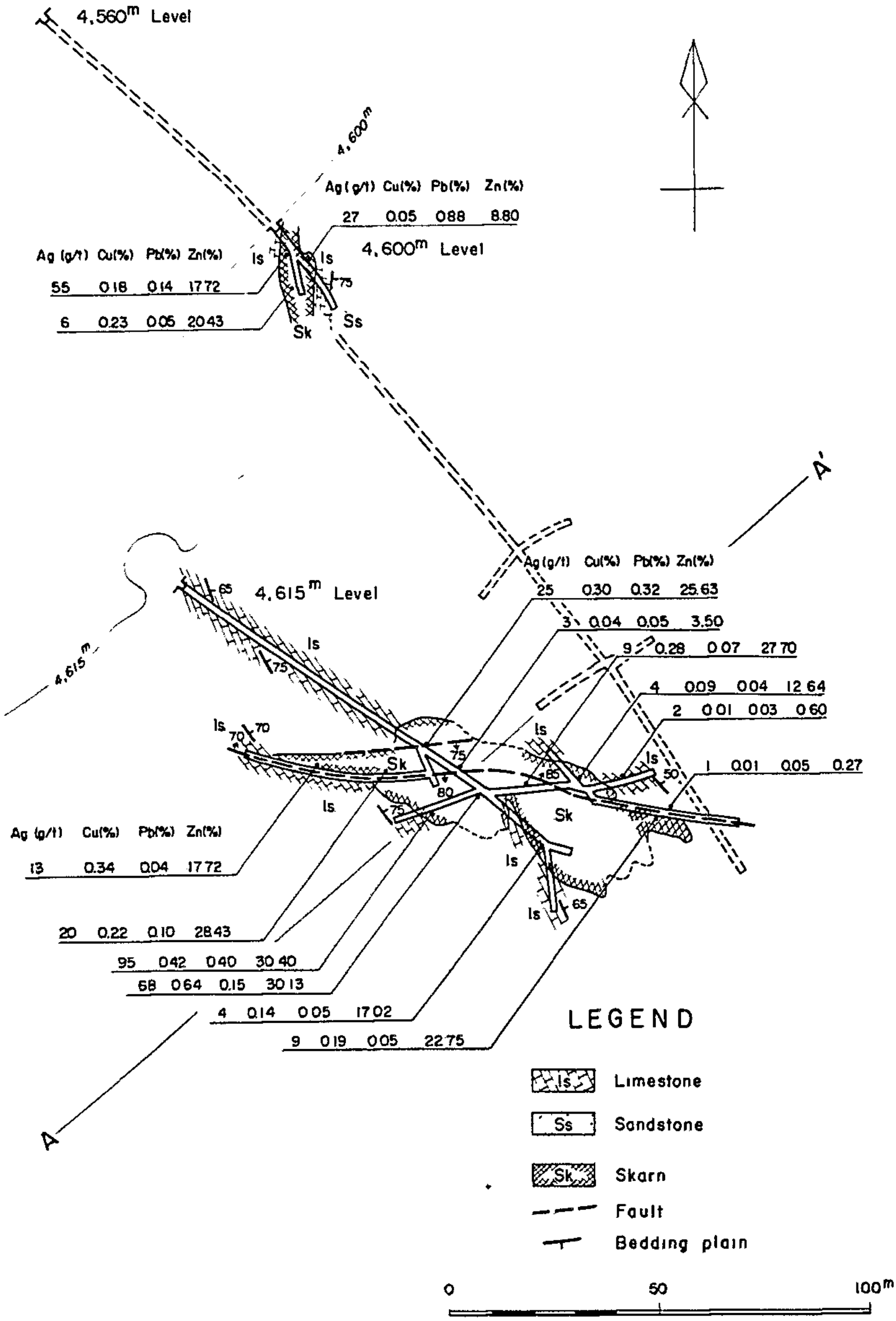


Fig. I-7. Geological Survey Map of the Chupa Mine

(1) 4,615m Level

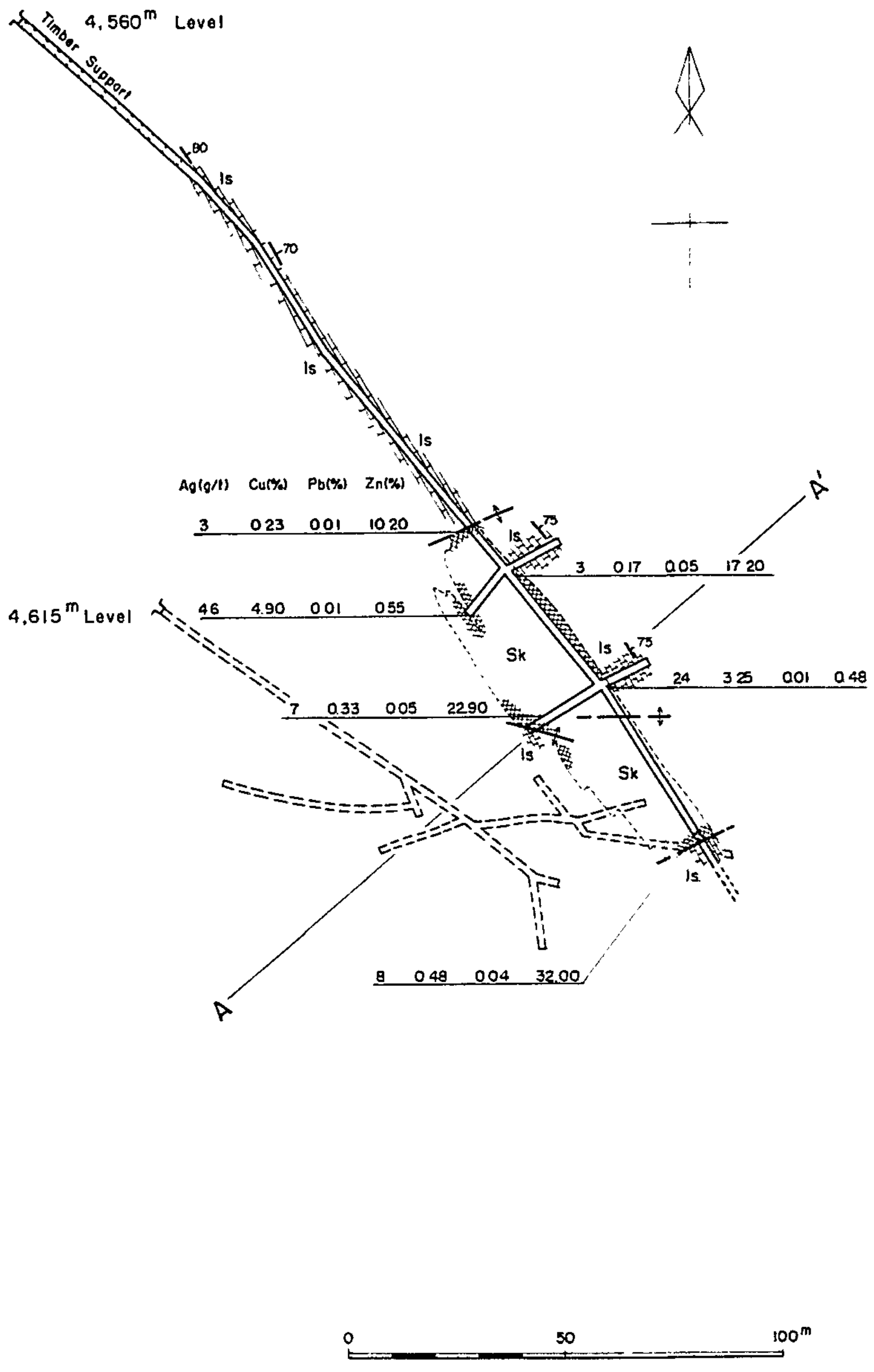


Fig. I-7. Geological Survey Map of the Chupa Mine
(2) 4,560m Level

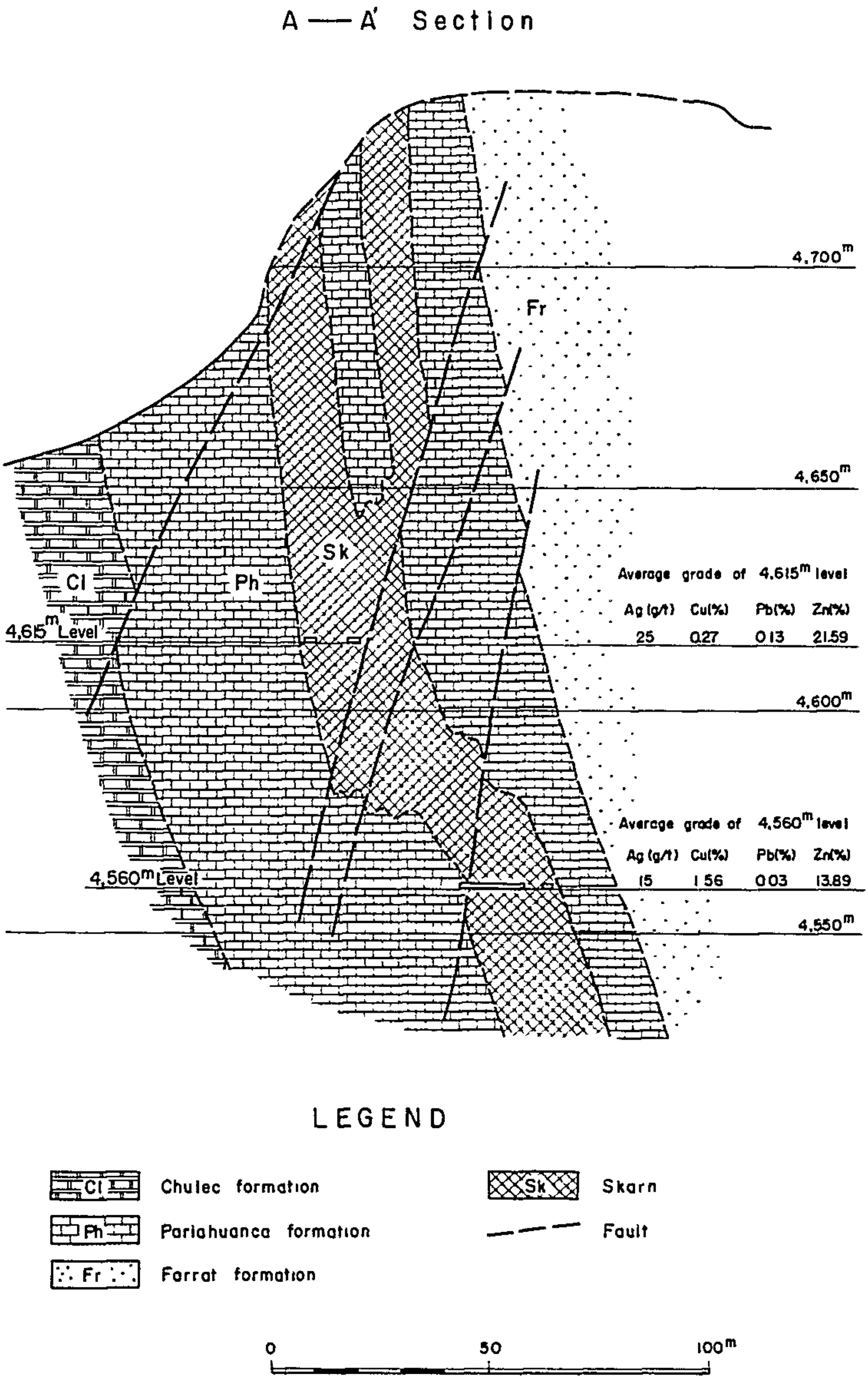


Fig. I-7. Geological Survey Map of the Chupa Mine

(3) Section, WSW – ENE

Table I-3 List of mineralized zones in the surveyed area

Area	Zone	Location	Kind of Ores	Host Rock		Type of Mineralization	Mode of Occurrence	Scale of Mineralized Zone	Scale of Unit Orebody		Direction	Grade of Ore	Ore Minerals	Gangue Minerals	Remarks
				Formation	Lithology				Length	Width					
D	Iscay Cruz	IC-No.1	Pb,Zn	St	Ls,Do	rep	mas-band	1,200m	140m	25m	NNW-SSE	Cu 30ppm Pb 0.71% Zn 4.76%	Zn-Ox, Sp,Gl	Ge,Qt, Sid,Dm	Low grade Pb,Zn diss. ore in siderite confirmed by drilling.
		IC-No.2	Pb,Zn	St	Ls,Do	rep	mas-band	650m	50m	23m	NNW-SSE	Cu 35ppm Pb 0.14% Zn 2.81%	Zn-Ox, Sp,Gl	Ge,Qt, Sid,Dm	
		IC-No.3	Pb,Zn	St	Ls,Do	rep	mas-band	800m	30m	5m	NNW-SSE	Cu 49ppm Pb 2.24% Zn 1.06%	Sp,Gl, Py,Po	Dm,Sid, Qt,Ge	High grade Pb,Zn ore with mas. Py confirmed by drilling.
		IC-No.4	Pb,Zn	St	Ls,Do	rep	mas-band	1,000m	80m	12m	NNW-SSE	Cu 0.09% Pb 0.07% Zn 1.97%	Sp,Gl, Py,Po	Hm,Sid, Qt,Ge	
		IC-No.5	Pb,Zn	St	Ls	skarn	dis	100m	100m	20m	NNW-SSE	Cu 0.14% Pb 0.04% Zn 2.06%	Sp, Py,Mg	Tr,Gn, Qt	
		IC-No.6	Cu,Zn	St	LS,Do	rep	mas-band	450m	100m	20m	NNW-SSE	Cu 0.65% Pb 0.18% Zn 1.94%	Cp,Sp, Py,	Qt,Ge	
		IC-No.7	Pb,Zn	St	LS,Do	rep	mas-band	300m	250m	24m	NNW-SSE	Cu 0.03% Pb 0.14% Zn 1.50%	Zn-Ox	Ge,Qt, Hm	
		Chupa	Cu,Zn	Ph	Ls	skarn	mas, diss	170m	90m	22m	NNW-SSE E-W	Cu 0.66% Pb 0.13% Zn 18.22%	Cp,Sp, Py,Po	Tr,Hd, Qt	Explored by tunnelling.
	Chiuchin	Vizcachaca	Ag, Pb,Zn	Cp	Volc	fr-fil	Vein	100m	50m	1m	N80°E	Cu 0.05% Pb 7.6 % Zn 11.0 %	Gl,Sp	Qt	Abandaned
B	Cochaquillo	Cochaquillo	Ag, Pb,Zn	Jm	Ls	skarn	mas, diss	400m x 200m	100m	5m	NNW-SSE	Ag 190g/t Pb 22.7 % Zn 16.0 %	Gl,Sp Py,Mg	Gn,Tr, Qt	Surveyed by pitting
	Chagapata	Chagapata	Ag, Cu,Zn	St	Ls	skarn	mas, diss	500m	50m	5m	NNW-SSE	Ag 80g/t Cu 0.6 % Zn 0.5 %	Cp,Sp, Py	Qt,Sk	
	Jatunpata	Jatunpata-E	Ag, Pb,Zn	Ph	Ls	fr-fil	network	150m x 150m	10m	0.1m	N60°E	Ag 672g/t Pb 2.9 % Zn 11.8 %	Tet, Gl,Sp	Rdc,Qt	
		Jatunpata-S	Ag, Pb,Zn	Cz	Sh,Ss	fr-fil	vein	50m	+50m	0.5m	N20°E	Ag 52g/t Pb 4.2 % Zn 5.4 %	Gl,Sp	Rdc,Qt	

St: Santa
Ph: Pariahuanca
Jm: Jumasha
Cz: Carhuaz
Cp: Calipuy

Ls: Limestone
Do: Dolostone
Sh: Shale
SS: Sandstone
Volc: Volcanics

rep: replacement
fr-fil: fracture-filling
mas-band: massive-banded
diss: dissemination

Zn-Ox: Zn-Oxides
Sp: Sphalerite
Gl: Galena
Cp: Chalcopyrite
Py: Pyrite

Po: Pyrrhotite
Mg: Magnetite
Tet: Tetrahedrite
Hm: Hematite

Ge: Goethite
Qt: Quartz
Dm: Dolomite
Sid: Siderite

Tr: Tremolite
Hd: Hedenbergite
Ga: Garnet
Rdc: Rhodocrosite
Sk: Skarn minerals

Table I-4 Summary of X-ray diffraction test

Sample No. \ Mineral	Quartz	Calcite	Dolomite	Siderite	Barite	Tremolite	Rhodonite	Vermiculite	Sericite	Phlogopite	Tolc	Chlorite	Kaolinite	Copiapite	Bianchite	Pyrophyllite	Chalcophanite	Sphalerite	Galena	Pyrite	Pyrrhotite	Hematite	Magnetite	Goethite
NO-304	◎			○								∘						⊚		•		•	∘	
NO-309														◎	○									
No-312	∘																							⊚
NO-313	⊚								○															
NO-317		◎	◎								○	○												•
NO-320	∘			∘								•						◎	○	∘	◎			
NO-322	⊚											○												∘
NO-324	⊚																							◎
NO-325	◎												∘									⊚		
NO-333	⊚																					∘		◎
NO-334	⊚															⊚				•			∘	
NO-346						⊚		◎	○															
NO-381	○	•											∘											⊚
NO-382	⊚	•											∘				∘							◎
NO-383	∘	•											∘											⊚
NO-384	∘	∘			∘				•				∘					○						⊚
NO-385				⊚									•											○
NO-388	∘		⊚										•											
NO-389	∘	∘			○								∘				•	○						○
NO-394	•	⊚																						
NO-395	⊚		∘															•						∘
NO-401	•											○						⊚	⊚	•				
SO-216	⊚								⊚															
TO-227	○						○			⊚			∘					○						
IC-602	◎								∘		◎	◎							∘			◎		•
IC-620	◎			◎					◎								•	•						○
IC-641	⊚								∘								•							∘
IC-645	⊚								∘															◎
TP-204	○	○		∘					•				∘					⊚					○	
TP-206	◎		•						◎			⊚												

⊚ Very abundant ◎ Abundant ○ Common ∘ Rare • Very rare

Table I-5 Assay results of rock-forming elements

No.	Field No.	Location	Rock Type	Ca (%)	Mn (%)	Fe (%)	Mg (%)	Ba (%)	Sr (%)	SiO_2(%)	Co (ppm)
1	NO-301	IC-5	Ls	38.09	0.02	0.21	0.37	< 0.1	< 0.1	3.24	2
2	NO-305	IC-5	Do	20.49	0.32	1.39	11.37	< 0.1	< 0.1	7.07	1
3	NO-310	IC-5	Ls	38.62	0.01	0.19	0.38	< 0.1	< 0.1	2.16	1
4	NO-319	IC-3	Ls	38.05	0.01	0.49	0.38	< 0.1	< 0.1	1.56	1
5	NO-321	IC-5	Ls	38.55	0.01	0.24	0.49	< 0.1	< 0.1	1.74	1
6	NO-323	IC-5	Ls	34.80	0.23	0.61	0.59	< 0.1	< 0.1	9.13	1
7	NO-329	IC-5	Ls	35.39	0.06	0.23	1.09	< 0.1	< 0.1	7.20	1
8	NO-381	IC-1	Gs	0.04	15.76	27.70	8.52	< 0.1	< 0.1	13.41	4
9	NO-388	IC-1	Do	21.52	0.38	0.89	11.41	< 0.1	< 0.1	3.04	2
10	NO-392	IC-2	Do	20.39	1.58	0.74	11.38	< 0.1	< 0.1	7.09	1

Ls --- Limestone, Do --- Dolostone, Gs --- Gossan

Chapter 4 Geochemical Survey

4-1 Purpose and Method

1) Purpose

Geochemical survey was conducted with the purpose of determining (1) geochemical characteristic of host rocks having ore deposit; (2) characteristics of mineralized zone; (3) abnormal concentration halo of metals in unexplored area.

For sample media, rock, gossan and stream sediments were used. Taking of rock samples was done with the purpose to clarify geochemical characteristic at the time of deposition and intrusion and to obtain clue for abnormal concentration of metals. Gossan samples were taken with the purpose of clarifying characteristics of mineralization and stream sediments were taken to detect halo of abnormal concentration of metals. For indicating elements, Cu, Pb, and Zn were assayed.

2) Sampling Method

Following methods were used for taking of samples and their subsequent treatment.

(1) Rock: Taken by hammer. Fresh portion was selected, and crushed and quartered at the Churin office to obtain assay samples.

(2) Gossan: Basically 2 m to 4 m channel samples were taken.

(3) Stream sediments: 80 mesh sieve was used to wash and separate organic matter and silt. Undersize was used for samples.

In this year, 30 rock, 78 gossan and 20 stream sediments samples were taken and assayed. Adding last year samples, the total becomes 304 rock, 210 gossan and 64 stream sediments samples.

4-2 Statistical Method of Data Processing

Rock, gossan and stream sediments are clearly different from population so they were input to computer separately and treated statistically. Frequency distribution of assay values shows distribution of positive skewness which is different from normal distribution. For this reason, all assay values were converted to logarithm values to obtain lognormal distribution. By using the latter, geometrical mean and standard deviation were calculated and background value was studied. Next, by studying the cumulative frequency curve, threshold value was determined, and abnormal values were detected and studied. For rock samples, population was divided by formation and by geological group and statistical analysis was conducted. Also to clarify special features of metal concentration structure and difference, principal component analysis and factor analysis were conducted.

4-3 Discussion on Results (see Table 6 and Fig. I-8, 9)

4-3-1 Rock Sample

1) Background Value (geometrical mean)

Geometrical mean by kind of rock is as follows. The mean is conjectured to represent background value of each kind of rock and group.

Geological Group	Cu (ppm)	Pb (ppm)	Zn (ppm)
Upper Calcareous r.	6	28	31
Santa limestone	6	27	24
Middle clastics	7	10	34
Lower clastics	5	12	24
Igneous rocks	5	5	48
Total	5	21	29

In the case of Cu, there is no difference among the rock, while Pb is evidently high in limestone and high concentration of Pb in limestone may be due to process of deposition. Zn has a tendency to be concentrated in igneous rock and it may be due to igneous activities which brought mineralization. Compared to other rocks, there is no evidence of metal concentration in the Santa formation, so that it is difficult to expect any dipositional ore deposit in the Santa formation of this area.

2) Threshold Value

The cumulative frequency curve of rock samples shows that there is bending point at about 5% in cumulative frequency for Cu, Pb, and Zn. This point almost coincides with the point of geometrical mean plus twice the standard deviation (M + 2σ) so it is taken as threshold value which is shown below.

Geological Group	Cu (ppm)	Pb (ppm)	Zn (ppm)
Upper Carcaleous r.	16	49	131
Santa limestone	15	125	123
Middle clastics	49	96	220
Lower clastics	186	422	192
Igneous rocks	76	114	283
Total	26	162	153

Variance of assay values is low in limestone, but high in clastics and igneous rocks which is estimated to be influence of mineralization brought by igneous activities.

3) Selection and Study of Abnormal Value

In the population of rock samples, samples with over threshold value are selected and in the case of Cu, it is 7, for Pb 3, and for Zn 12 samples. Characteristics of distribution differ with formations and groups so that removal of their influence becomes necessary. For this reason, samples with over threshold value are selected by formation and group. As a result, samples showing abnormal values are for Cu none, for Pb 3, and for Zn 11 samples, and among the samples taken this year, for Pb 3 and for Zn 3 samples. Samples with abnormal value are as follows.

Sample No.	Assay (ppm)	Formation	Rock Type
NO-301	Zn 440	St	Ls
NO-310	Zn 249	St	Ls
NO-311	Pb 427	Cm	Brc-Qt.
NO-313	Pb 166	St	Ald-r
NO-375	Zn 157	St	Ls
SO-208	Pb 195	Ig	Ry

(1) Both NO-301 and 311 were taken from south slope of Cumbre de Cunsha Punta which is limestone near the mineralized zone and within the zone so naturally they received strong influence of mineralization.

(2) SO-208 is much altered acidic intrusive taken from east slope of Cumbre de Cunsha Punta. NO-311 is brecciated dike tainted with limonite which was produced in Chimu quartzite near acidic intrusive. Both of them show the influence of igneous activity elated to mineralization.

(3) NO-313 is altered rock mainly composed of quartz and sericite and taken from bed equivalent to Santa formation on the north slope of Cumbre de Cunsha Punta. It shows the effects of mineralization and weathering.

(4) NO-375 is Santa limestone which was taken from eastern edge of A-area where thrust fault contacts Santa limestone. It hints the relation between mineralization and NNW-SSE system of thrust fault.

4-3-2 Gossan

Geometrical mean of gossan samples taken mainly from Santa formation of the Iscay Cruz area is as follows.

	Cu (ppm)	Pb (ppm)	Zn (ppm)
Gossan	61	968	11,092

Above values when compared to Santa limestone, for Cu it is 10 times, for Pb 36 times and for Zn 462 times which show that the addition of Zn was specially big.

4-3-3 Stream Sediments (see Fig. I-10)

The followings are geometrical mean and geometrical mean plus twice the stand deviation.

	Cu (ppm)	Pb (ppm)	Zn (ppm)
Mean	20	31	115
M + 2σ	110	455	445

Geometrical mean is thought to represent background values and compared to the contents of rock, for Cu it is 4 times, for Pb 1.5 times and for Zn 4 times, which is specially concentrated. Variance is big for Pb, and for Cu and Zn, it is slightly less.

If M plus 2σ value is considered as threshold value, abnormal values for Cu are 3, for Pb 1, and for Zn 1 sample. For samples taken this year, for Cu it is only SD-205 and its assay is 165 ppm. SD-205 was taken at Chagapata in B-area where skarn is present nearby and wide-spread pyrite gossan is recognized. This area requires detailed geological survey in future.

4-3-4 Result of Principal Component Analysis and Factor Analysis

Coefficient of correlation of assay values of Cu, Pb, and Zn for rock, gossan, and stream sediments, their coefficient of principal component and coefficient of factor are as follows.

Correlation Matrix

	Cu-Pb	Pb-Zn	Zn-Cu
Rock	54.1	11.7	14.1
Gossan	-15.1	47.0	5.1
Stream sediments	3.9	10.2	22.5

		Component Matrix		Factor Matrix	
		I	II	I	II
Rock	Cu	85.8	-17.8	87.2	8.8
	Pb	85.1	-22.3	87.9	4.2
	Zn	36.9	92.9	7.3	99.7
Gossan	Cu	-18.4	96.4	-2.3	98.1
	Pb	83.0	-8.6	84.4	-22.8
	Zn	83.1	30.4	86.9	16.3
Stream sediments	Cu	71.6		74.4	
	Pb	40.3		10.4	
	Zn	76.7		66.4	

Results of analyses of principal component and factor show that among the three elements of Cu, Pb, and Zn, correlation is entirely different.

In the case of rock, correlation between Cu and Pb is very close. It hints that during deposition, process of attachment and precipitation between the two elements is very close. In the case of gossan, correlation between Pb and Zn is very close. It shows that during mineralization the process of transfer, concentration and deposition of metal elements, specially between the two elements is very close. In the case of stream sediments, correlation among Cu, Pb, and Zn is low which perhaps due to disturbance of oxidation and leaching or during transfer.

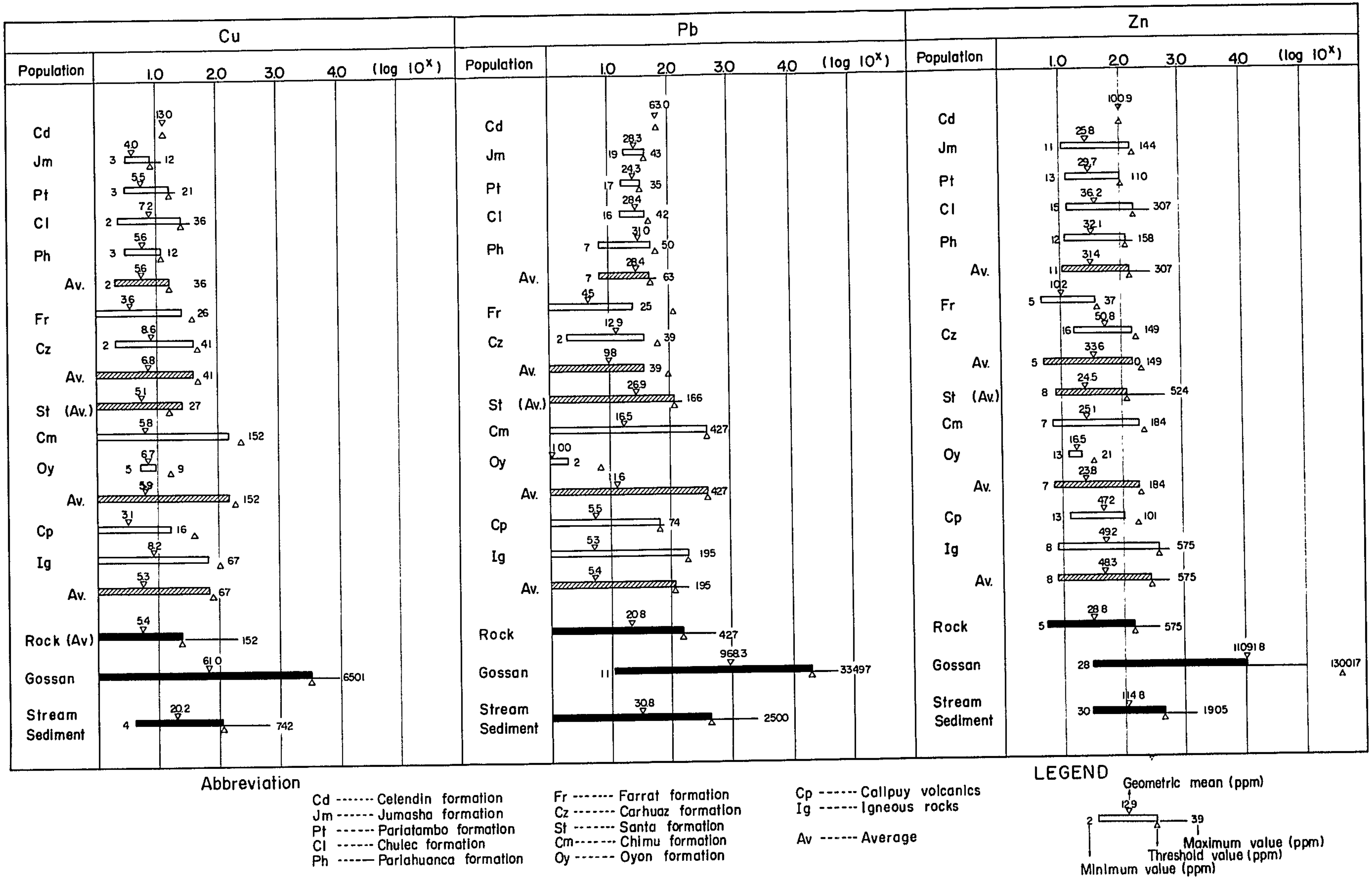


Fig. I-8. Value Dispersion of Geochemical Samples in the Surveyed Area

Fig. I-9 Histogram and Cumulative Frequency Curve for Cu, Pb and Zn contents of Geochemical Samples

(1) Rock Samples

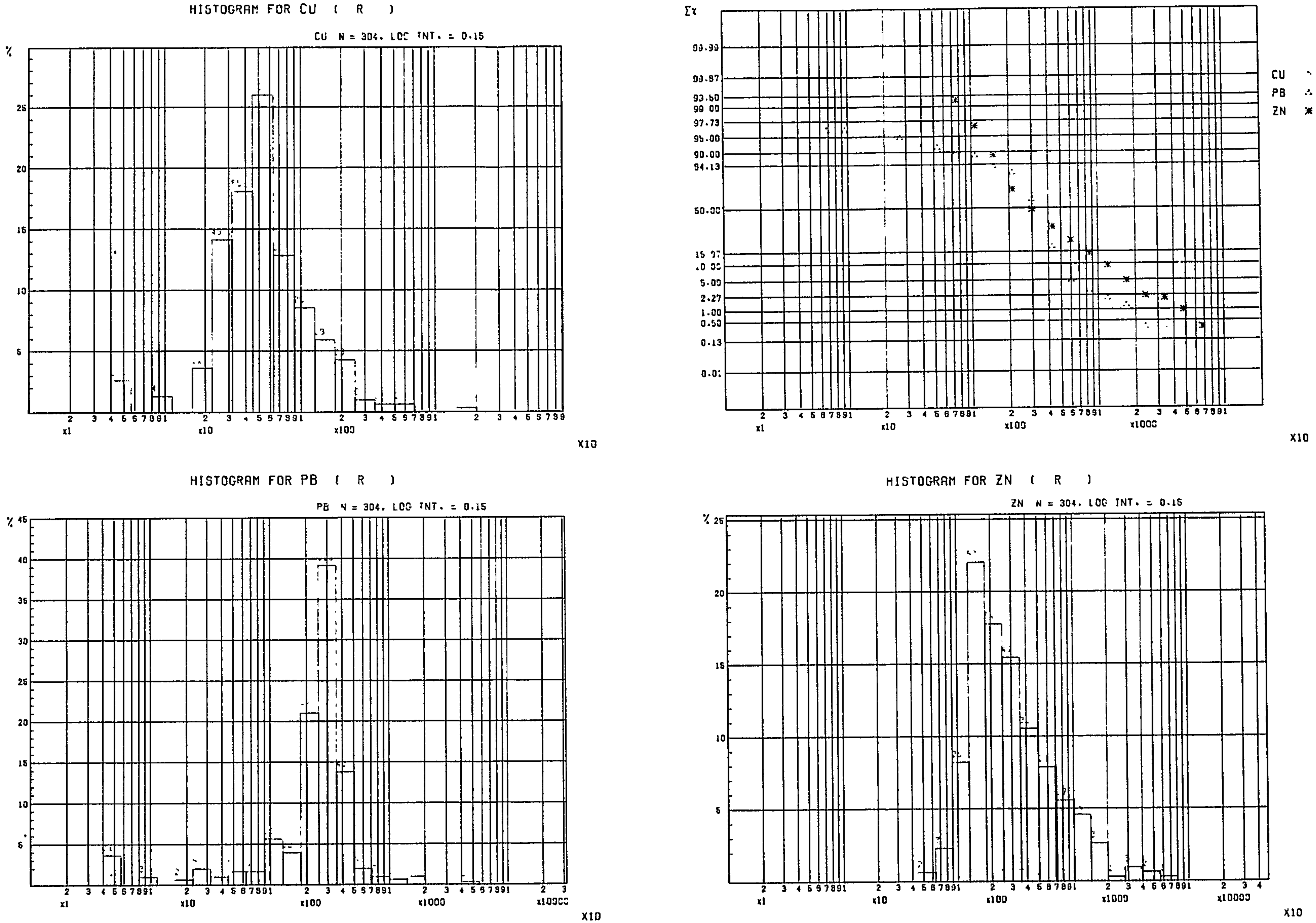
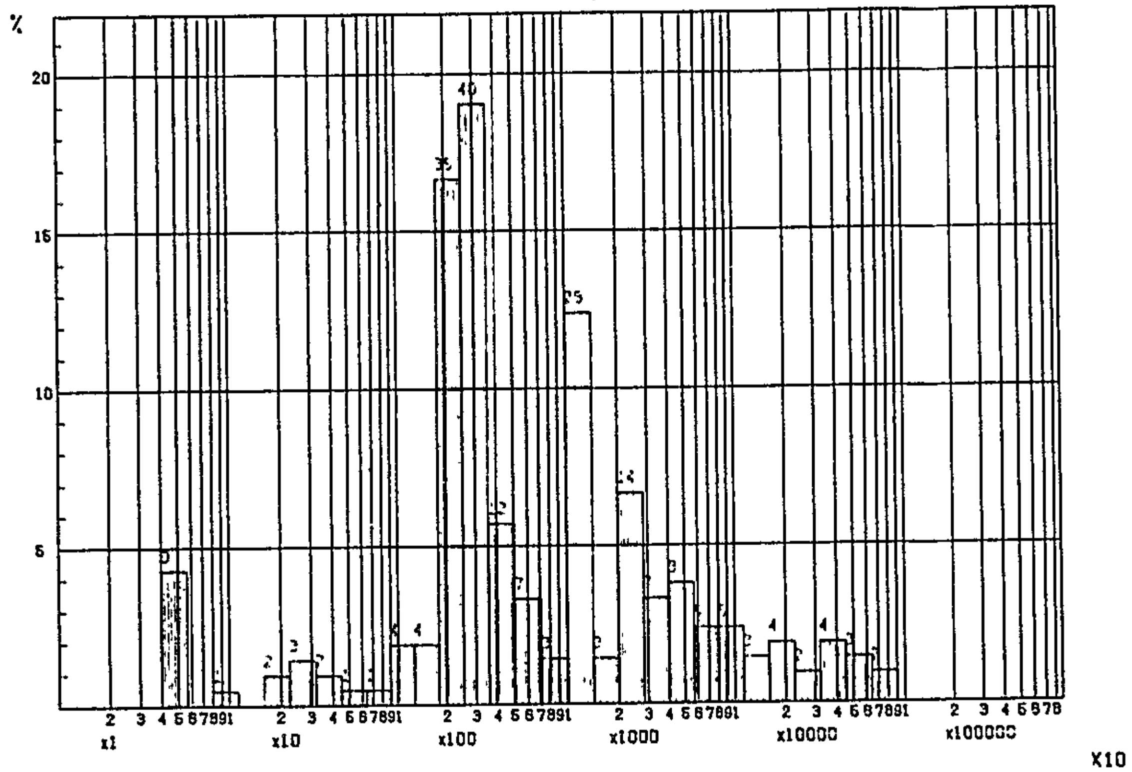
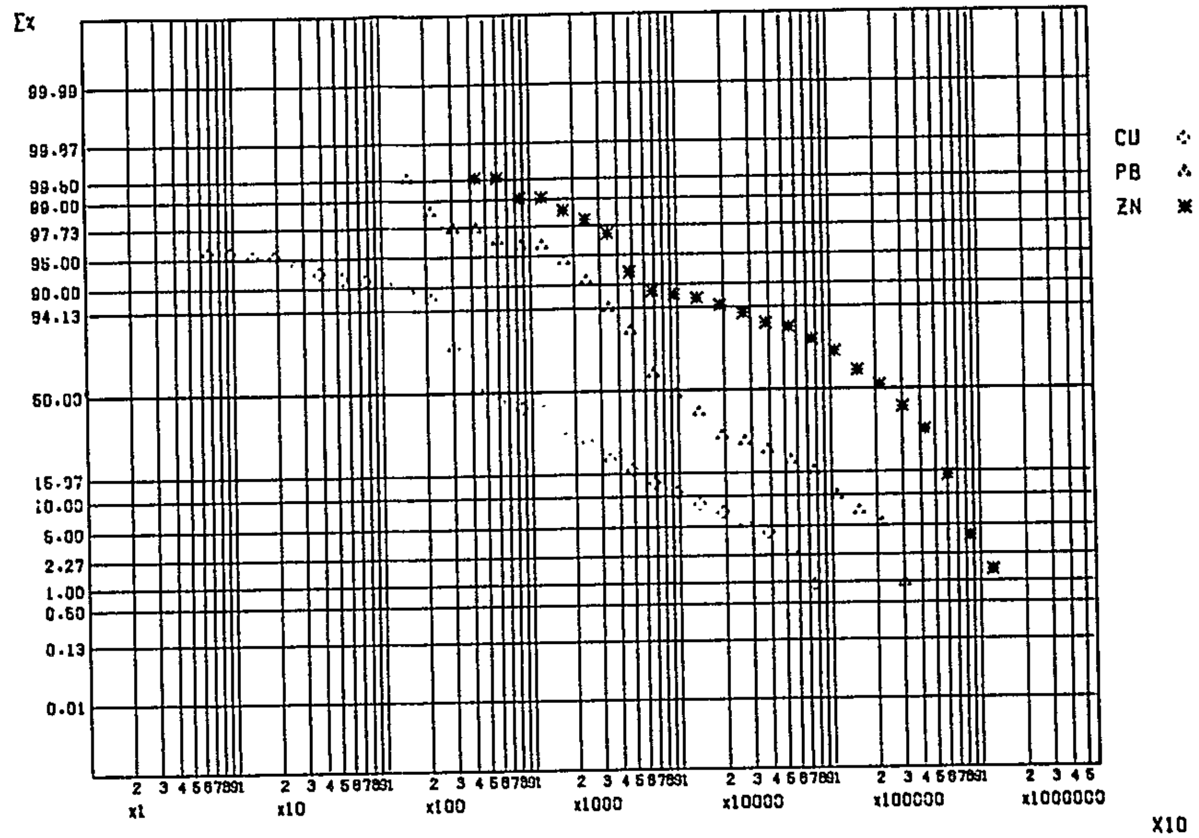


Fig. I-9 Histogram and Cumulative Frequency Curve for Cu, Pb and Zn contents of Geochemical Samples
(2) Gossan Samples

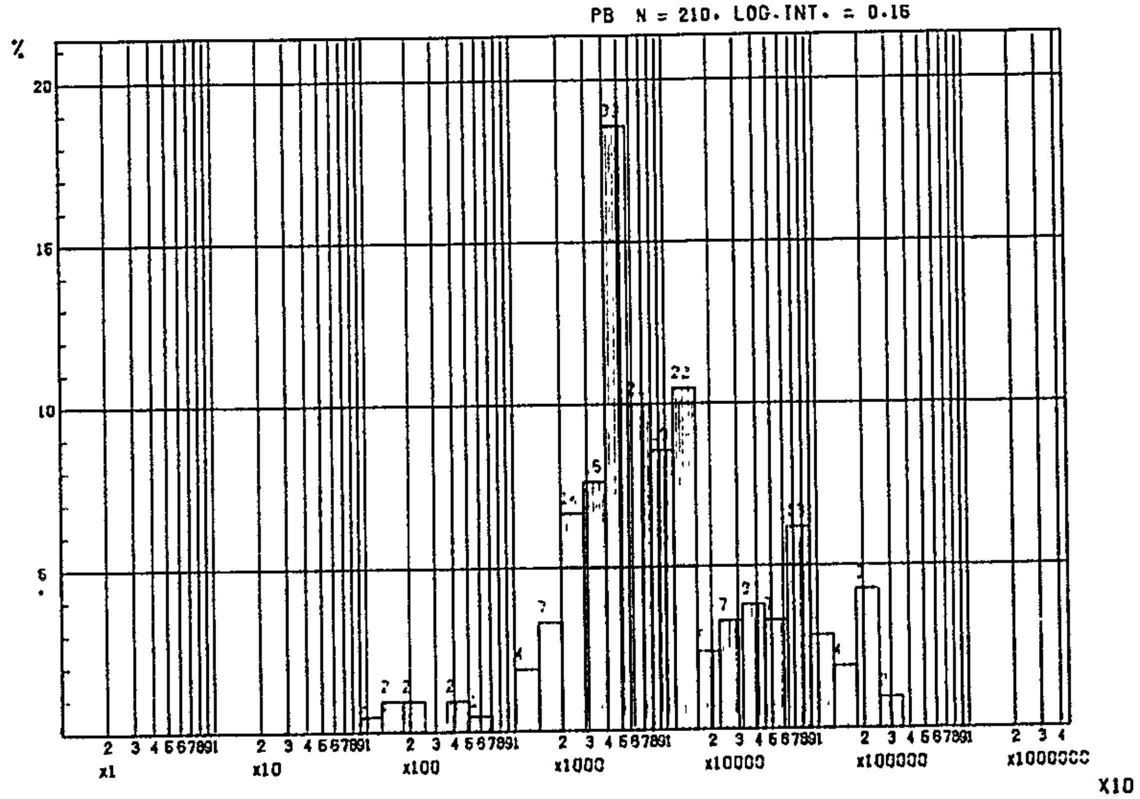
HISTOGRAM FOR CU (G)



CUMULATIVE FREQUENCY DISTRIBUTION FOR CU, PB AND ZN (G)



HISTOGRAM FOR PB (G)



HISTOGRAM FOR ZN (G)

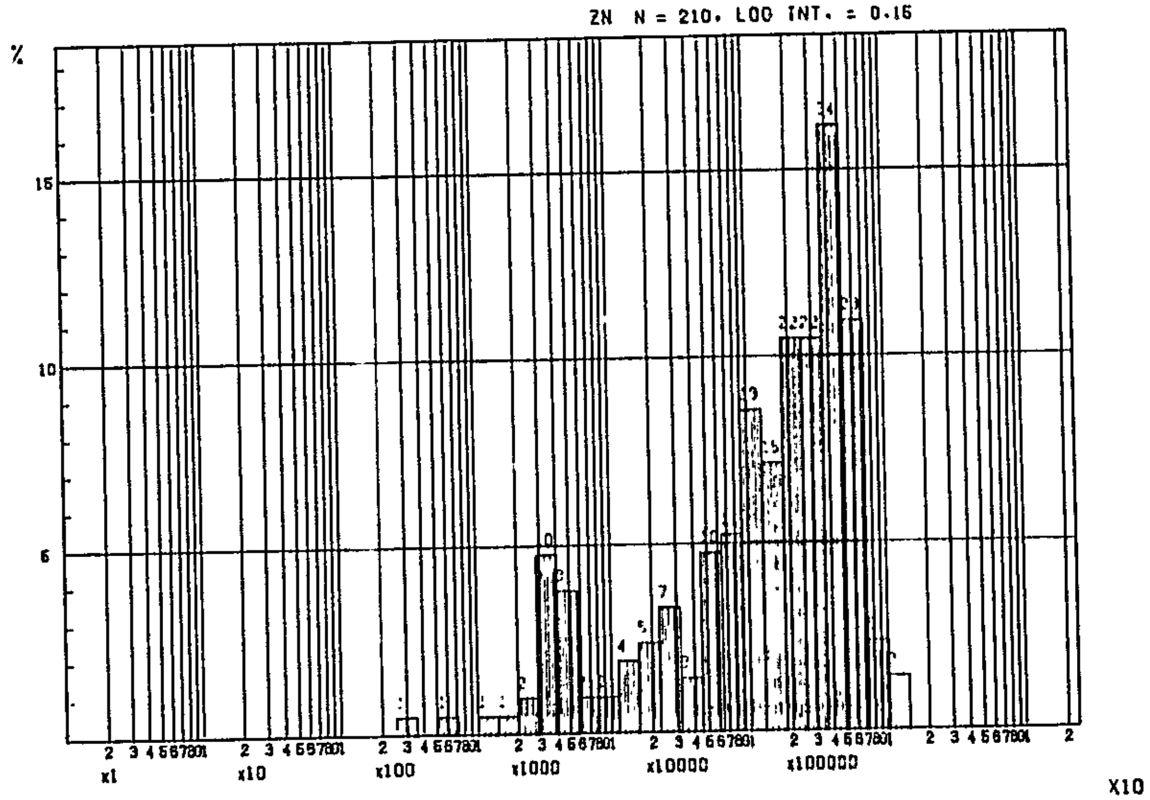
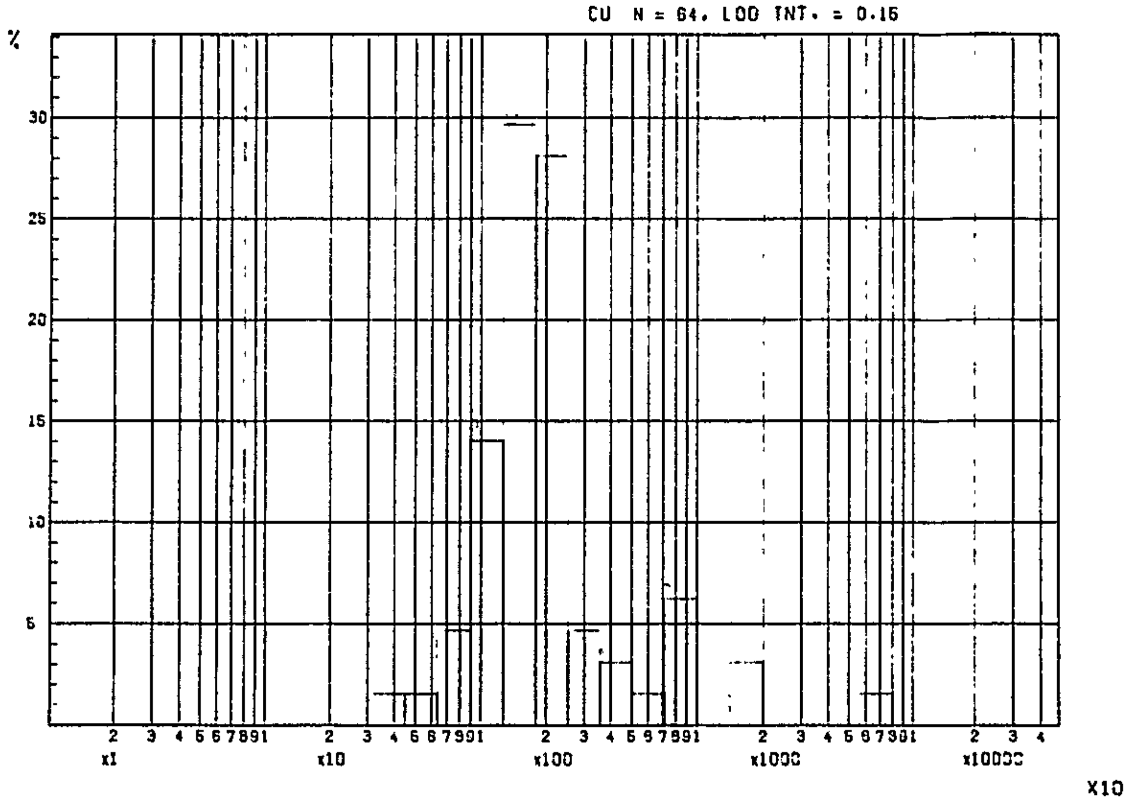
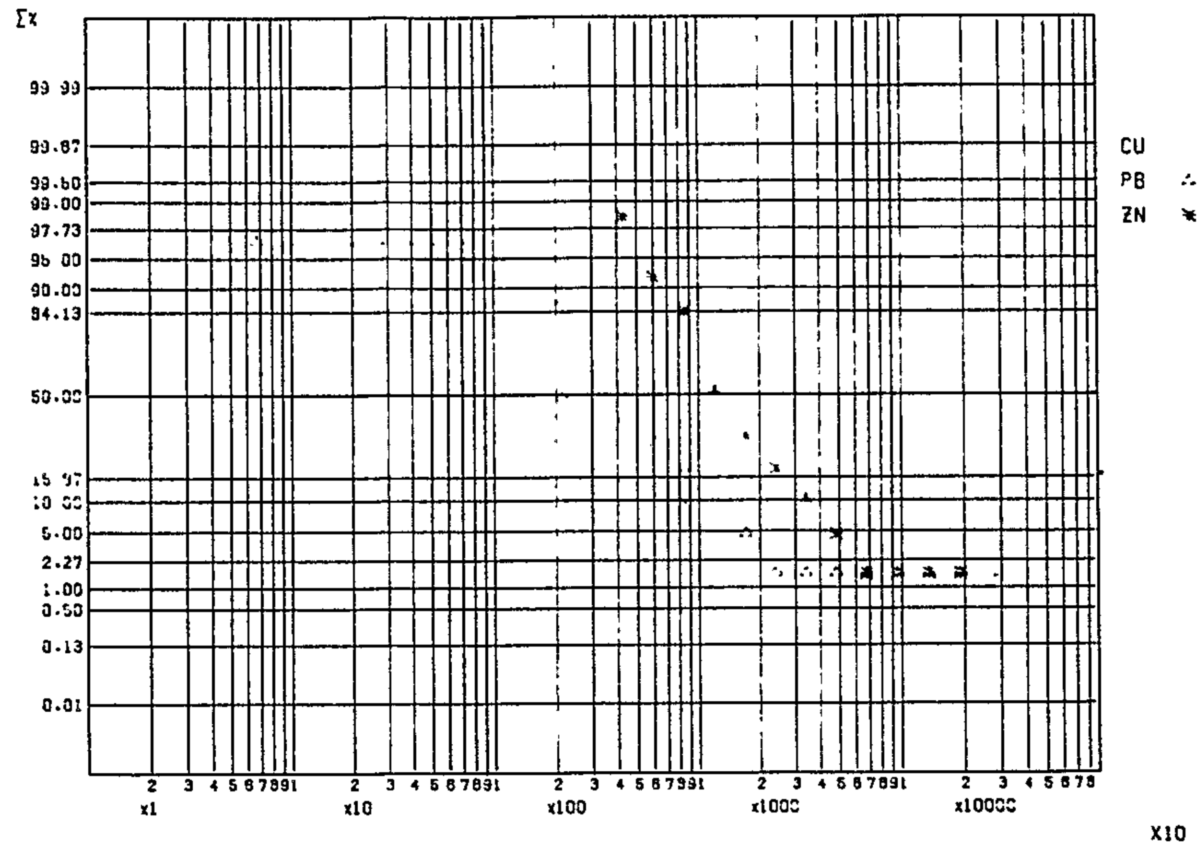


Fig. I-9 Histogram and Cumulative Frequency Curve for Cu, Pb and Zn contents of Geochemical Samples
(3) Samples of Stream Sediments

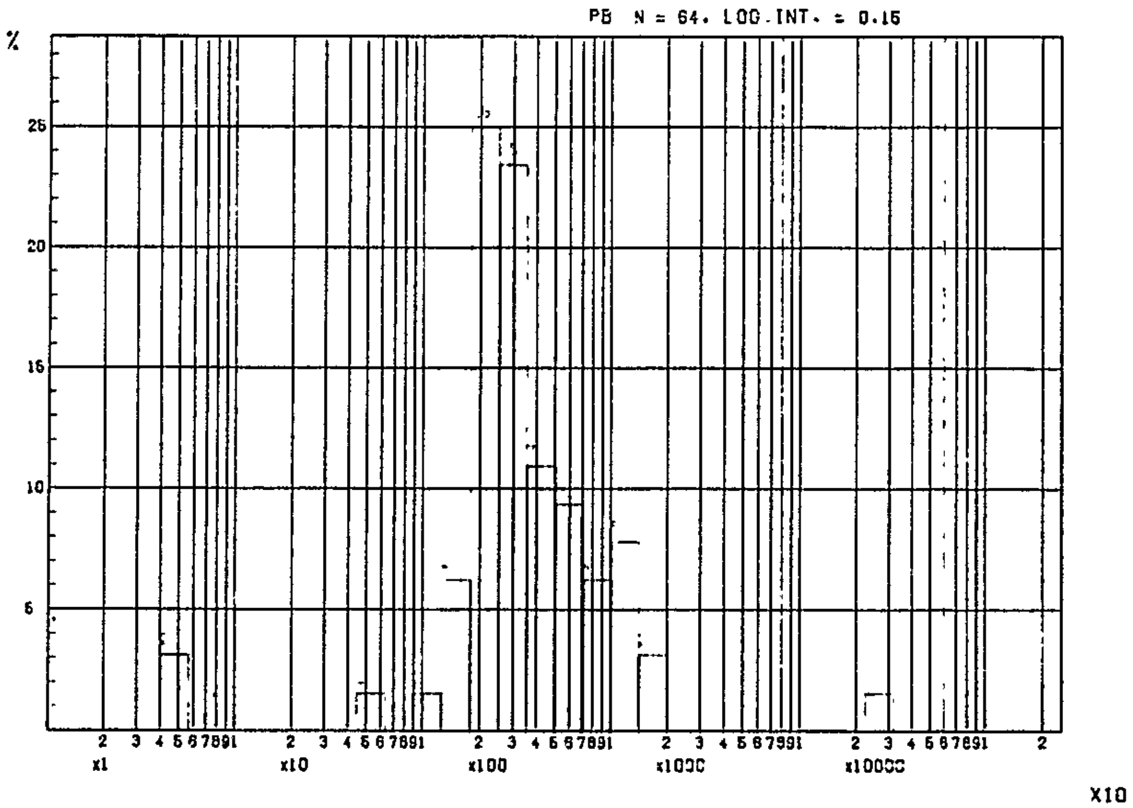
HISTOGRAM FOR CU (S)



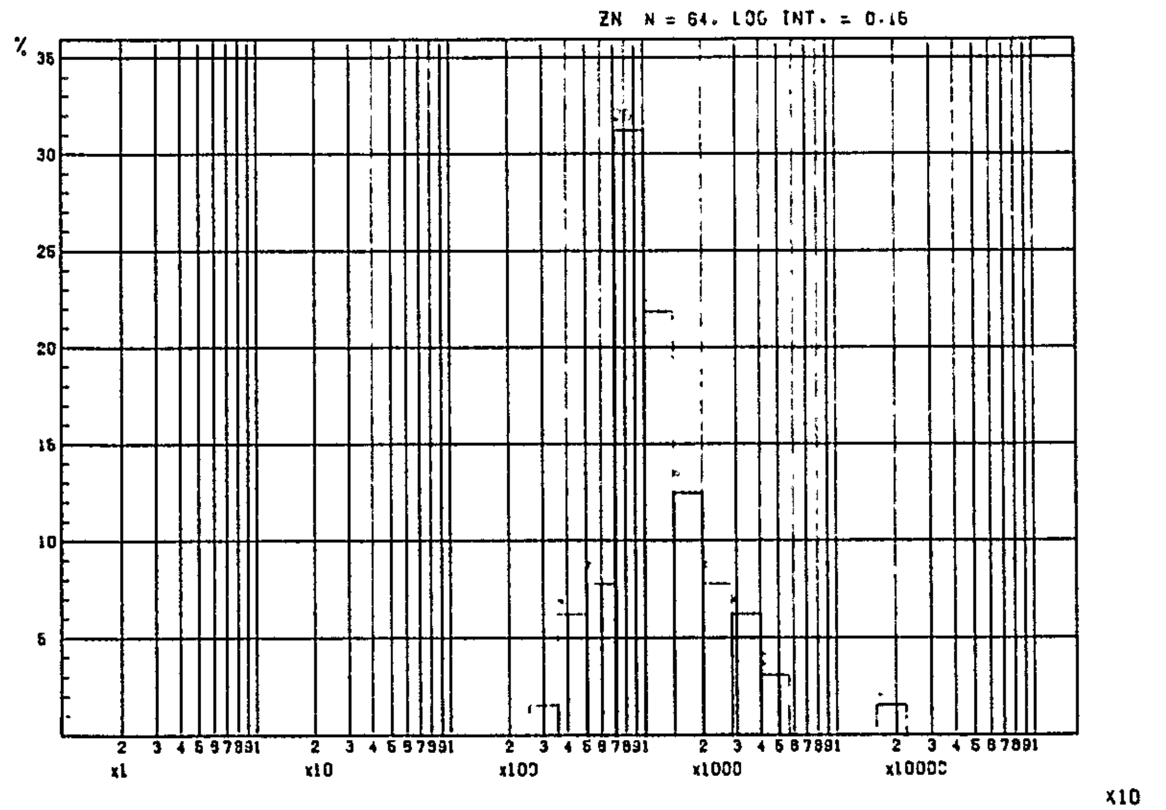
CUMULATIVE FREQUENCY DISTRIBUTION FOR CU, PB AND ZN (S)

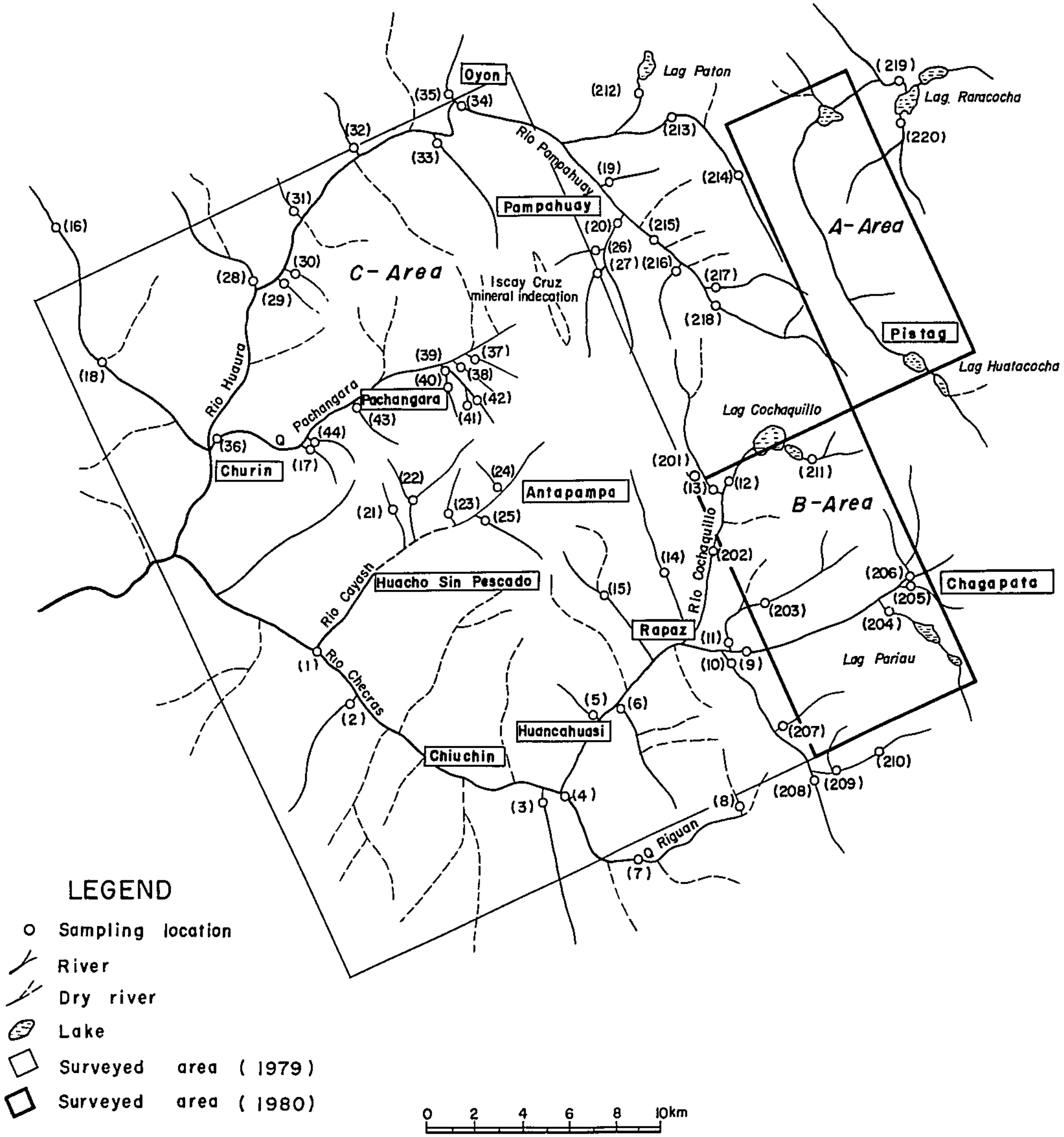


HISTOGRAM FOR PB (S)



HISTOGRAM FOR ZN (S)





(1979)

Sample NO	Cu ppm	Pb ppm	Zn ppm
SD- 1	20	52	85
SD- 2	15	38	106
SD- 3	21	20	156
SD- 4	17	29	92
SD- 5	16	29	191
SD- 6	21	20	69
SD- 7	10	23	67
SD- 8	22	20	42
SD- 9	39	40	223
SD-10	14	194	183
SD-11	14	17	56
SD-12	16	20	209
SD-13	18	22	124
SD-14	97	25	310
SD-15	16	19	46
SD-16	742	168	416
SD-17	21	60	83
SD-18	79	120	172
SD-19	32	27	287
SD-20	14	21	115
SD-21	18	26	74
SD-22	13	26	82
SD-23	16	23	77
SD-24	14	14	77
SD-25	28	26	83
SD-26	16	100	76
SD-27	6	0	77
SD-28	182	103	114
SD-29	12	37	78
SD-30	77	63	1,905
SD-31	73	83	147
SD-32	23	2,500	300
SD-33	20	77	395
SD-34	19	60	104
SD-35	36	134	240
SD-36	18	80	106
SD-37	11	49	88
SD-38	19	23	104
SD-39	15	26	104
SD-40	16	29	124
SD-41	16	29	127
SD-42	11	26	117
SD-43	12	34	79
SD-44	25	43	81

(1980)

Sample NO	Cu ppm	Pb ppm	Zn ppm
SD-201	27	24	181
SD-202	19	15	93
SD-203	8	6	81
SD-204	69	72	415
SD-205	165	33	162
SD-206	9	24	61
SD-207	13	12	55
SD-208	16	24	221
SD-209	17	39	89
SD-210	11	18	75
SD-211	24	26	44
SD-212	8	56	30
SD-213	19	58	204
SD-214	7	108	160
SD-215	19	23	100
SD-216	13	15	43
SD-217	11	26	100
SD-218	4	Tr	105
SD-219	19	29	87
SD-220	11	41	73

Fig.I-10. Location Map and Assay Results of Stream Sediments

Table I-6 Results of statistical analysis on the geochemical samples

	Population	Number of Samples	Cu (ppm)		Pb (ppm)		Zn (ppm)	
			Mean	Mean+2σ	Mean	Mean+2σ	Mean	Mean+2σ
1	Type of Samples							
	Rock	304	5.4	26	20.8	162	28.8	153
	Gossan	210	61.0	3,055	968.3	21,478	11,091.8	358,922
	Stream Sediment	64	20.2	110	30.8	455	114.8	445
2	Rock Samples Classified by Group							
	Upper calcareous rocks (Cd,Jm,Pt, Cl,Ph)	93	5.6	16	28.4	49	31.4	131
	Upper clastic rocks (Fr, Cz)	27	6.8	49	9.8	96	33.6	220
	Lower calcareous rocks (St)	141	5.1	15	26.9	125	24.5	123
	Lower clastic rocks (Cm, Oy)	16	5.9	186	11.6	423	23.8	192
	Igneous rocks (Cp, Ig)	27	5.3	76	5.4	114	48.3	283
3	Rock Samples Classified by Formation							
	Celendin formation (Cd)	1	13.0	13	63.0	63	100.9	101
	Jumasha formation (Jm)	18	4.0	8	28.3	43	25.8	150
	Pariatambo formation (Pt)	22	5.5	17	24.3	35	29.7	99
	Chulec formation (Cl)	21	7.2	26	28.4	47	36.2	155
	Pariahuanca formation (Ph)	31	5.6	12	31.0	58	32.1	121
	Farrat formation (Fr)	7	3.6	36	4.5	121	10.2	39
	Carhuaz formation (Cz)	20	8.6	45	12.9	63	50.8	169
	Santa formation (St)	141	5.1	15	26.9	125	24.5	123
	Chimu formation (Cm)	14	5.8	233	16.5	413	25.1	231
	Oyon formation (Oy)	2	6.7	15	1.0	7	16.5	33
	Calipuy volcanics (Cp)	12	3.1	38	5.5	63	47.2	171
	Intrusive rocks (Ig)	15	8.2	104	5.3	185	49.2	409

Mean ; Geometric mean

σ ; Standard deviation

Chapter 5 Synthesis of the Results in the Iscay Cruz Mineralized Zone

5-1 Geologic Structure and Mineralization

Mineralization in this area occur in calcareous rocks of Santa formation. This formation constitutes wing of folded sedimentary rocks. Because of tight folding, however, the dip here is nearly vertical and partly overturned. The thickness varies from 40 m to 80 m.

Throughout prominent mineralized zones in the Limpe area, Cunsha Punta area and Chupa ore deposit, the host formation is overturned, and the lower unit of Chimu formation, which is arenaceous sandstone of Farrat formation in the case of Chupa deposit, is distributed in the apparent hanging wall side. Chemically inert sandstone seems to have acted as shattered rock against chemically reactive limestone of the host horizon where the ore minerals are concentrated.

In the Iscay Cruz area, shear faults and fractures are densely developed in ENE-WSW direction which is diagonal to the folding axis. Mineralization of the Chupa ore deposit is strongly controlled by the diagonal fracture system. These fractures are considered to be important as channel way of the ore solution and also as the place of precipitation of the ore minerals. The fractures as well as NNW-SSE faults may effect extension of mineralized zone.

5-2 Igneous Activity and Mineralization

Dacite porphyry intrudes as stock at about 1 km west of the Cumbre de Iscay Cruz. This stock is only weakly altered and skarnization in the surrounding limestone is also faint. Thus the intrusion may not be related to the mineralization. Andesitic porphyry dike is recognized in this area, which is later than the mineralization.

In Oyon and Chimu formations to the east of Cumbre de Cunsha Punta, present are more than ten dikes of acidic compositions. These dikes themselves and the intruded wall rocks are both intensely altered hydrothermally, and the original minerals are converted to quartz, sericite and pyrophyllite. Pyrite and limonite are disseminated in the altered rocks. Distinct brecciation is seen at margin of these dikes, and breccia dike or vein is formed in some places. These dikes are distributed, though sporadically, in the entire Iscay Cruz area along the anticlinal axis, and in the Cumbre de Limpe area, they intrude into Santa formation. The strong alteration as well as spatial relationship of the dikes with mineralized zones suggest that the acidic dikes are most closely related igneous activity to the mineralization in the surveyed area. Because of the intense alteration, the original composition of the dikes is hardly identified. Yet they are assumed originally a quartz porphyry, for the remaining phenocrysts of quartz and feldspars.

5-3 Wall Rock Alteration

Host rocks of the known mineralized zones are limestone of Santa formation which intercalates tuffaceous siltstone and shale. The limestone in this area appears to be clayey, as compared with limestones in the other areas. It is not clear, however, whether this character is due to the original impure nature or due to later alteration such as silicification, dolomitization and sideritization.

To the north of Cumbre de Cunsha Punta, skarn occurs with disseminated chalcopyrite and sphalerite. In the massive sulfide orebody recognized to the north of Cumbre de Limpe, a large amount of pyrite and pyrrhotite replace limestone. Horse stone in the orebody and the surrounding wall rocks are distinctly silicified, sideritized and dolomitized. In the vicinity of

Cumbre de Iscay Cruz, silicified siderite is seen widely and is disseminated with galena and sphalerite. The surrounding rocks of shale and marlstone are pyrite disseminated. Brecciation of the host rocks is distinct in the high grade part. Prominent alterations related to the mineralization are sideritization and silicification. Chemically, iron, manganese and silica are added. This addition is considered due to hydrothermal alteration.

5-4 Zonal Distribution of Ore and Gangue Minerals

The mineralization tends to occur along Santa formation for about 12 km in length, and concentration of the ore minerals is sporadic within this horizon. However, an overall view indicated a regional zonation of the ore minerals. In the place like north of Cumbre de Cunsha Punta which is very close to the center of acidic igneous activities, present are skarn deposits containing chalcopyrite, sphalerite, magnetite, pyrite and pyrrhotite.

To the north and south flanks of this mineralized zone, i.e., around Cumbre de Limpe and to the south of Cumbre de Cunsha Punta, massive sulfide orebody is formed. Galena and sphalerite are disseminated in the massive pyrite and pyrrhotite orebody. In the outermost zone like the vicinity of Cumbre de Iscay Cruz and Antapampa area, only galena and sphalerite are disseminated in manganiferous siderite mass. This lateral variation on type of mineralization and on kind of ore minerals is considered to have resulted in a series of mineralized solution brought up from the acidic igneous center just mentioned above.

5-5 Consideration on the Genesis

The skarn deposit is tentatively considered as contact metasomatic deposit of a magmatic stage and limestone replacement deposit is product of a hydrothermal stage mineralization. The siderite-hosted deposit may have been formed at much lower temperature stage. Coexistence of the variety of mineralization is characteristic in this surveyed area, and is in accord with the Cordilleran type of ore deposits by Petersen (1965). In order to confirm this interpretation, however, mineralogical studies of particularly temperature measurements are necessary.

REFERENCES

Bellido, B.E. (1969)
Sinopsis de la geologia del Peru.
Serv. Geol. Min., Peru, Bel. 22.

Bellido, B.E., Luis de Montreuil, D. y Girard, P.D. (1956)
Aspectos generales de la metalogenia del Peru.
Serv. Geol. Min., Peru.

Benavides, v. (1956)
Cretaceous system in Northern Peru.
Amer. Mus. Hist. Bull., v.108, p.252-494.

Cobbing, J. (1973)
Geologia de los cuadrangulos de Barranca, Ambar, Oyon, Huacho, Huaral y Canta. Ser. Geol. Min., Peru, Bol.26.

Coney, P.J. (1971)
Structural evolution of the Cordillera Huayhuash, Andes of Peru.
Geol. Soc. Amer. Bull., v.82, p.1863-1884.

Cossio, A. (1964)
Geologia de los cuadrangulos de Santiago de Chuco y Santa Rosa.
Com. Carta Geol. Nac., Bol.8.

Cristi, J.M. (1956)
Chile, Handbook of South American Geology.
Geol. Soc. Amer. Memoir. 65, p.187-214.

Einaudi, M.T. (1977)
Environment of ore deposition at Cerro de Pasco, Peru.
Econ. Geol., v.72, p.893-924

Evans, R.B. and Greenwood, P.G. (1968)
Electromagnetic surveys for metalliferous mineral deposits in selected areas of Central Peru.
Institute of Geological Science, Report No. 9, p.11-17.

Fukahori, Y., Aikawa, K. and Kawasaki, M. (1980)
Geology and ore deposit of the Huanzala mine - Mineralogical Study. (in Japanese). Min. Geol. Japan, v.30, p.103-118.

Hamilton, W. (1969)
The volcanic central Andes, a mordern model for the Cretaceous batholiths and tectonics of western North America.
Oregon Dept. Geol. Min. Ind. Bull., v.65 p.175-184.

Harrison, J.V. y Wilson, J.J. (1960)
Geologia de la region comprendida entre Huacho y Vinchos.
Soc. Geol. Peru, Tomo 35.

Horita, A., Oikawa, J. and Tagami, Y. (1973)
Geological features of the Huanzala ore deposits, Peru.
(in Japanese). Min. Geol. Japan, v.23, p.265-274.

James, D.E. (1971)
Plate tectonic model for the evolution of the Central Andes.
Geol. Soc. Amer. Bull., v.82, p.3325-3346.

Japan International Cooperation Agency and Metal Mining Agency of Japan (1978-1979), Report on geological survey of the Cordillera Oriental, Central Peru. Vols. 6-8.

Japan International Cooperation Agency and Metal Mining Agency of Japan (1980)
Report on geological survey of the Oyon area. Vol. 1.

Jenks, W.F. (1948)
Geology of the Arequipa quadrangle.
Inst. Geol., Peru, Bol. 9.

Jenks, W.F. (1956)
Peru, Handbook of South American Geology.
Geol. Soc. Amer., Memoir, 65, p.215-247.

Jenks, W.F. (1979)
Geology of South America, Geology of the World. (in Japanese) Iwanami, Tokyo, p.143-172.

Kross, G. and Nunez, J. (1979)
Un concepto genetico para el yacimiento de zinc y plomo "el extrano" y su importancia para la mineria. Bol. Soc. Geol. Peru. Tomo 63, p.205-216.

Lewis, R.W. y Harvaez, S. (1921)
Los depositos minerales de la Provincia de Cajatambo. Congreso Nacional de la Industria Minera, Lima, Tomo 4, p.25-43.

Lipertier, C. (1969)
A simplified stratistical treatment of geochemical data by graphical representation. Econ. Geol., v.64, p.538-550.

Mclaughlin, D.H. (1924)
Geology and physiography of the Peruvian Cordillera, Departaments of Junin and Lima. Geol. Soc. Amer. Bul., v. 35, p.591-632.

Miyashiro, A. (1979)
Orogenesis based on the plate tectonics, the Trasitional Earth. (in Japanese). Iwanami, Tokyo, p.35-144.

Petersen, U. (1965)
Regional geology and major ore deposits of Central Peru. Econ. Geol., v.60, p.407-475.

Petersen, U. (1970)
Metalogenetic provinces of South America. Geol. Rundschau, v.59, p.834-897.

Samniego, A. and Amstutz, G.C. (1979)
Yacimientos estratoligados de Pb, Zn (Ag, Cu) en el Cretaceo inferior del Peru Central. Bol. Soc. Geol. Peru, Tomo 62, p.192-224.

Santolalla, M. (1921)
El carbon el Peru, Hulleras Oyon.
Congreso Nacional de la Industria Minera, Lima, Tomo 4, p.196-200.

Sato, H. and Saito, N. (1977)
Pyrite zones and zonal distribution of Cu-Pb-Zn ores in Huanzala mine, Peru. (in Japanese).
Min. Geol. Japan, v.27, p.133-144.

Stewart, J.W., Evernden, J.F. and Snelling, N.J. (1974)
Age determination from Andean Peru : a reconnaissance survey.
Geol. Soc. Amer. Bull., v.85, p.107-116.

Jurekian, K.K. and Wedepohl, K.H. (1961)
Distribution of the elements in some major units of the earth's crust. Geol. Soc. Amer. Bull., v.72, p.175-192.

Wilson, J.J. (1963)
Cretaceous stratigraphy of Central Andes of Peru.
Amer. Assoc. Petrol. Geol. Bull., v.47, p.1-34.

Wilson, J.J., Reyes, L. y Garayer, J. (1967)
Geologia de los cuadrangulos de Mollebamba, Tayabamba, Huaylas, Pomabamba, Cuarhuaz y Huari.
Serv. Geol. Min., Peru, Bol.16.

PARTICULARS
PART II
GEOPHYSICAL PROSPECTING

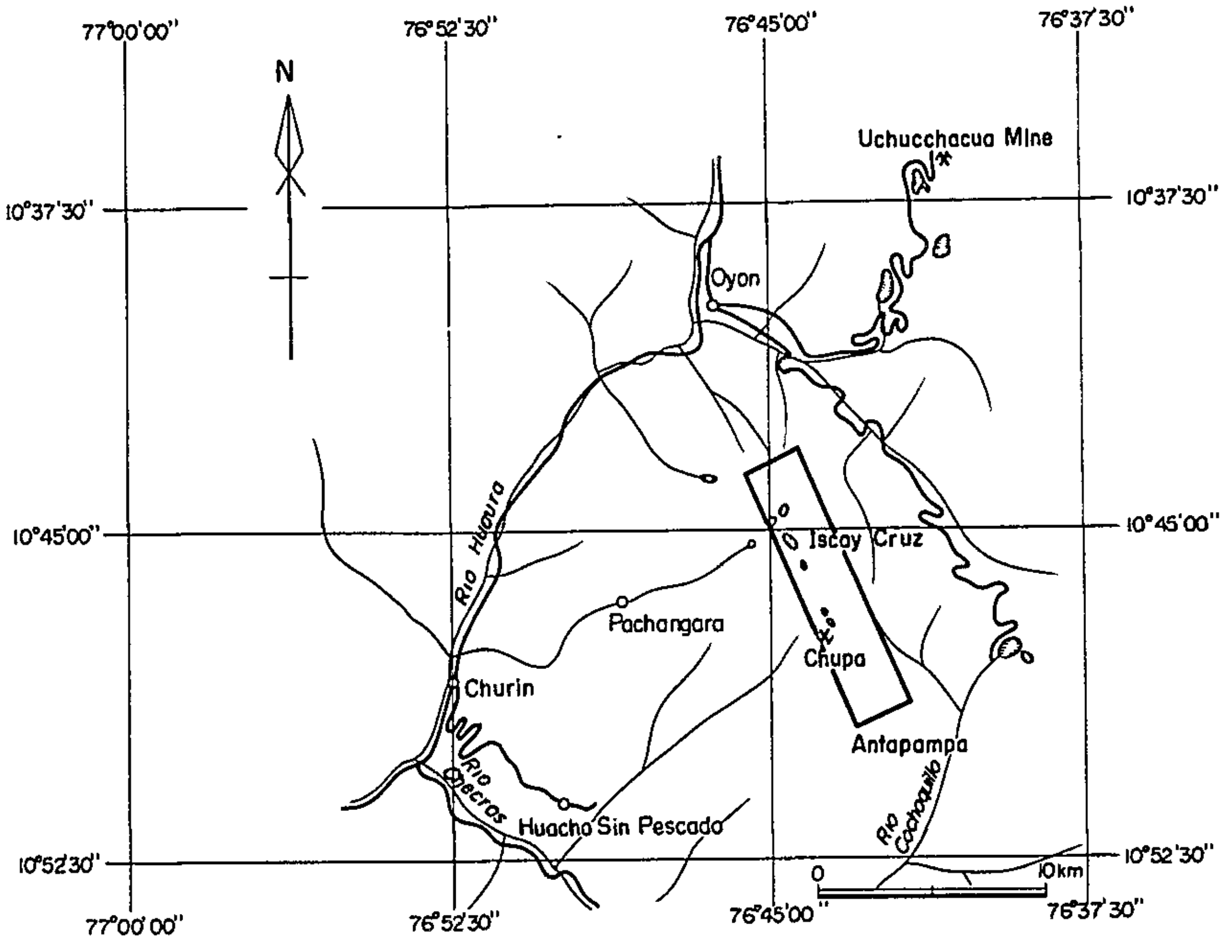
PART II

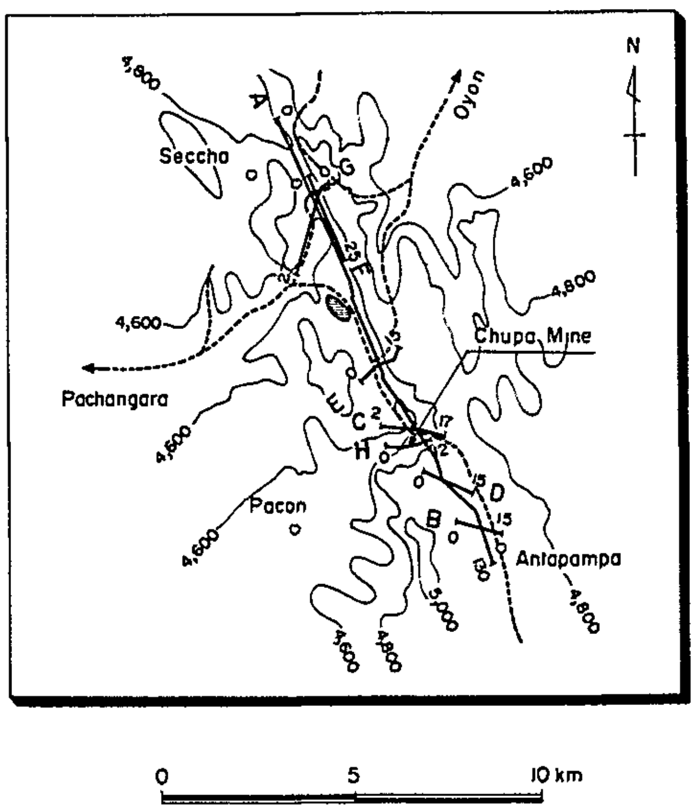
GEOPHYSICAL PROSPECTING

CONTENTS

LIST OF FIGURES

LIST OF TABLES





LEGEND

- Area of IP survey
- Mine/abandoned mine
- Town and village
- Road
- River
- Lake

Fig. II-1 Location map of the surveyed area

LIST OF PLATES

Chapter 1. Outline of the Geophysical Prospecting (See Fig. II-2)

The geophysical prospecting (IP Method and partially EM Method) was carried out in order to clarify the location of electrochemical polarization anomaly and resistivity anomaly, and to estimate the scale and concentration grade of the ore deposit zones of lead and zinc in Iscay Cruz mineralization zone which was found through the first year geological survey.

The Iscay Cruz ore deposit is a hydrothermal replacement deposit with the host rock of limestones in the Santa formation. It is composed of iron quartz gozzan, containing lead and zinc, disseminated lead and zinc sulfide, and the like. The ore deposit extends in a distance of 12 km within which mineralized zones from first to seventh are recognized. In addition, Chupa ore deposit zone lies in Pariahuanca formation about 400 m west of the fifth mineralized zone.

The surveyed area is temporarily divided from the north (side) into Northern Part, Central Part, and Southern Part. Northern Part contains from first to third mineralized zone. The first mineralized zone, particularly on its ground surface, has the gozzans containing galena and sphalerite. In Central Part, only the fourth mineralized zone is included, containing sulfides.

In the Southern Part, the Chupa ore deposit containing skarn minerals of galena and sphalerite, and mineralized zones from the fifth to seventh occur.

The fifth and sixth mineralized zone contain sulfides, while the seventh mineralized zone has black gozzans.

Induced Polarization Method (IP Method) was employed all over the afore-mentioned areas using dipole-dipole electrode configuration. For some of survey lines in the Central and Southern Parts, where in the IP

indications are particularly remarkable, Electromagnetic Method (EM Method) was employed using Induction method and VLF method.

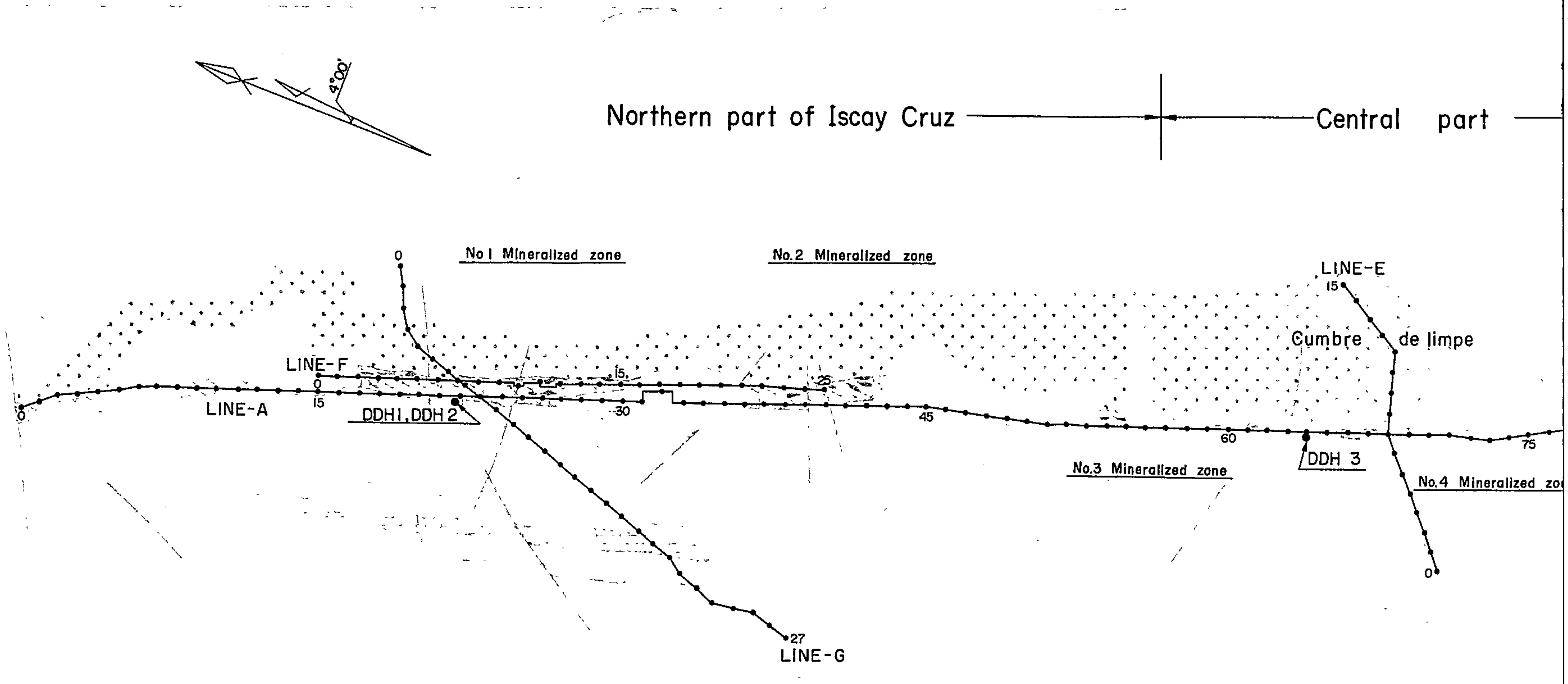


Fig. II-2. Explanatory map of the surv

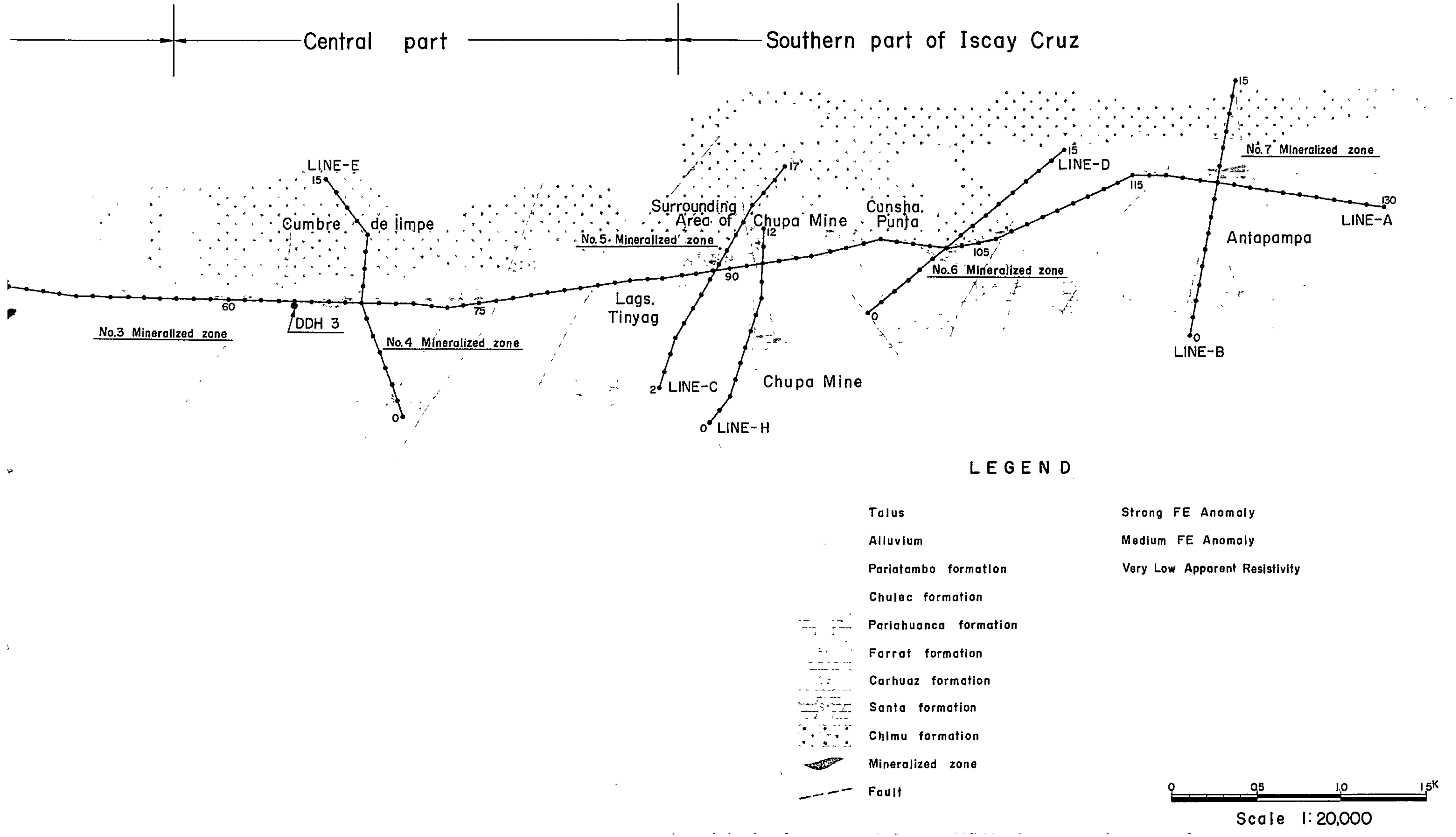


Fig. II-2. Explanatory map of the surveyed area

Chapter 2. Method of Prospecting

2-1 IP Method

2-1-1 Principles of IP Method

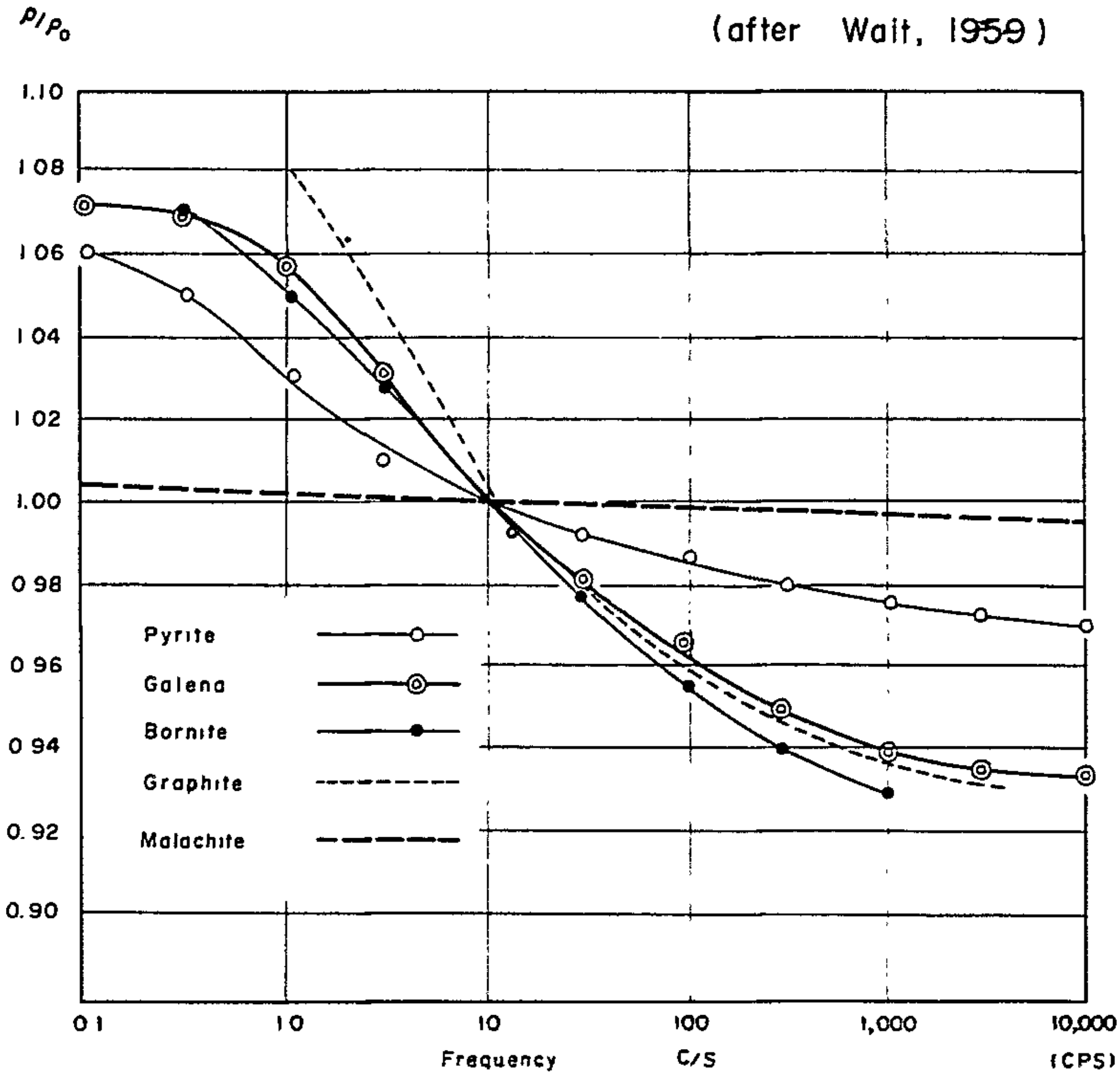
When two electrodes are grounded separately while the direct current is turned on through the ground, potential difference is usually caused between these electrodes. When the current supply is suspended, the potential difference may take several seconds to several minutes to decline completely without turning to zero immediately. When the current is turned on suddenly, on the contrary, the potential difference between the two electrodes does not attain constance immediately, but reaches the constance only after several seconds or several minutes. This type of geoelectric phenomenon is referred to Induced Polarization or IP. The method of geophysical prospecting making use of the phenomenon is called IP Method.

Although the mechanism that produces IP has not yet been clarified completely, the mechanism is mainly attributed to the overvoltage (or electrode polarization) and membrane polarization.

Summer (1976) and Seigel (1967) give more details on the principle, measuring method, analysis theory, etc. of IP method.

The methods of IP measurement are categorized into two methods of frequency domain and of time domain. The method explained here is only the frequency domain method that was employed with the recent survey.

The resistivity of mineral sulfides and graphite are the functions of frequencies. The frequency domain method is to find out the existence of IP phenomenon of the earth through measuring the changes in the resistivity following frequency variation. Non-dimensional FE (frequency effect



Matrix andesite 2 0 – 0 84 mm dia

Electrolyte 5 % 0 01N NaCl solution

Mineral 3 % by solid volume 2 0 – 0 84 mm dia

Fig. II-3. Resistivity-frequency characteristics for metallic and nonmetallic minerals

or PFE: percent frequency effect) is used as the coefficient to indicate the IP measured value obtained through frequency domain method. In this Report, FE is defined as follows:

$$FE = \frac{R_1 - R_2}{R_2} \times 100\ (\%) \quad \cdots\cdots (1)$$

Where:

R_1 = Apparent resistivity value measured with the lower frequency.

R_2 = Apparent resistivity value measured with the higher frequency.

Although the ways of indication of FE is slightly different by investigators, the difference consists mainly of using R_1 or $\sqrt{R_1 R_2}$ as the denominator in the foregoing expression (1), instead of R_2. However, no substantial difference from expression (1) results from the substitution.

An apparent resistivity value measured with a pair of current electrodes and a pair of potential electrodes set up on ground surface is given by the following expression.

$$R = K\frac{\Delta V}{I}\ (\text{ohm}\cdot\text{m}) \quad \cdots\cdots (2)$$

Where:

R = Apparent resistivity value (ohm·m).

K = Geomatric constant to be decided with electrode arrangements.

I = Current supplied to the earth from current electrodes (ampere).

V = Potential difference between the potential electrodes (Volt)

There is the so called MF (metal Factor) or MCF (Metal Conduction Factor) that is used often for IP analysis. MF is obtained from FE when FE is divided by apparent resistivity, multiplied by the constant and deleted properly of a part of its fraction. In this Report, MF is defined as follows:

$$MF = \frac{FE}{R_2} \times 10^3 \quad \cdots\cdots\cdots\cdots \quad (3)$$

In general, the rocks containing high percentage of metals and sulfides, the object minerals for prospecting, are low in resistivity but high in FE. Therefore, the MF obtained near a mineral deposits is larger than that of the surrounding area. For this reason, MF is used for metallic mineral deposit prospecting.

2-1-2 Measuring Procedures

Representative examples of configuration of current electrodes and potential electrodes for IP measuring are shown in Fig. II-4. In the present survey, IP method of frequency domain was employed by means of dipole-dipole electrode configuration.

The power for supply to current electrode is generated into 400 cps of alternating converter with an engine generator. The alternating current is once rectified through the converter within the transmitter and oscillated into alternating current with a very low frequency to supply to the electrodes.

Non-polarization electrode pots are used as the potentional electrodes. Out of received signal and noise, only a signal with the same frequency as of transmitter current is taken out through the filter within the receiver and is read out with the potentiometer. The power source for this receiver is usually dry batteries.

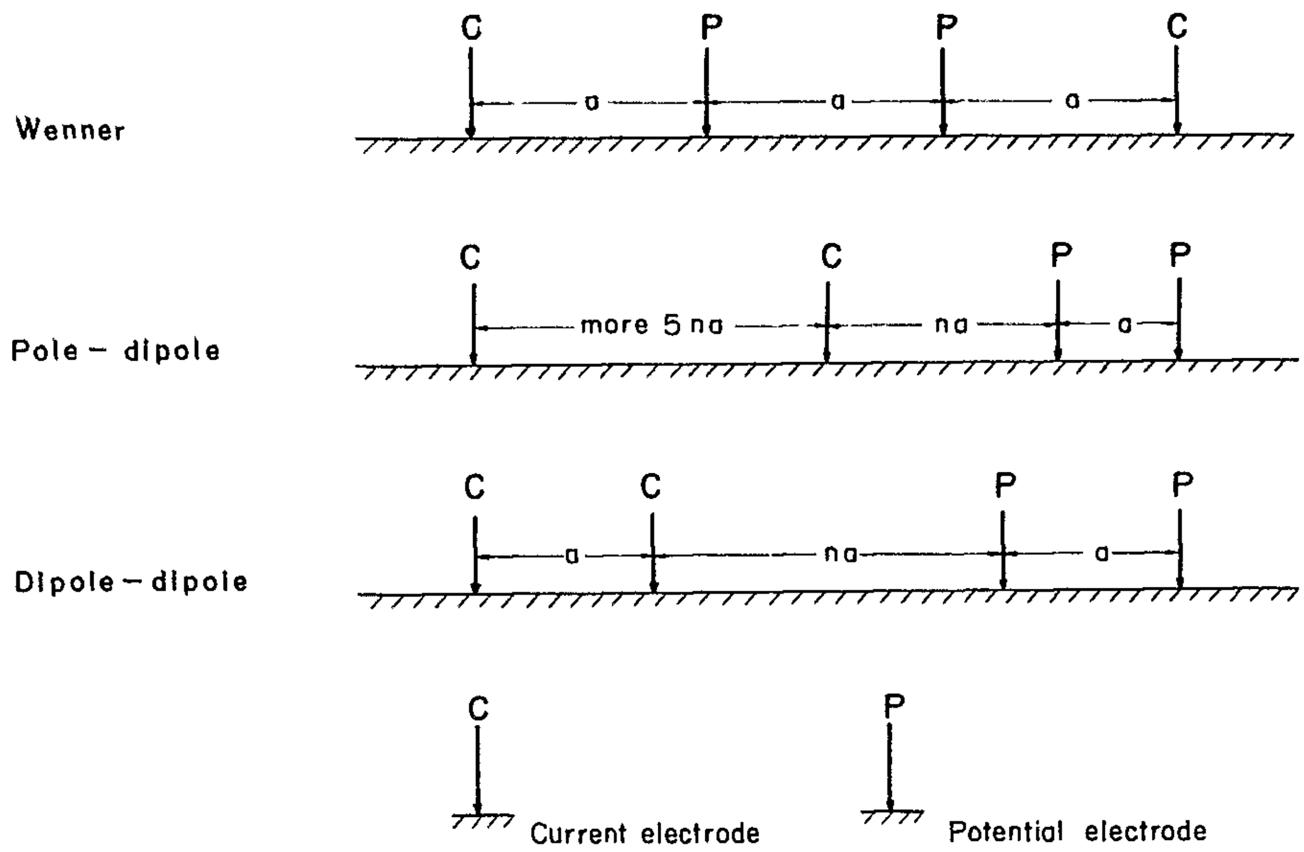


Fig. II-4. Electrode configuration

2-1-3 Measuring Equipment

The measuring equipments and their main specifications used in the present survey are listed hereafter.

(1) IP Transmitter

Model CH-508-A, -B manufactured by Chiba Electronic Laboratory

Weight	:	Approx. 25 kg.
Output Voltage	:	20V - 800V
Output Current	:	0.1A - 3.0A
Frequency Range	:	3Hz, 1.0Hz, 0.3Hz, 0.1Hz DC

(2) IP Receiver

Model P-660 manufactured by Mcphar

Weight	:	2 kg.
Maximum Sensitivity	:	100μV
Frequency Range	:	5.0Hz, 2.5Hz, 1.25Hz, 0.3125Hz, 0.125Hz
Input Impedance	:	2 MΩ

(3) Engine Generator

Model M-421 manufactured by Geotronics

Weight	:	37 kg.
Output Voltage	:	110V
Frequency	:	400Hz
Output Power	:	2 kw

2-1-4 Field Procedures

(1) Land Survey

Laying out of survey lines was carried out with a pocket compass and a measuring tape, both are the products of Ushikata.

The intervals between stations were measured with measuring tape, while azimuth and dipping angle were measured with the pocket compass. On each position of measuring stations stones were piled up and the station number was marked with paint on the stone.

As the base point of the land surveying, a point at Cumbre de Iscay Cruz 4680 m above sea level was selected.

The direction of a main survey line was set approximately north to south along the Santa formation, excepting the cases when it was deflected slightly at the places where the survey and measurement were impossible due to the unfavourable topography. Six survey lines were set almost in east to west to meet at right angles with the main survey line, and measuring stations were set up at every 100 meters in horizontal distance on each survey lines.

Through consultations with the geologist, the most effective arrangements of survey lines were selected under the consideration of geology and topography of the field. The figures specified in the specifications were compiled with in deciding the survey line length, electrode spacing, and electrode separation index.

Survey line	Length	Electrode spacing	Electrode separation index	Remarks
A	13.0 (km)	a = 100 m	n = 1∿5	Along the Santa formation
B	1.5	"	"	
C	1.5	"	"	
D	1.5	"	"	
E	1.5	"	"	The fourth mineralized zone from the 1979 geological survey
F	2.5	"	"	The first mineralized zone
G	2.7	"	"	
H	1.2	"	"	Chupa Mine
Total	25.4 (km)			

(2) IP Measuring Work

① Grounding of Current Electrodes and Wiring Work

Copper plates of about 30 cm x 40 cm in dimensions as the current electrodes were buried at 50 cm to 1 m depth. In order to keep the copper plates in good contact with earth, the soil mixed with salt water was used to sandwich the copper plates. A plural number of the copper plates were buried where sufficiently low earthing resistance was not attained with single copper plate. In order to minimize measurement error from wiring, due to coupling between cords and leakage current, neither intersection nor approach to each other between potential cord and power cord was made, and in addition, the maximum insulation resistance was provided with electric cord.

② Potential Electrodes

Spiral copper electrode soaked in a pourous pot filled with saturated aqueous solution of copper sulfate was used as a potential electrode. The pourous pot is so designed that copper sulfate solution ooze out gradually from the bottom of the pot and the copper electrode and earth are connected electrically through the copper sulfate solution. This electrode is regarded practically as to be a nonpolarizable electrode. In order to maintain a good grounding of the potential electrode, saturated aqueous solution of copper sulfate was poured in a 10 cm deep hole dug at potential electrode point, then the potential electrode was buried in the hole. The resistance of the whole system of the measurement potential electrodes was maintained between 1 and 2 kilo·ohms through this way of grounding. This resistance value is sufficiently small when compared with 10 megaohm input impedance of the receiver.

2-2 EM Method

2-2-1 Principles of EM Method

Electromagnetic method is one of the methods to prospect good electric conductors in the underground (hereinafter referred to as conductors). Electromagnetic field (the primary magnetic field) produced artificially cutting across the good conductor, produces the secondary magnetic field from the good conductor. Now, therefore, this method is applied to measure the secondary magnetic field.

With respect to the means of producing artificial primary magnetic field, frequencies of electromagnetic waves to be used and ways how to measure the secondary magnetic field, various practical ways have been developed coping with the purposes and object materials for the prospecting. The undermentioned Table II - 1 shows the electomagnetic prospecting methods classified by frequency.

Table II - 1 Classification of electromagnetic methods

Frequency	Cotegory	Signal source
1500KHz ∿ 500KHz	Radiowave method	Artificial (broadcasting and exclusive uses)
25KHz ∿ 10KHz	VLF method	" (Military use)
5KHz ∿ 200Hz	Induction method	" (Exclusive use)
660Hz ∿ 220Hz	TURAM method	" (")

The methods used in the present survey are VLF method and induction method.

(1) VLF Method

VLF method utilizes the powerful VLF radiowaves transmitted by the