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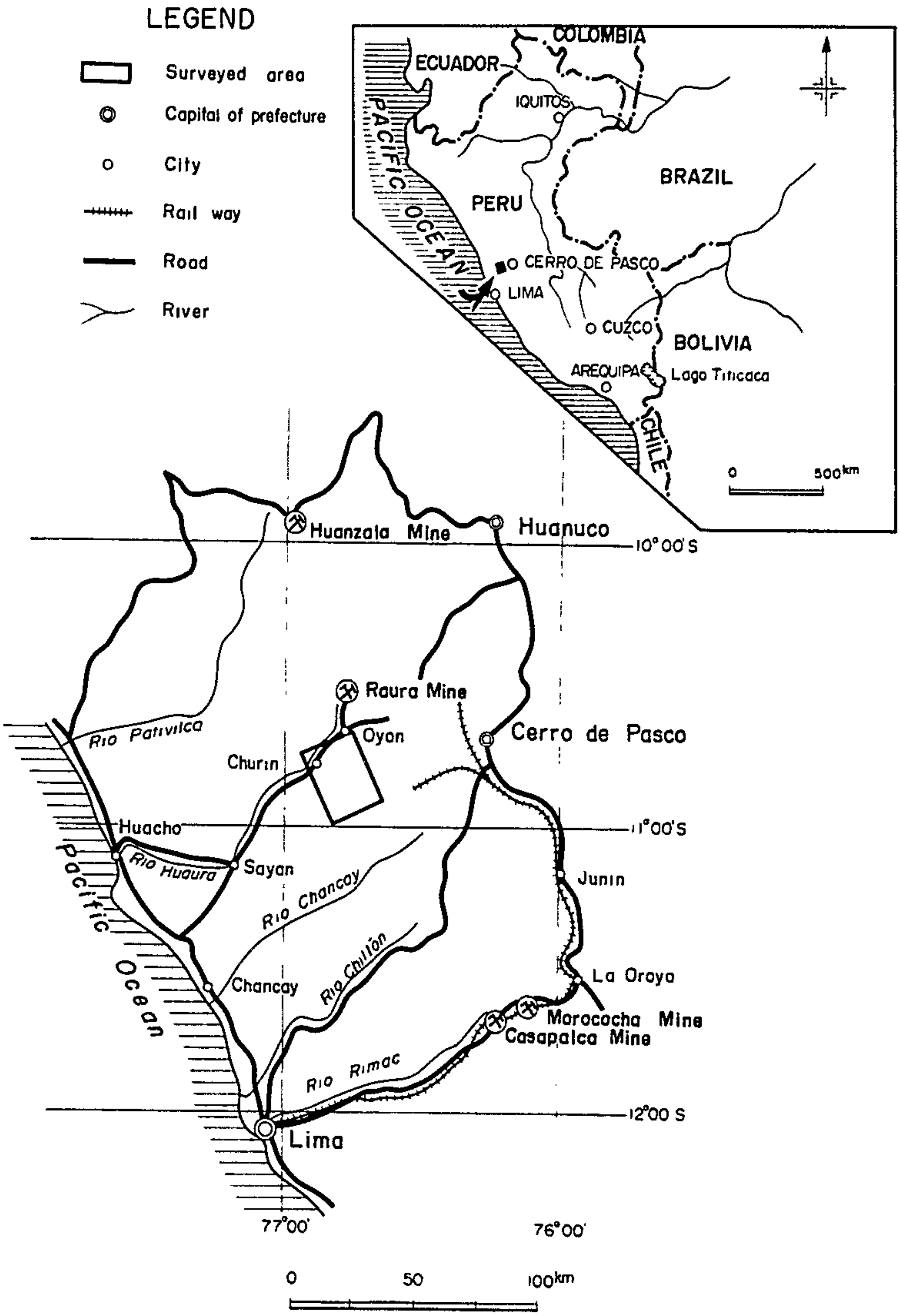

Fig. I. Index Map

Integrated Contents

SUMMARY

This report summarizes the results of survey which was carried out in the Oyon area of the Republic of Peru for the purpose of obtaining the basic data for the mineral resources development in 1979. This survey was planned to clarify the geological structure and obtain the detailed infromation on minerals indication so that effective guidance can be given to the succeeding prospecting activities. The first year field survey consisting of the geological survey and geochemical survey was performed in September through November, 1979 in the area of about 700 km^2 extent, the western part of the Oyon area. The data analysis started in succession of the field survey and will be completed by February 1980. The results of the survey are summarized as follows.

The surveyed area mainly consists of the Cretaceous sediments and Tertiary volcanics which contain intrusive rocks formed after the Tertiary age. These sediments are of heavily folded complex structure with the NNW-SSE axis accompanied with remarkable thrusts in parallel with the folding axis.

The Iscay Cruz, Chupa and Viscachaca ore deposits exist in the surveyed area. The Iscay Cruz ore deposit is of hydrothermal replacement ore deposit occurring in the Santa limestone as host rocks accompanied with iron-quartz gossan containing lead and zinc, and disseminated lead and zinc supfides, etc. The minerals indication was found in 6 area covering 11 km distance. As for the scale and ore grade, gossan in the No. 1 minerals indication (northern part of the Iscay Cruz ore deposit), and lead and zinc sulfides in the No. 4 minerals indication (southern part of the Iscay Cruz ore deposit) are remarkable. In the mineralized zone, the zonal distribution of copper, lead, and zinc can be seen, but the igneous rocks and structural control which had participated in

the mineralization have not been clarified. The Chupa ore deposit located adjacent to the Iscay Cruz ore deposit consists of skarn minerals containing copper and zinc. Igneous rocks which participated in the mineralization have not been found, but it can be assumed that the Chupa ore deposit was formed in conjunction with the mineralization of the Iscay Cruz ore deposit. The Viscachaca ore deposit is small scale and fracture-filling ore deposit containing silver, lead and zinc.

The geochemical survey was carried out sampling for rocks and stream sediments, of which copper, lead and zinc were analyzed as indication elements. Except the Iscay Cruz area, no remarkable anomaly has been found. The background value and the genesis of dolomite were examined for the Santa formation. By this examination, it is considered that there is almost no possibility for the occurrence of strata-bound type lead and zinc ore deposits.

From the survey and analyses, the Iscay Cruz ore deposit, occurring in the Santa formation as a host rock has been selected as the most important area to which the detailed prospecting is necessary in the future. in the 1st year survey, the structure of mineralized zone, distribution of minerals, tendency of zonal distribution, etc. were clarified. It is necessary in the future to survey the Iscay Cruz ore deposit for the scale of sulfide ore body expected in underground and the degree of concentration of ore minerals. To achieve this purpose, the following activities are necessary.

(1) Geological survey: The survey of gossan and alteration zone in the Iscay Cruz mineralized zone, including the Chupa ore deposit, in order to clarify the relationship of the mineralized zone, fracture system and igneous rocks.

(2) Geophysical prospection: The electric prospection by means of the IP method in the Iscay Cruz mineralized zone to clarify the existence of pyrite bodies and review the scale and concentration of the lead and zinc in the mineralized zone.

(3) Drilling: The drilling in order to further clarify the various informations and geological structure obtained by the geological and geophysical surveys at the No. 1 and No. 4 minerals indications in the Iscay Cruz mineralized zone.

GENERAL

General Contents

LIST OF ILLUSTRATIONS

LIST OF TABLES

LIST OF APPENDICES

LIST OF PLATES

Chapter 1 Introduction

1-1 Purpose of the Survey

In the Oyon area, the geological and geochemical surveys have been carried out on the purpose to clarify the geological structure and to find the geological environment, in which the ore deposits are expected, and the indications of mineralization as a clue to the further surveys.

The present survey has been performed in cooperation with Instituto de Geologia, Mineria y Metalurgia (INGEMMET). The data of the working 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) Surveyed area

The surveyed area extends up to about 700 km^2, including Churin, Oyon, and Chiuchin (Fig. 1).

(2) Method of the survey

The regional survey was carried out on the whole Oyon area, and the detailed survey including trenching was made in the Iscay Cruz area where the existence of ore resources are highly expected.

The geochemical survey was performed as well as the geological survey. The rock samples were usually collected, and also the ore samples and stream deposits as far as possible.

(3) Laboratory works

In the analyses of the results of the geological survey, aerophotographs, published geological maps, and literatures were referred. The samples collected in the field were chemically analysed, and microscopic observation, X-ray diffraction, determination of isotopic age, and electron probe microanalysis were done as for as necessary.

1-3 Organization of the Survey Team

The field survey and data analyses were performed by a cooperative team. Members of the survey team are as follows.

Japanese member

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Leader	Toshiatsu Bojo	JICA *1
Member	Kenji Sawada	MMAJ *2
"	Hajime Myoi	MITI *3
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2nd time

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"	Kazuyasu Sugawara	"

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Leader	Edgardo Ponzoni	INGEMMET
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Geologist	Oscar Palacios	INGEMMET
"	Fernando Llosa	"
"	Manuel Montoya	"
"	Zenen de la Cruz	"
"	Cesar Zedano	"

Chapter 2 Conclusion and Future Outlook

2-1 Conclusion

From the field survey consisting of the geological and geochemical surveys for the Oyon area carried out in this fiscal year together with the analyses of existing data, the following has been clarified.

2-1-1 Geology

(1) The Oyon area is in "la zona de la cuenca cretacea" (by Cobbing in 1973) from the standpoint of stratigraphy and located in "la zona pliegues y sobreescurrimientos" (by Wilson in 1967) from the standpoint of geological structure. In this area, the Cretaceous sediments and Tertiary volcanics are distributed and contain intrusive rocks such as tonalite and dacite, etc.

(2) The total thickness of sedimentary rocks amounts to more than 3,000 m. The strata are distributed in the most part of the surveyed area. The lithology is quite different between the upper and lower parts. The lower part is of clastic rocks mainly consisting of siliceous sandstone, sandstone and shale. The upper part is of limestones containing marl and shale. The former corresponds to the stage from the Neocomian to the Aptian and the latter is from the Albian to the Turonian.

(3) The Santa formation is in a long and narrow belt-shape distribution along the upper layer of siliceous sandstone of the Chimu formation in the lower clastic rocks. The Santa formation is overlaid with alternation beds of sandstone and shale of the Carhauz formation and consists of limestone containing sandy limestone, marl and dolostone. The formation is generally 150 m thick, but is about 100 m thick in the eastern part of the surveyed area.

Dolostone in the Santa formation is remarkably distributed in the eastern part of the surveyed area, especially in the Iscay Cruz area. The thickness is 20 m to 25 m in some places. A part of the dolostone stratum has the mineralization of lead and zinc and forms a large scale of gossan on the surface.

(4) Tertiary volcanics in the surveyed area is called the Calipuy volcanics and is limitedly distributed in the western part of the surveyed area. These volcanics are in the unconformable relation with the sedimentary rocks in the northern part and in the fault relation in the southern part. These volcanics mainly consist of andesite, dacite and rhyolite in form of lava and pyroclastic rocks. The lithology is not uniform, namely, is greatly various horizontally and vertically. The isotopic age of andesite lava in these volcanics measured by means of the K-Ar method shows 17.9 ± 0.9 million years corresponding to the Miocene in the Tertiary period.

(5) The intrusive rocks consist of tonalite, dacite porphyry as a stock and porphyrite, dacite, etc. as a dike. Tonalite which corresponds to granodiorite from the standpoint of normative composition has intruded in sedimentary rocks in the western part of the surveyed area. The isotopic age measured by means of the K-Ar method indicates 10.6 ± 0.5 and 10.9 ± 0.5 million years which belongs to the Pliocene in the Tertiary period. Dacite porphyry has intruded in the area 1 km west of the Iscay Cruz mineralized zone. It runs NE-SW in the shape of composite dikes. A part of it extends toward the Iscay Cruz mineralized zone. Its isotopic age measured by means of the K-Ar method is 31.3 ± 1.6 million years which belongs to the Oligocene in the Tertiary period. This intrusive rock has brought weak metamorphism or alteration to the surrounding rocks.

(6) The geological structure of the surveyed area is characterized by the heavily folded structure, thrusts running in parallel with the folding

axis, shear faults obliquely intersecting the axis. In sedimentary rocks, a complicated folding structure of the NNW-SSE axis developes conspicuously. The Oyon and Chimu formations in the lower clastic group mainly form the anticlinal zone, and the Jumasha formation in the upper limestone group mainly forms the synclinal zone. Interval of the folding axis is usually 2 to 3 km. In some places, the anticlinal and synclinal foldings are repeated in the intervals of several ten meters.

In faults and fractures, there are several systems having the peculiar direction; (1) NNW-SSE, (2) NE-SW and WNW-ESE, and (3) ENE-WSW. The fault and fracture system of (1) has the characteristic of thrust and is most remarkable in the surveyed area. The Picoy fault in the central part and the Puñun fault in the western part are confirmed as principal faults. The existence of (1) can be suggested in the Santa formation of the Iscay Cruz area. The system (2) obliquely intersects the folding axis and moved the eastern blocks westward. The Viroc fault in the northern part and the Pucayacu fault in the southern part are principal. The system (3) perpendicularly intersects the axis and has the characteristic of tension fracture. Dikes of dacite in the Iscay Cruz area occur mainly in this direction.

It can be considered that the folding and faulting in the surveyed area are ascribed to the large compression in the earth crust and uplift of the block due to the Andean orogeny.

2-1-2 Ore Deposits

(1) The Oyon area, which belongs to "la Sub-Provincia Polimetalica del Altiplano" in Peru is extensively distributed by metal ore deposits containing mainly silver, lead and zinc. In addition to the above, non-metal mineral deposits such as coal, gypsum, etc. are distributed.

In the surveyed area, the Iscay Cruz, Chupa and Viscachaca are main ore deposits which were formerly exploited and operated. Outside the surveyed area, there are the Raura, Chanca and Uchucchacua ore deposits in which mines are currently operated. These ore deposits are classified in the following types based on the geology and occurrence of ores.

1) Contact metasomatic deposits of copper, lead and zinc formed in the contact zone between Cretaceous limestones and intrusive rocks.

.... Raura ore deposit

Chupa ore deposit

2) Silver, lead and zinc fracture-filling ore deposits in Cretaceous limestones and Tertiary volcanics.

.... Raura ore deposit

Chanca ore deposit

Uchucchacua ore deposit

Viscachaca ore deposit

3) Bedded or massive hydrothermal replacement ore deposits occurred in Cretaceous limestones.

.... Iscay Cruz ore deposit

(2) The Iscay Cruz ore deposit area is located about 9 km south-southeast from Oyon. The ore deposits are in the Santa formation of the west wing of the anticline of which the axis is composed of the Chimu formation. The ore deposits exist in carbonate rocks and consist of iron-quartz gossan, disseminated Pb-Zn sulfides and skarn, and are found in 6 places ranging from the No. 1 minerals indication in the northern part to the No. 6 minerals indication in the southern part in extent of 11 km distance.

The No. 1 minerals indication consists of iron-quartz gossan and has the largest scale in the Iscay Cruz ore deposit. The deposits exist in the Santa formation in 2 rows. The lower row is 1.2 km long and 12 m wide (maximum: 25 m). The upper row is 300 m long discontinuously and 6 m wide. The gossan consists mainly of quartz and limonite and contains together with goethite, hematite, etc., but no sulfide has been found. Lead and zinc are likely contained as an oxide of chalcophanite, except very small quantities of sphalerite in carbonate rocks existing in contact with gossan. The average grade of the No. 1 minerals indication is 0.71 % for Pb, and 4.76 % for Zn in the average width of 11.6 m.

The No. 2 minerals indication is sporadically distributed with gossan on a small scale in an area of 650 m long. Gossan consisting of iron and quartz is not massive, but is of network. The average grade of gossan is 0.14 % for Pb and 2.59 % for Zn, and the average width is 7.0 m. In the upper part of this minerals indication, a vein of 1.9 m wide with white clay band was found. This vein contains 0.13 % Pb and 6.93 % Zn.

The No. 3 minerals indication consists of five small exposures and is sporadically scattered in an area of 800 m long. These exposures consist of disseminated sphalerite and galena which can be classified into two types: one is the dissemination in dolostone and the other is the concentration surrounding massive pyrite. The former type was found in four places and the average grade is 0.12 % for Pb, and 0.73 % for Zn in the average width of 5.0 m. The grade of the latter is 12.33 % for Pb and 2.65 % for Zn, and the average width is 4.2 m.

The No. 4 minerals indication consists of, like as the No. 3, disseminated sphalerite and galena. This minerals indication is distributed in two rows. The lower row is in dotted distribution which is 800 m long and 7 m wide in average. The upper row is dotted with minerals in an area of 100 m long. Both rows consist of sphalerite and galena disseminated in dolostone in which metals concentration of lens shape in 2 to 5 cm wide is observed in some places. In the southernmost area, galena is found together with pyrite. The average grade is 0.13 % for Pb, and 1.84 % for Zn in the average width of 7.0 m.

The No. 5 minerals indication consists of 100 m long and 20 m wide skarn and contains 3,400 ppm Zn. The No. 6 minerals indication consists of iron-quartz gossan, similar to the No. 1, and contains 3,500 ppm Zn.

(3) The Chupa ore deposit is located about 500 m westward from the Iscay Cruz No. 5 minerals indication. This is a contact metasomatic deposit which has been formed in limestone of the Pariahuanca formation belonging to the upper limestone group. Minerals consisting mainly of sphalerite and pyrite are disseminated in the skarn zone of 20 m wide and more than 90 m long. The average grade is 1.56 % for Cu, 0.03 % for Pb, and 13.89 % for Zn, that is to say, the quality being not homogeneous. It can be said that there exists a complicated control of mineralization of which sphalerite and chalcopyrite are mainly disseminated. The igneous rocks which related to the above mineralization and skarnization have not been cleared.

(4) The Viscachaca ore deposit is located in the southwesternmost part of the surveyed area. This deposit is of fracture-filling type existing in the syenite porphyry dike intruded in the Calipuy volcanic rocks. The vein is 1 m wide and contains silver-bearing galena and sphalerite. The mine was formerly operated, but is currently closed.

(5) Coal occurs in the lowest formation of the surveyed area, the Oyon formation, and has been mined on a small scale in the southeast and southwest parts of Oyon. Gypsum is in sandstone overlaid with the Carhuaz formation and concentrated in a lenticular shape of maximum 5 m thick and 50 to 70 m long. Gypsum is mined on a small scale in several areas near Churin.

2-1-3 Geochemical Survey

(1) It can be considered that the background values of Cu, Pb, and Zn

contained in rocks distributed in the surveyed area are 5 ppm, 22 ppm, and 35 ppm respectively. For each formations and rock types, the background values are 5 ppm, 30 ppm, and 35 ppm for limestones, 5 ppm, 10 ppm, and 30 ppm for clastic rocks, and 7 ppm, 5 ppm, and 55 ppm for igneous rocks. When comparing the above values with those presented by Turekian et al. (1961), the above values for Pb and Zn in limestone are slightly high and other values are almost same. However, when comparing the abave values with those of carbonate rocks in the Cordillera Oriental of Peru which contains strata-bound type lead and zinc ore deposits, the above values are low; for Pb and Zn, the content is 1/3 to 1/4.

It can be considered that the background values in stream sediments are 22 ppm for Cu, 30 ppm for Pb, and 80 ppm for Zn.

(2) When the threshold values of Cu, Pb, and Zn contained in rocks are assumed to be 10 ppm, 220 ppm, and 500 ppm respectively, numbers of anomalous samples are 1 for Cu, 7 for Pb and 15 for Zn. Anormalies are scattered over the whole area, but the majority of them is distributed in the Iscay Cruz horizon of the Santa formation. Anomaly of the Iscay Cruz horizon is found in gossanized dolostone and carbonate rocks adjoining gossan which were clearly influenced by mineralization. The other anomalies are found in the Pariahuanca and Santa formations located 15 km south-east of Oyon. In this area, limestone has not been altered and is only associated with calcite veins. This area is located in the extension of dacite stock in the Iscay Cruz area. Therefore, the mineralization relating to the volcanic activity exists possibly.

(3) When the anomalous threshold values of Cu, Pb, and Zn contained in stream sediments are assumed to be 120 ppm, 270 ppm, and 500 ppm respectively, only one sample for each elements meets those values. When comparing the data with the contents in the samples collected from adjacent rivers and

the neighboring geology, anomaly or slightly higher background values are found in the area of Calipuy volcanic rocks distributed and the Santa formation corresponded to the Iscay Cruz horizon.

2-1-4 Mineralization in the Iscay Cruz Area

(1) There is almost no possibility that the Iscay Cruz ore deposit in the Santa limestone was formed by syngenetic mineralization.

Excepting geochemical samples which were clearly influenced by mineralization in the Iscay Cruz area, the average contents of Pb and Zn contained in the Iscay Cruz horizon of the Santa formation go lower as 25 ppm for Pb and 22 ppm for Zn. From this fact, it can be assumed that limestones in the Iscay Cruz horizon were not deposited together with concentrated Pb and Zn. The maximum Mg content in carbonate rocks of the Santa formation in the Iscay Cruz area is 8.9 %. The Mg/Ca molar ratio is 0.7 to 0.8 for many samples. This fact shows that the dolomite ratio of dolostone distributed in the Iscay Cruz area is low.

As described above, no remarkable juvenite concentration of Pb and Zn is in the Santa formation and the dolomitization is weak. Furthermore, no trace of the secondary concentration has been found and is expected as well. Therefore, there is almost no expectation for the existence of strata-bound type lead and zinc ore deposits.

(2) It is likely that copper, lead and zinc in the Iscay Cruz area were added by hydrothermal mineralization together with iron-quartz forming gossan. As for the minerals distribution, the northern part of the No. 1 indication is characterized by high concentrations of Pb and Zn with high ratio of Pb, and the No. 3 and No. 4 indications are abundant in Zn with a small quantities of Pb and Cu. The No. 5 and No. 6 indications show high ratio of Zn, especially the Chupa ore deposit contains Cu in abundance as well as Zn. In other words the Chupa ore deposit, containing

much Cu and Zn, is located in the central part of the Iscay Cruz mineralized zone which is surrounded by Zn zone and in the outermost zone Zn-Pb zone is located. This type of zonal arrangement is clear from the ratio of Cu, Pb and Zn elements in each ore deposit area and similar to that of the Cerro de Pasco and Huanzala ore deposits.

(3) Igneous rocks in the Iscay Cruz mineralized zone are dacite in the western part of the No. 1 area and acidic igneous rock in the No. 4 area. Dacite intruded in the Jumasha formation has given weak alteration to the surrounding rocks. Acidic igneous rocks are also found in the mineralized zone of the Huanzala ore deposit. A zonal arrangement of elements is found in this zone as above mentioned and the Chupa ore deposit seems to be located in the central part of the zone. However, igneous rocks which are related to the formation of the Chupa ore deposit have not been cleared. This mineralized zone is 11 km long. It can be considered that mineralization of this zone resulted from the complicated involvement of faults and fractures which have been formed in the Santa formation, the above mentioned igneous rocks, and the igneous rocks which influenced on the Chupa ore deposit. It is important to clarify the details of igneous rocks, which control the mineralized zone, and the structural control in the future survey.

2-2 Future Outlook

By the geological survey, geochemical prospecting and the comprehensive analyses conducted in this fiscal year, the anomalies which indicate the probable existence of metal ore deposits can be clarified in the following three areas.

(1) The Iscay Cruz area including the Chupa ore deposit.

(2) The area where the Calipuy volcanic rocks are distributed.

(3) The area where the Pariahuanca and Santa formations are distributed southeastward from Oyon.

In the area of the Calipuy volcanics distributed, comparatively high values were recoginized by the geochemical prospecting. In this area, there are the Chanca ore deposit which is in operation but is located outside the surveyed area and the small scale Viscachaca ore deposit in the surveyed area of which the operation has been discontinued. No minerals indication has been found southeastward from Oyon. On the other hand, gossan containing considerably large quantities of lead and zinc and exposures of copper, lead, and zinc sulfides are situated over 11 km in the Iscay Cruz area. Accordingly, it can be concluded that the Iscay Cruz area is most important in the survey area.

By the survey of this time, the structure, minerals distribution and zonal arrangement of elements in the Iscay Cruz mineralized zone can be clarified. However, the relationship of igneous rocks, mineralization and the control by faults and fractures have not been cleared. These are the subject which must be solved to clarify the scale of sulfides body and the degree of concentration of copper, lead, and zinc in the Iscay Cruz area. To achieve the above subject, the following activities will be necessary.

(1) Geological survey

Exposures in the No. 1 through No. 4 minerals indications were mainly surveyed in this fiscal year. In the 2nd year survey, it is necessary to clarify, for the purpose of obtaining useful data to the further survey, the mineral component and zonal structure of gossan, existence and features of the alteration zone, fractures in the mineralized zone, relationship between the igneous rock distribution and mineralization, etc. To achieve the above, it is necessary to carry out the detailed geological survey for the southern part of the Iscay Cruz area, including the Chupa ore deposit, in addition to the No. 1 through No. 1 minerals indications.

(2) Geophysical survey

Indication of ore deposits on the surface is mainly for iron-quartz gossan. It can be considered that this gossan resulted from the oxidation of pyrite which has been formed by the hydrothermal mineralization. Therefore, the clarification of pyrite body existed deep under the surface is important to examine the degree of concentration of the lead and zinc and scale of the mineralized zone. Accodingly, it is necessary to carry out the geophysical survey, especially the electric prospecting by means of the IP method, for the Iscay Cruz mineralized zone.

(3) Drilling

Since the Iscay Cruz ore deposit is overlaid with talus, informations collected by the geological surveys are limited, concerning in the geological structure, formation of mineralization and distribution of minerals. It is necessary to drill the No. 1 and No. 4 minerals indications to further improve the informations obtained by the geological and geophysical surveys and further clarify the geological structure of the Iscay Cruz ore deposit.

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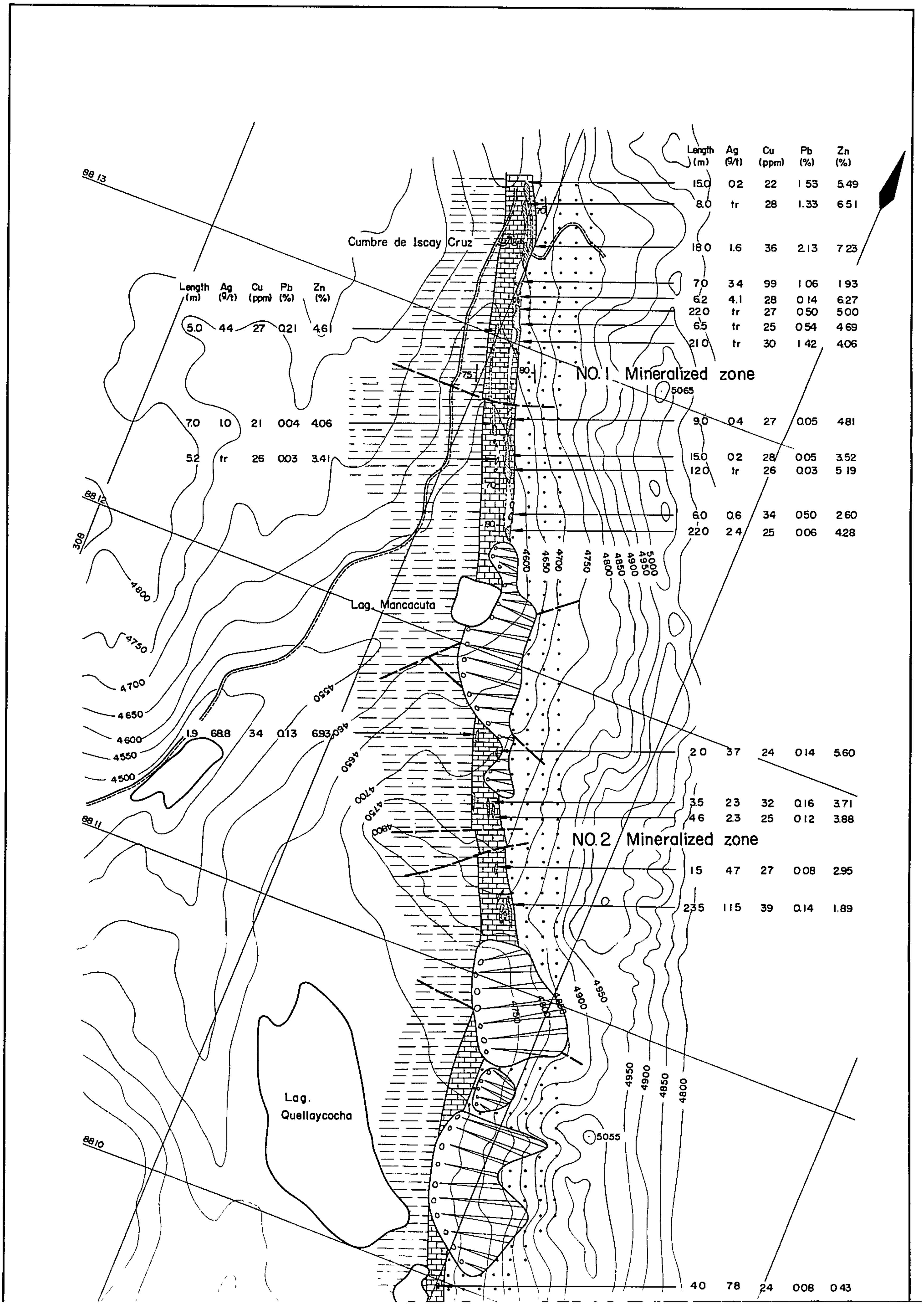
NO.1 Mineralized zone
NO.2 Mineralized zone
Cumbre de Iscay Cruz
Lag. Mancacuta
Lag. Quellaycocha
Length (m) Ag (g/t) Cu (ppm) Pb (%) Zn (%)
15.0 02 22 1 53 5.49
8.0 tr 28 1.33 6 51
18 0 1.6 36 2.13 7 23
7 0 3 4 99 1 06 1 93
6.2 4.1 28 0 14 6.27
22 0 tr 27 0 50 5 00
6.5 tr 25 0 54 4 69
21 0 tr 30 1 42 4.06
9.0 0 4 27 0.05 481
15.0 0 2 28 0 05 3.52
12 0 tr 26 0 03 5 19
6 0 0.6 34 0 50 2 60
22 0 2 4 25 0 06 428
2 0 37 24 0 14 5.60
3 5 2 3 32 0.16 3.71
4 6 2 3 25 0 12 3.88
1 5 47 27 0 08 2.95
23 5 1 15 39 0.14 1.89
4 0 78 24 0 08 0 43
Length (m) Ag (g/t) Cu (ppm) Pb (%) Zn (%)
5.0 44 27 0.21 4.61
7.0 1.0 21 004 4.06
5.2 tr 26 003 3.41
1.9 68.8 34 0.13 693
5065
5055
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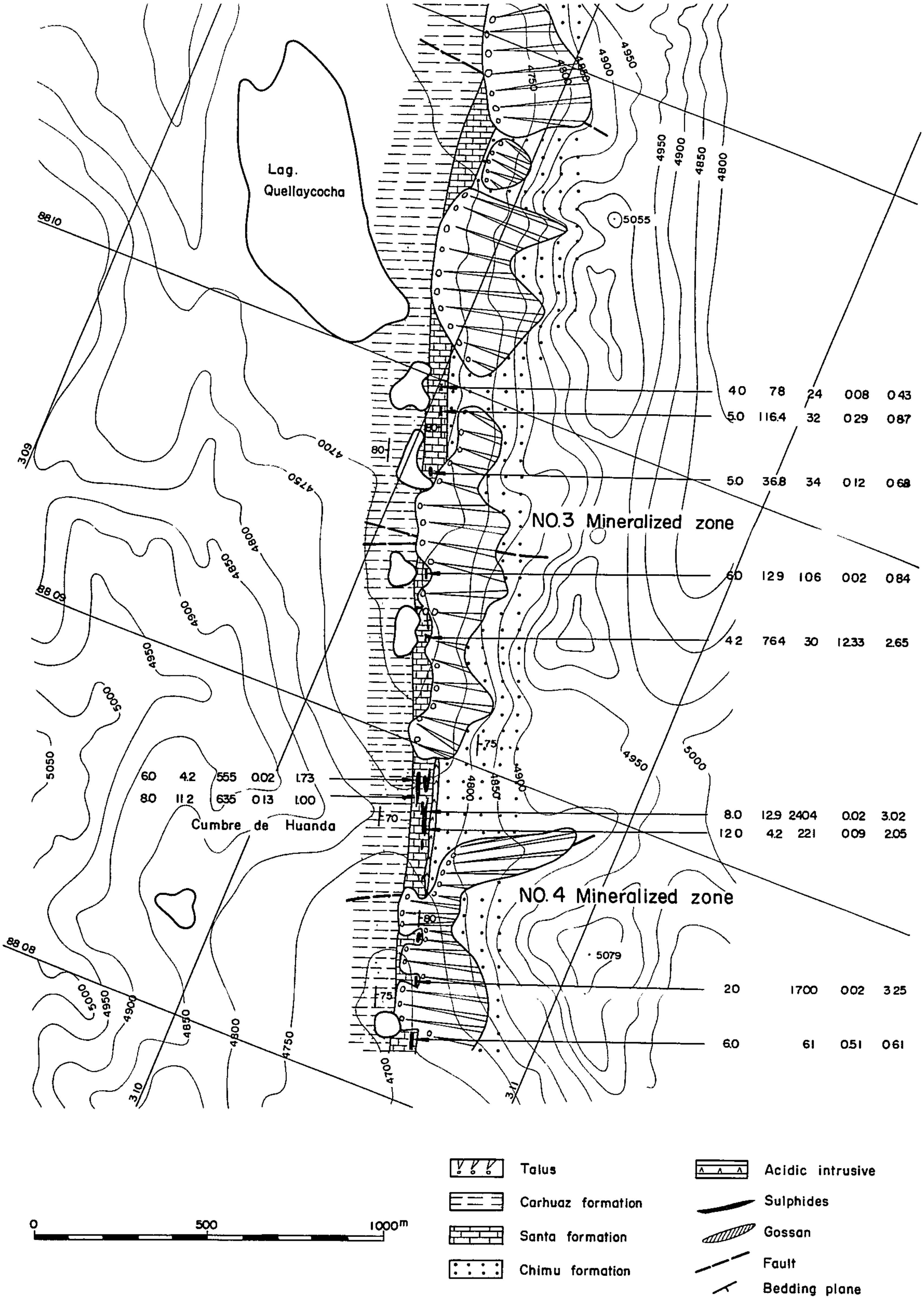


Fig. 2. Generalized Geological Map of the Iscay Cruz Area

PARTICULARS

Particulars Contents

Chapter 1 Outline of the Survey

1-1 Purpose of the Survey

The Oyon area belonging to polymetallic sub-province of Andean plateau (Sub-Provincia Polimetalica del Altiplano) in Metallogenetic Province of Western Andes (Provinca Metalogenica Andina Occidental) proposed by Bellido, et al. (1969), is surrounded by the following areas: the Huallance-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.

Although there are no working mines in the surveyed area, the minerals indications of Cu-Pb-Zn such as the Iscay Cruz areas are known, and the existence of mineral resources is expected. The survey, therefore, has been carried out on the purpose to clarify the geological structure, to find the minerals indications, and thus to understand the relationship between the geological structure and the nature of mineralization.

1-2 Scope and Period

(1) Location and extent of the surveyed area

The surveyed area is located in the upper stream region of Rio Huaura, about 100 km north of Lima, the capital of the Republic of Peru.

The area which includes Churin, Oyon, and Chiuchin extends in the basin of Rio Checras and Rio Pampahuay, both of which are branches of Rio Huaura, forming a rectangle of 700 km^2 (Fig. 3).

The detailed survey has been carried out on the Iscay Cruz area which is about 30 km^2 and is located about 10 km SSE of Oyon.

(2) Period

67 days have been spent for the field works and 79 days for the laboratory works.

Fieldworks: September 19, 1979 - November 25, 1979.

Laboratory works: November 26, 1979 - February 12, 1980.

1-3 Method of the Survey

A cooperative team consisting of 6 Japanese geologists and 5 Peruvian geologists has been formed at Lima, and a base camp has settled at Churin. Five to six small groups, including a Japanese geologist, a Peruvian geologist, 2-4 laborers, and a horse driver, have been formed at Churin.

The area lies in the central part of the Cordillera Occidental and has many steep rocky peaks. The sea level at Churin, the lowest part in the area, is 2,300 m and that at Oyon 3,600 m. In general, however, the sea levels attain about 4,000 m and the Iscay Cruz area, on which the detailed survey was carried out, lies at 4,600 m to 5,000 m above the sea level.

In order to perform the survey more effectively in this area, adaptation to high-land is needed. The survey, therefore, began in the lower part of the area, Rio Huaura and Rio Checras. As the drive roads were laid around the base camps of Churin and Oyon, the jeeps were used to perform the survey.

In the other areas, the camps were moved as the survey proceeded and horses were used in the survey and the transportation of materials. Using horses makes it possible to perform the fieldworks at the high land. The materials needed for the survey and camping were carried from Japan, and the oxygen vessels were also prepared.

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 minerals 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. The samples for geochemical studies were usually collected from each lithofacies and each formation. These samples were crushed and prepared in Peru for the chemical analysis, and the various studies including microscopic observation were made for the important samples.

In this area, taluses are developed and the cultivated lands with developed water channels are founded in many places. There is a little running water in the valleys. However, usually it is difficult to collect the samples from the stream sediments; nevertheless it was done as far as possible. At the outcrops of ore in the Iscay Cruz and gossan areas, the channel samplings with 10 cm in width and 2-4 m in length were attempted 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

Following the field works, the laboratory works have been carried out on the various samples, and the data obtained in the field works have 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...................... 29

(2) Microscopic observation of polished sections of ores........... 11

(3) Chemical analysis of ores.. 14

(4) X-ray diffraction.. 9

(5) Electron probe microanalysis..................................... 3

(6) Determination of isotopic age.................................... 4

(7) Identification of fossils.. 7

(8) Chemical analysis of the samples for geochemical study (total).. 450

Rocks (Cu, Pb, Zn)... (289)

Minerals indications (Cu, Pb, Zn, Ag)........................... (117)

Stream sediments (Cu, Pb, Zn)................................... (44)

(9) Chemical analysis of trace elements (Sr, Ba, Ca,

Mg, Mn, Fe).. 28

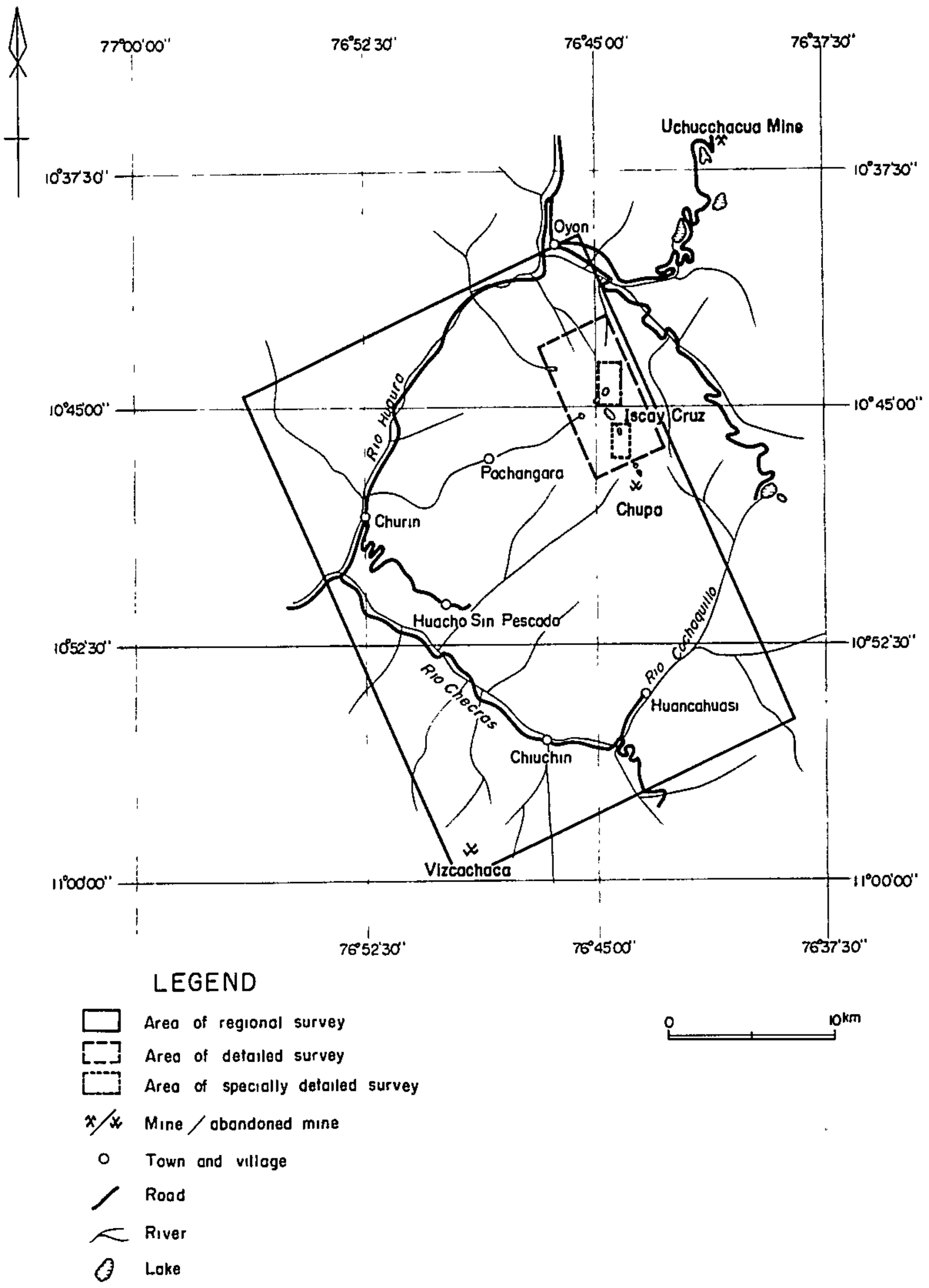


Fig. 3. Location Map of the Surveyed Area

Chapter 2 General Circumastances of the Surveyed Area

2-1 Location and Access

The surveyed area lies 100 km north of Lima, the capital of 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. 4). The two-lane pavement road, the Pan-American High Way, is available from Lima to Huacho, and the road from Huacho to the 15 km of Sayan is paved. The shortcut from Chancay to the surveyed area, however, is not 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 an hour and 20 minutes. To attain the Iscay Cruz area, on which the detailed survey was carried out, taking the route from Oyon is easiest and it takes 30 minutes for 10 km by car and then about 3 hours by horse, total 3 hours and a half.

2-2 Topography

The surveyed area lies in the Cordillera Occidental, a main range of the Western Andes, and Rio Huaura belonging to the Pacific coast water system has its source in this area. 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 forms from 4,200 m to 4,800 m, and the difference in topography is clearly observed above and below 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. 5).

The flat plane, known as "la Superficie Puna", shows maturity topography and is estimated to have been formed in the Pliocene epock. Its sea level was probably 2,000 to 3,000 m at that time.

In this area, therefore, since the Pliocene epock 2,000 to 3,000 m rise has been taken place as a part of the Andean Orogenic Movement.

The topography and water system in this area reflect the geological structure: The Jumasha formation consisting of massive limestone forms the highest peaks strectching in the NNW-SSE direction, then the Chimu formation of quartzite forms the mountains of intermediate height, and the Carhuaz formation composed of shale and sandstone forms lower cols. The water systems of NNW-SSE and ENE-WSW directions are well developed and crosses to each other. Ther water system of NNW-SSE reflects the folding structure and distribution of the formations, while that of NNE-SSW reflects the fracture (or fault) system.

2-3 Meteorogy

The climate changes from place to place depending on the topography, height, and distance from the Continental Divide.

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 influenced by the monsoon from the Amazon area 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 cosiderable amounts near the Continental Devide.

As the height decreases toward west, the climate becomes dry and mild. It is dry and mild with little rainfall in Churin during a year. The average temperature in winter from June to September is 18°C, in summer from November to March 28°C, and during a year 23°C in average.

2-4 Inhabitants and Industries

(1) Inhabitants and their life

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 transportaions 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. Only a few grasses grow in the highlands or along the valleys, and therefore the lands suitable for farming are restricted. Small scale farming on the slops with water channels and cattle breeding on the plateaus are carried. Milk, dairy products, potatoes, corns, and beans are produced and a part of these products are shipped to Churin to afford the necessaries of life.

The main villages and their populations in the areas are as follws:

Area	Village	Male	Female	Total
Pachangara	Churin	733	765	1,498
	Pachangara	491	412	903
	Others	770	906	1,676
	Total	1,994	2,083	4,077
Andajes	Andajes	536	840	1,376
	Others	173	208	381
	Total	709	1,048	1,757
Oyon	Oyon area	5,750	5,750	11,500
	Rapaz	395	398	793
	Mallay	394	370	764
	Others	305	343	648
	Total	6,844	6,861	13,705
Chancay	Parguin	454	450	904
	Others	504	587	1,091
	Total	958	1,037	1,995
Checras	Punun	600	700	1,300
	Others	1,217	1,165	2,382
	Total	1,817	1,865	3,682
	Total sum	12,322	12,894	28,716

(2) Industries

The mordern mines are being worked around Oyon. Although these mines are in small or moderate scale, they are core of the industiral activities in this area, bringing the most stable earnings to the comunity. Coal minings have also carried since long time ago, but as the scale are small and staying at handiwork, the weight in the local economy is not high.

There are spas in the Churin and Chuchin areas and these areas are known as resort areas. Because of mild climate and the close distance to Lima, recently the areas are prospecting as a tourist resort area and they are earning cash.

Except the mining and tourist industries mentioned above, there are no industries to be noticed, and the inhabitants are living in self-sufficient with old-fashioned farming and cattle breeding.

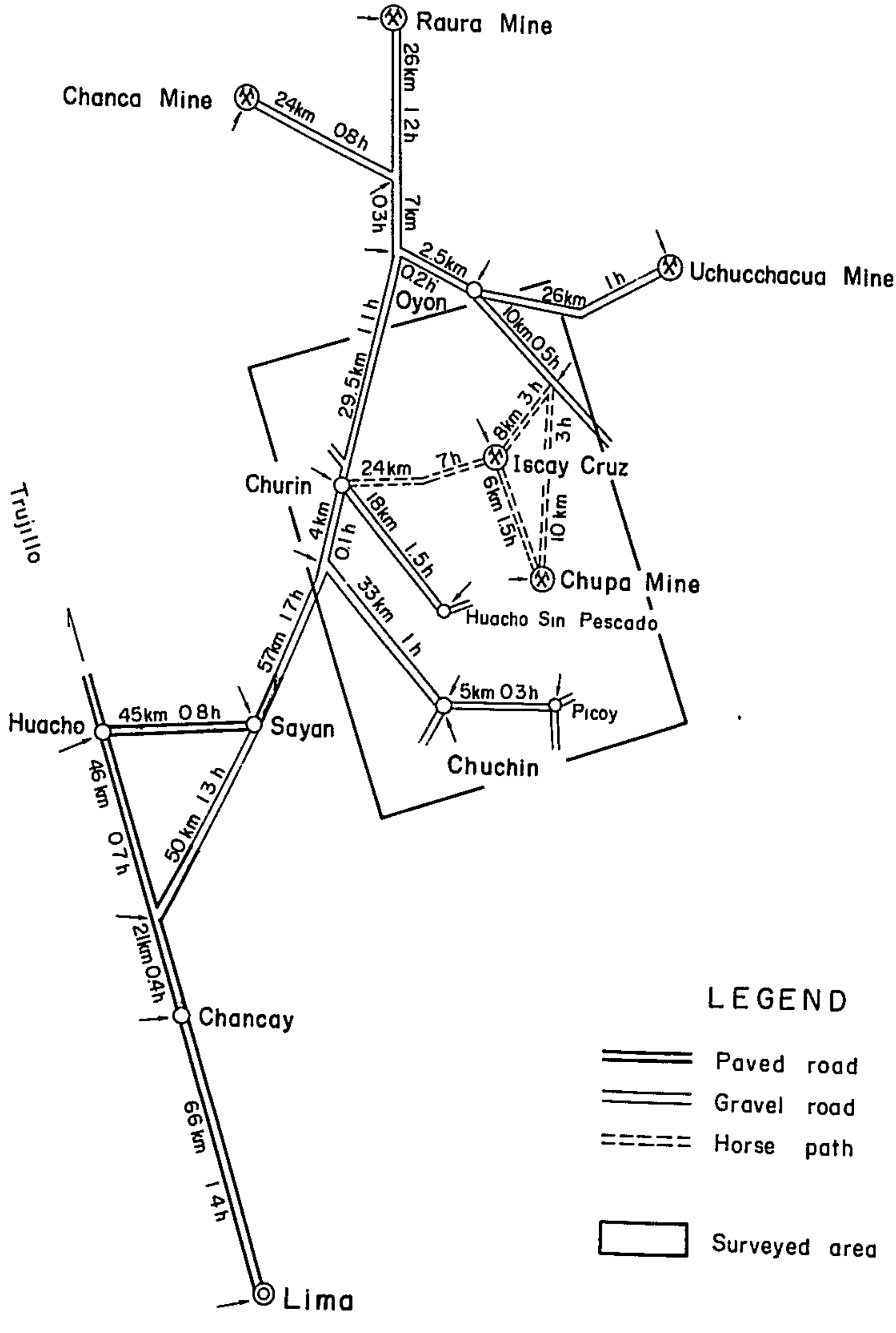


Fig. 4. Access Map of the Surveyed Area

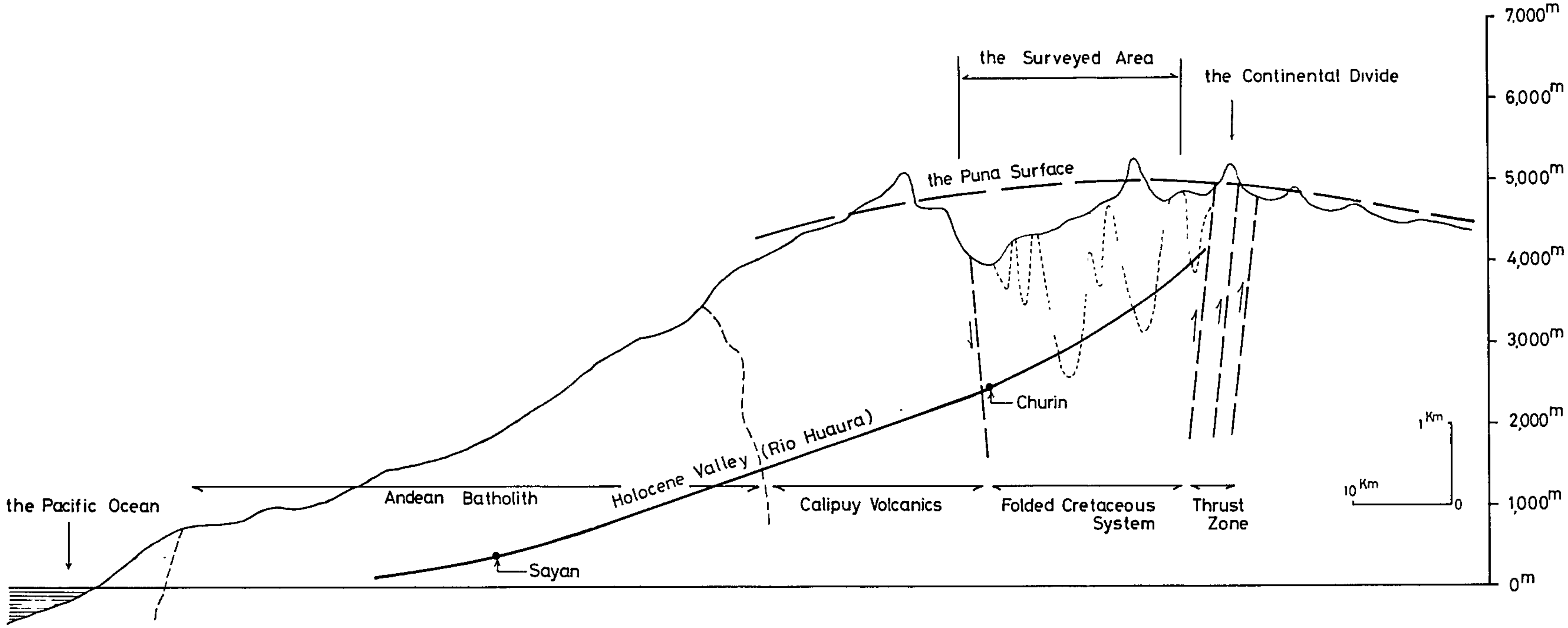


Fig. 5. Schematic Profile of Topography and Geology (Direction of WSW—ENE)

Chapter 3 Geology

3-1 Geological History of the Central Andes

The teritory of Peru is situated on the western part of South American Continent, stretching from NNW to SSE along the coast, and devided by the Andes constitues the Central Andes area together with Bolivia and northern part of Chile. The Central Andes consists of two or three ranges of the western Cordillera (Cordillera Occidental), the eastern Cordillera (Cordillera Oriental), and the Sub-Andes (Cordillera Sub-Andina). The topography of the Andes stretching over 8,000 km along the western margin of the South American Continent has been formed by the upheaval movement since the Pliocene in the late Tertiary. The Andes is a complicate mountain range and has a relatively long geological history. The eastern Cordillera consists of the miogeosyncline sediments of Paleozoic, whereas the western Cordillera consists of the eugeosyncline sediments, volcanic rocks and plutonic rocks of Mesozoic and Tertiary.

The Oyon area, surveyed area, is located on the western Cordillera which is a main range in the west part of the Andes and contains the basin of water system generated at the Continental Divide. The mechanism of evolution and development of the Andean orogenic belt is reviewed from the view point of plate tectonics theory by Bellido, Jenks, James, Miyashiro and others. On the basis of these results, in order to clarify the situation of Oyon area in the regional geology, the geological history of the Central Andes will be reviewed briefly from the view of plate tectonics theory.

The oldest rocks that crop out in the Central Andes region are metamorphic rocks of Precambrian consisting of crystalline schist and gneiss. These rocks are distributed intermittently in the coastal area of the southern Peru and the eastern Cordillera and forms the spine of this area. In the Paleozoic Era, clastic sediments accumulated considerably on the continental shelf and slope of the western margin of the South American Plateau. These Paleozoic formation consisting mainly of shale and sandstone was folded through the following orogenic movement and formed the eastern Cordillera.

During the late Permian in Paleozoic to the Triassic in Mesozoic, an important event took place, that is the separation of the Pangaea accompanied with the separation and differentiation of South American continent and African continent.

From Triassic to Jurassic period, the western margin of continent consisting of Guiana shield and Brazilian shield became considerably unstable, and a continental plate and a oceanic plate, Nazca plate, were converged at this part. In the Jurassic, the subduction of Nazca plate became active, the main part of geological activities moved westward, the volcanic arc was formed at the west, and then a large amount of andesite lava was erupted. The andesites have been preserved in the southern Peru and northern Chile.

In the Cretaceous period, long and slender volcanic islands were formed by the volcanic activity and to the east of these islands a boat-shaped basin separated from the ocean was developed. The sediments with various lithologies deposited in this basin. At the early Cretaceous a considerable amount of clastic materials was brought from the continent to the east and the clastic rocks carrying coals deposited. At the middle Cretaceous transgression progressed and thick strata of limestone were formed. These Cretaceous sediments are widely distributed along the central spine of the western Cordillera.

From the late Cretaceous to the Paleogene, the volcanic activity took place again along the volcanic arc formed in the Jurassic, and a large amount of andesite was erupted and plutonic bodies intruded into the lower part of volcanic arc. These volcanic rocks are continuously distributed to the west side of the western Cordillera. To the further west of the volcanic rocks a large batholith crops out, which is considered that the basal part of volcanos was exposed by later erosion (Jenks, 1979).

In the Miocene of Neogene period rhyolitic and dacitic pyroclastic flows were produced. In the Quaternary andesitic lavas were erupted from many vents on the vast pyroclastic rocks. From southern Peru to the northern Chile, more than 1,000 volcanos with 5,000 - 6,000 m in height were formed and parts of them are still active at present. The volcanic activity in the Miocene was accompanied by many small intrusive bodies with intermediate composition, almost of which were associated with mineralization (Bellido, 1969).

When the magma that causes volcanic activity on the surface is cooled in the crust, plutonic body is formed. The violent volcanic activity continued from the Jurassic to the present is a characteristic feature of the Andean orogeny, and brought about the eruption of lavas and the intrusion of plutonic bodies. As the result, the crust was considerably expanded and strong compression was produced. It is considered that this compression caused the strong folding and uprising of the thick sediment zone in the eastern and western Cordillera. The magma was continuously supplied by partial melting of subducting plate (James, 1971; Miyashiro, 1979).

In the Oyon area, strongly folded Cretaceous sediments and Tertiary volcanic rocks are mainly distributed. The geological history of Andean orogenic belt such as evolution and development of environment of sedimentation, violent volcanism, and bending and fracturing of the crust, is inscribed in these rocks (see Fig. 5).

3-2 Outline of Geology of the Oyon Area

Geology of the Central Andes containing the Oyon area has been studied by many investigators. McLaughlin (1924) formerly reviewed the stratigraphy of the whole Central Andes. Harrison (1940-1956) made a survey on the regional geology. Jenks (1948) and Benavides (1956) investigated the southern and the northern parts, respectively. Detail investigations on the Oyon and adjacent areas were made by Wilson (1963). Cobbing (1973) established the geological map by reviewing the geology in this area and by using air-photographies. Jenks (1948) and Bellido (1960) published the books which give an outlines of the geology of the whole territory of Peru.

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

The thick Cretaceous sedimentary rocks are widely distributed in this area. Their lithology is extremely different in the lower part and upper part to each other; the former is composed mainly of clastic group, i.e. siliceous sandstone, sandstone, shale and others, and the latter calcareous group associated with marl and shale. It is suggested that the environments of sedimentation in the Cretaceous sedimentary basin changed from the continental to the marine conditions.

In this report, the stratigraphic classification and the name of each formation by Cobbing (1973) and Wilson (1967) are used.

The clastic group in the lower part is divided into the Oyon, Chimu, Santa, Carhuaz and Farrat formations, and the calcareous group in the upper part the Pariahuanca, Chulec, Pariatambo and Jumasha formations in ascending order. These Cretaceous sedimentary rocks are intruded by tonalite and dacite in post-Cretaceous period, and are covered by the Tertiary Calipuy volcanic rocks in the western part of this area. The eastern area of a watershed of the Andes belongs to the Cretaceous sedimentary block (Zona del bloque cretaceo) by Cobbing, and the lower clastic group is bundled up as the Goyllarisquizga Group, because each formation does not show the development of differentiation (refer to Fig. 6. 7).

The Cretaceous sedimentary rocks were intensely folded, owing to the Andean orogeny to form the 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 exposed repeatedly at the surface. Structure of the axis usually shows an acute angle. In many cases the upper strata are folded in between the lower strata, and the latter are interbeded as the plug with the former.

3-3 Stratigraphy and Lithology

3-3-1 Oyon Formation

(1) Distribution

The Oyon formation, the lowest formation in the Oyon area, is distributed underneath the Chimu formation in NNW-SSW trend along the axis of anticline. The exposures of this formation is limitted in the eastern part of the area and its typical outcrops observed 2 and 5 km west and 5 km southeast of Oyon.

(2) Constituents and lithology

This formation is composed mainly of the fine alternation of dark gray sandstone and shale and carries coal beds in the upper part. The interval of alternation is usually 10 - 30 cm. Sandstone is fine-grained, argillaceous and poorly sorted. There are three coal beds, and the maximum thickness attains up to 1 m. The shoot is usually found in the axis of anticline, occurs as lens, and is discontinuous, ascribed to the vigorous orogenic movement after the accumulation (refer to Chapter 5).

(3) Thickness

Since only the upper part of 100 to 400 m crops out in this area, the base of this formation is not clear. The observed thickness of this formation is not less than 400 m.

(4) Correlation

The name of Oyon formation was proposed by Harrison (1956), on the basis of the observation of lower layers of the Chimu formation. Although, based on the fossils occurred, Wilson (1963) correlated this formation with the Neocomian and Valanginian stages.

They also suggested a possibility that it is equivalent to the Tithonian stage of the uppermost Jurassic. Cobbing (1973) showed that this formation grades into shale in the Tithonian Chicama formation at the north of this area. This formation is correlative with the lowest part of the Goyllarisquizga Group distributed in the eastern part of this area.

3-3-2 Chimu Formation

(1) Distribution

The Chimu formation is most widely distributed in this area as well as the overlying Carhuaz and Jumasha formations. This formation is exposed in three or four belts along the axis of anticline with NNW-SSE trend in the eastern and western parts of this area. It occurs as a long slender zone, or in the form of a dome in the overlying Santa and Carhuaz formations.

(2) Constituents and lithology

This formation consists mainly of white to pale gray and fine to medium-grained siliceous sandstone, but contains some intercalated blackish gray sandstone or sandy shale. Sandy shale contains bituminous beds in places. The thickness of siliceous sandstone attains up ten to several ten meters, whereas fine-grained sandstone and sandy shale are about a few meters thick. Siliceous sandstone is composed mostly of rounded quartz, which is cemented by silica to form orthoquartzite. As recrystallization proceeds, it sometimes resembles metaquartzite in appearance.

In the upper part of this formation, proportion of fine-grained sandstone and sandy shale increases and alternation zone attaining several tens meters thick is present in the siliceous sandstone. There is a little difference in lithology between the formations in the eastern and the western parts of this area. In the eastern part of the area siliceous sandstone is dominant, but fine-grained sandstone and shale increase in amount in the western part of the area.

Siliceous sandstone in this formation is relatively homogeneous and vertically and regionally extends with little change in lithology. This rock has cross bedding and ripple mark. Wilson (1963) studied cross bedding and slump structure in this rock with the result that the direction of transportation of sediment is predominant in southwest. This formation is regarded as delta and flood plain deposits from the evidence of lithology, sedimentary structure, plant fossils and others.

This formation forms the rugged mountains consisting of the massive and solid rocks, and is easily distinguished by the topography from other formations.

(3) Thickness

This formation ranges in thickness from 600 to 700 m in general. It is estimated to attain about 1,000 m in thickness in the western part of the area, although, for lack of outcrops of the underlying formation, it is difficult to clarify the real thickness.

(4) Correlation

Benavides (1956) defined that the type locality of the Chimu formation is Chicama valley in the northern Peru. Since this formation contains only the fragments of plant fossils, the correlation based on the fossils can not be useful. Nevertheless, judging from the stratigraphic relations to the overlying Santa formation (late Valanginian stage), this formation is correlated with the Valanginian stage. This formation conformably covers the Oyon formation. Lithology and sedimentary environments of the formation are similar to those of the Goyllarisquizga Group distributed in the eastern part of this area.

3-3-3 Santa Formation

(1) Distribution

The Santa formation is distributed in a long and slender zone covering the Chimu formation. This formation forms the steep cliffs in contact with the rock wall consisting of siliceous sandstone of the underlying Chimu formation, but is interbeded as a plug with the overlying Carhuaz formation from Churin to Huacho sin Pescado or Acain in the western part of the area.

(2) Constituents and lithology

This formation consist mainly of fine stratified bluish gray limestone associated with sandy limestone and marlstone. Limestone carries the fragments of shell and nodules of chert. Lenses or thin beds of dolostone, about a meter in thickness, usually occur in this rock. The surface of dolostone has been weathered to turn yellowish brown. Dolostone is mainly distributed in the eastern part of the area, especially in the Iscay Cruz area. A part of the rock is associated with the mineralization of lead and zinc, and a large amount of gossan has been formed on the surface. Gypsum ranging from 5 to 6 cm in width is embedded in the rock at Huacho sin Pescado. This formation contains no pelagic invertebrates, but a large amount of the fragments of shells, suggesting that this formation is littoral deposit (refer to Fig. 8).

(3) Thickness

This formation is usually about 150 m in thickness. The thickness attains 500 m in appearance at Huacho sin Pescado, but it seems to result from repeated folding of limestone beds.

(4) Correlation

The Santa formation was defined at the north of this area by Benavides (1956). This formation is widely distributed in the Central Andes. No identifiable fossils have been found in the central part of Peru, but Bendavides correlated this formation to the late Velanginian stage on the basis of the fossil evidence in the Santa formation distributed in the northern part of Peru. This formation conformably covers the Chimu formation.

3-3-4 Carhuaz Formation

(1) Distribution

The Carhuaz formation most widely distributed along the saddle of mountain range consisting of the Chimu and the Jumasha formations. This formation usually constitutes the wing of fold and the axis of syncline.

(2) Constituents and lithology

This formation is composed mainly of alternation of sandstone and shale and intercalates 3 or 4 thin limestone or dolostone beds, 1 to 2 m in thickness. Gypsum, 5 to 6 m in thickness, is intermittently embedded at about 50 m above the base of the formation. Variation of the interval of alternating bed of sandstone and shale ranges from a few centimeters to a few meters, and often attains several tens meters. Shale contains calcareous part and coaly layers. Sandstone is usually dark gray and fine to medium-grained, but the surface of the rock has been weathered to turn grayish brown. The shale shows various colors, dark gray, dark brown, black, pale green to brightening red.

In the middle and upper parts of the formation, shale with brightening red, is dominant, and especially that in the upper part can be used as a key bed in the field survey as it attains 150 m in thickness and is traceable.

The plant fossils and thin coal beds in the formation suggest that it accumulated in lake with streams by seashore. Thin intertrappean limestone indicates that shallow sea has once been formed. The sandstone in this formation has many cross laminations and ripple marks. Wilson (1963) estimated that the stream is in direction of about west at that time.

(3) Thickness

This formation is composed of flexible incompitent rocks, and therefore the thickness of this formation is extremely variable depending upon the form and the situation in the structure of the fold. The thickness is generally thin at the axis and wing of anticline and thick at the axis of syncline. This formation is usually 500 to 800 m in thickness, and becomes thicker to the west, attaining up to 1,000 m.

(4) Correlation

The Carhuaz formation was first defined by Benavides (1956) at the Santa valley. Since the Carhuaz formation described by Benavides, however, contains sandstone of the overlying Farrat formation, Wilson (1963) re-defined that the Carhuaz formation in this area excludes the overlying siliceous sandstone. This formation carries no identifiable fossils, but is stratigraphically correlated to the early Hautervian to Aptian stage. This formation conformably covers the underlying Santa formation.

3-3-5 Farrat Formation

(1) Distribution

The Farrat formation is distributed in a narrow zone, and interbedded between the underlying brightening reddish shales of the Carhuaz formation and overlying massive limestone of the Pariahuanca formation. This formation together with the Pariahuanca formation forms the small projections running through the slopes of a mountainside.

(2) Constituents and lithology

This formation is composed of light color, medium-grained siliceous sandstone and pale gray medium-grained calcareous sandstone. The siliceous sandstone constitutes the lower part of this formation, and the calcareous sandstone makes up the upper part of this formation. The siliceous sandstone consists mainly of the rounded quartz grains, and rarely contains the rock fragments. Black and white stripped patterns are irregularly observed in this formation. This formation exhibits cross laminations and is estimated to be delta and flood plain deposits. According to Wilson (1963), analyses of cross bedding indicate that the average direction of stream is southwest during the sedimentation.

The siliceous sandstone in this formation is similar to that in the Chimu formation, but is less cemented by silica and coarser-grained than that in the Chimu formation. The calcareous sandstone is slightly muddy and inhomogeneous as a whole, and contains brown patches. This rock is easily weathered and dissolved, and the surface turns pale brown.

(3) Thickness

The thickness of siliceous sandstone in the lower part is about 80 m, and that of calcareous sandstone in the upper part attains up to 40 m, but extremely varies from place to place. The total thickness is about 100 to 120 m.

(4) Correlation

Wilson (1963) defined that the siliceous sandstone in the lower part is the Farrat formation and claimed that the calcareous sandstone in the upper part corresponds to the base of the overlying Pariahuanca formation. There is, however, a little difference in lithology and sedimentary environment between siliceous sandstone and calcareous sandstone. Therefore, in this report, it is described that the calcareous sandstone constitutes the upper part of the Farrat formation. This formation carries no fossils, but is stratigraphically correlative with the late Aptian. Further, this formation is correlated to the uppermost part of the Goyllarisquizga Group distributed in the eastern area on the basis of the similarity of lithology and situation in stratigraphic sequence.

3-3-6 Pariahuanca Formation

(1) Distribution

The Pariahuanca formation in contact with the underlying Farrat formation is distributed in long and slender to surround the mountain chain constiting of the Jumash 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 air photographies.

(2) Constituent and lithology

This formation consists of the thick stratified dark gray massive limestone. This rock is compact to be protected from the weathering, and forms the small projections running through the slope of mountain. The surface of outcrop has been corroded to show wavy structure and turn pale gray. This rock becomes often soft and yellowish brown, owing to the severe weathering. Since this formation carries the fossils mostly broken into fragments and no marine fossils, it may have accumulated in the neritic sea.

(3) Thickness

This formation becomes thin eastward and thick westward. The thickness usually ranges from 80 to 200 m.

(4) Correlation

The fossil is found in the formation, but is poorly preserved in general. Benavides (1956) claimed, based on the occurrence of Paraoplite of Ammonoidea, that this formation is correlated to the early Albian, and belongs to the same stage as that of Inca formation distributed in the northern Peru. This formation thins to the west and disappears at the eastern side of the Continental Devide, suggesting the beggining of the Albian transgression on a large scale. This formation conformably overlies the Farrat formation. In this report, the Pariahuanca formation is restricted only to the massive limestone, while the sandy limestone in the lower part is included in the Farrat formation (see 3-3-5). The stratigraphic classification of the Pariahuanca formation in this report, therefore, slightly differs from that given by Benavides (1956) and Wilson (1963).

3-3-7 Chulec Formation

(1) Distribution

The Chulec formation, together with the overlying Pariatambo formation, is distributed to surround the mountain chain made up by the Jumasha formation. The boundary between Jumasha and Pariahuanca formations forms a topographical depression.

(2) Constituents and lithology

The formation consists of the alternation of marlstone, limestone, and shale. The intervals of alternation of strata vary in the range from 1 - 2 m to 10 - 20 m. The lowest part of the formation is composed of the alternation of marlstone and limestone, the middle part consists of the alternation beds of shale-marlstone and of marlstone-limestone, and the uppermost part consists mainly of marlstone. Fossils such as Gastropoda and Bivalvia occur abundantly in the alternating strata of marlstone-dolomite at the middle part. The marlstone is rather soft, pale gray to yellow, and has fissility. The dolomite is dark gray to pale gray, and the shale is black.

(3) Thickness

About 200 m.

(4) Correlation

The formation had been first described by McLaughlin (1924) as the lower part of Machay formation, but later it was defined as the Chulec formation by Benavides (1956). This formation produces various types of fossil abundantly, and the identification of these fossils was performed by many investigators. On the basis of the fossils, the formation is correlated to the early to middle Albian stage. The fossils are Ammonoidea such as Douvilleiceras. The study of fossil fauna clarified 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 westward and the sea became gradually deeper toward this direction. This formation is in conformable relation to the underneath Pariahuanca formation.

In this survey, several fossils were collected as shown in appendices A.5. (list of fossils) and A.6. (photographs of fossils). Those fossils are correlated to the Albian age.

3-3-8 Pariatambo Formation

(1) Distribution

The formation is distributed around the mountain chain and is in contact with the Jumasha formation which forms the mountain chain.

(2) Constituents and lithology

The formation consists of thin alternation of limestone, marlstone, and shale. All of these rocks contain butuminous materials, show dark gray to black color, and sometimes give off fetid odor. Limestone of several centimeters in thickness and marlstone or shale of several millimeters are alternated, and the cracks rectangular to bedding plane are developed. Near the axis of syncline intraformational foldings are repeated and the structure was made to be complicate.

(3) Thickness

About 150 m.

(4) Correlation

The formation had been first described as the upper part of Machay formation by McLaughlin (1924), and later was defined as Pariatambo formation by Benavides (1956). The formation has abundant Ammonoidea fossils and was correlated to the middle to later Albian stage by Willson et al. (1963). Judging from the lithology and fossil fauna, at that time the sea became shallower eastward and the formation is estimated to have accumulated under euxinic conditions. The formation is in the conformable relation to the underneath Pariahuanca formation.

3-3-9 Jumasha Formation

(1) Distribution

The Jumasha formation is distributed along the axis of syncline with NNW-SSE trend, forming the steep mountain chain brightening in light gray. Thus, the mountain chain made up by this formation, being a contrast to the rugged mountains composed of the Chimu formation, makes the landscape in this area diversified.

(2) Constituents and lithology

The formation consists mainly of dark gray massive limestone and in the lower part marlstone occurrs in places. The limestone contains dolomitic parts. The surface of outcrops are white and the wavy texture due to the corrosion is developed. In places mosaic texture due to the removal of muddy part by further weathering and corrosion is observed.

(3) Thickness

Although, since the upper part of this formation was lost by the erosion, the real thickness is not clarified, it is estimated at least to be 1,000 m. Harrison (1956) calculated the thickness near Rapaz to be 1,600 m. Cobbing (1973) estimated from the relation to the underneath Celendin formation to be 1,000 m to 1,800 m.

(4) Correlation

This formation had been first described as the limestone-dolostone formation attaining up to several hundred meters in thickness by McLaughlin (1924). Later, on the basis of the occurrence of Ammonoidea and the stratigraphic relation to the upper and lower formation, it was estimated by Wilson et al. (1963) to correspond to the late Albian to Turonian stage. The fossils such as Exogyra and Ostrea occur abundantly in this formation, but almost of them are crushed and may have accumulated along the coast under weak tide. This formation are correlated to the Cajamarca formation of the north Andes and has a conformable relation to the underneath Pariatambo formation.

3-3-10 Celendin Formation

The Celendin formation consisting mainly of marlstone constitutes the uppermost part of the Cretaceous calcareous group, corresponding to the Conician to Santonian stage. The Celendin formation in this area were completely denuded and does not crops out in this area, but it is observed to overlie conformably on the Jumasha formation to east of the surveyed area.

3-4 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, but are also distributed intermittently from place to place near the Continental Devide to the west of this area. The volcanic rocks have an unconformity relation to the Cretaceous sediments in the northwestern part, while are bounded on these sediments by fault in the southwestern part.

(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 gray in places. The phenocrysts of plagioclase, hornblende, and small amounts of biotite are 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 pale green, dark gray, 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 gray and contains the phenocrysts of biotite and quartze. The rhyolitic tuff is white to pale gray, medium to coarse-grained, and contain essential subangular breccias.

Conglomerate, consisting of the blocks of chert and silicified rock 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 volcanic rocks are distributed from the river bed of Rio Huaura (1,800 m above the sea level) to the summits of mountains on the either bank (4,800 m above the sea level), and the apparent thickness 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 Andes 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 Continuental 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.

(5) Bulk compositions and isotopic age

The bulk composition of the specimen of the andesite lava collected at the point about 6 km south of Chuchin (Sample No. AO-116) is given in

Table 1, and the isotopic age of this sample is presented in Table 2.

The rock is dark brown and contains plagioclase phenocrysts. Mafic minerals are altered and replaced by chlorite. Carbonate minerals are also observed. The groundmass shows intersertal texture.

The age of this rock by the K-Ar method is 17.9 ± 0.9 m.y., corresponding to the Miocene epoch and indicating that the age of this rock is surprisingly young. Since, as mentioned before, most mafic minerals are replaced by chlorite, the measurement of isotope ratio was made on the bulk rocks. By this method, the age younger than actual age is possibly obtained. However, it is more reasonable to interpret that the Calipuy volcanic rocks consist of various rocks which were formed during the volcanic activity for a long time.

3-5 Intrusive Rocks

3-5-1 Tonalite

(1) Shape and extent

Stock form tonalites intruding into the Cretaceous sediments occur 7 km northeast and 10 km north of Churin. The former extends to 3 km x 7 km and the latter 2 km x 0 5 km.

(2) Lithology

The tonalite is medium to coarse-grained, hollocrystalline, contains biotite and hornblende phenocrysts, and has granular texture. Plagioclase is the most abundant constituent mineral, and the minerals decrease in amount in the order of quartz, orthoclase, biotite, and amphibole (Sample Nos. CO-121 and CO-122). The tonalite body becomes finer in the grain size of minerals and richer in mafic minerals at the margin. Marble, hornfels, and skarn are produced in the surrounding rocks.

(3) Bulk compositions and isotopic age

The C.I.P.W. norms calculated from the bulk compositions plot in the quartz, potash-feldspar and plagioclase diagram as shown in Fig. 9. CO-121 was collected from the marginal part and CO-122 from the central part of the tonalite body. Both are plotted in the granodiorite region classified by Bateman et al. (1975).

The K-Ar isotopic ages were determined on the biotite separated from the individual samples, and are 10.6 ± 0.5 and 10.9 ± 0.5 m.y., respectively, indicating that the tonalite body is very young and was formed in the Pliocene epoch.

3-5-2 Tonalite Porphyry

(1) Shape and extent

The tonalite porphyry intrudes into the Cretaceous sediments to the west of Chiuchin. It is stock form and extends 5 km x 2.5 km.

(2) Lithology

The tonalite porphyry is fine to medium-grained and has plagioclase phenocrysts. Hornblende and biotite are also observed, but the latter is altered to chlorites. The rocks are fine-grained compared with the tonalite, and richer in the hornblende than in the biotite. The porphyry gives weak metamorphism to the surrounding rocks.

3-5-3 Dacite Porphyry

(1) Sape and extent

The dacite porphyry intruding into the limestone of the Jumasha formation occurs about 1 km west of the Iscay Cruz mineralized zone, and extends 1.5 km x 0.5 km. It appears to be stock shape, but may consist of many dikes. Around the porphyry, tuff and tuff breccia covering the Jumasha formation are distributed and are estimated to be formed before the intrusion of dacite porphyry.

(2) Lithology

The rocks have porphyritic texture and carry the phenocrysts of staut prismatic plagioclase, prismatic hornblend, and hexagonal biotite. The groundmass is aphanitic, but hollocrystalline in places. Silicification and impregnations of pyrite are observed. Weak alteration, silicification, and clay minerals are observed in the surrounding rocks.

(3) Bulk composition and isotopic age

The C.I.P.W. norms calculated from the bulk compositions resemble to those of the tonalite (Fig. 9). The K-Ar age is 31.3 ± 1.1 m.y., corresponding to the Oligocene epoch.

3-5-4 Dikes

The dikes of porphyry, dacite, rhyolite, and granite porphyry are found. The porphyry and dacite carry the phenocrysts of hornblende: the former is dark gray and the latter pale gray. The both rocks are distributed especially in the Iscay Cruz and Cerro Tapu areas, and have regularity in the intrusion direction: N 70° E in the former and N 70° W in the latter.

The rhyolite is light color, carrying a small amount of quartz and biotite phenocrysts, and flow-structure is observed in places. This rock crops out about 2.5 km and 1 km northeast of Iscay Cruz intruding in the direction of ENE-WSW.

The granite porphyry is light color, hollocrystalline, and has large phenocrysts of feldspar. This rock intrudes into the siliceous sandstone of the Chimu formation, in the NNW-SSE direction, 5 km west of Oyon.

Along the foot wall of the No.4 mineralized zone in Iscay Cruz, acidic dike estimated to be quartz-porphyry or rhyolite occurs. The dike is strongly silicified and altered to clay minerals, and dissemination of hematite is observed. Since the rocks receive alteration and leaching considerably, it is difficult to determine the original rock.

3-6 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 compressible force and emergence force of blocks produced through the Andean orogenic movement.

3-6-1 Folding 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. In the Oyon area, the lower Chimu formation cropping out in the western and eastern parts while the upper Jumasha formation lying in the central part, a synclinorium structure presents. In the eastern part of the Oyon area (on the zone connecting Iscay Cruz and Rapaz) and the middle western part (on the zone connecting Churin and Chiuchin) there is a zone where the folding structure is conspicuous. In this zone overturned structure is developed and the overtuned strata are often observed.

The cycle of folding is usually 2-3 km, and sometimes it becomes several ten meters and imbricate structure is developed (2 km east of Churin). The fold axis is horizontal, and according to Cobbing (1973), extends to 100 km. The dip of fold plane is usually 80^{o} to the west in the northern part of this area, though 80^{o} - 70^{o} to the east in the southern part. 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 (Pachangara area), while at the anticlinal part the lower strata are sandwiched in between the upper strata, showing plug shape (about 2 km east of Churin and 5 km west of Oyon).

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. It is observed that in the Iscay Cruz, eastern part of this area, thickness of the strata usually decreases at the wings of fold (Carhauaz formation and Pariatambo formation in the Iscay Cruz area), while increases at the axial part (Pariahuanca formation and Pariatambo formation in the Pachangara area). Near the axial part sometimes complicate intrastratum fold is developed and the thickness is considerably increased (Santa formation in the Huacho sin Pescado area and Pariatambo formation in the Pachangara area).

Assuming that the extent of strata does not change after and before the folding, the compressibilities of crust by folding in this area are 60 % at the part suffering the most violent folding and 63 % in average of the whole Oyon area.

3-6-2 Faults

In this area the faults of NNW-SSE, NE-SW, WNW-ESE, and ENE-WSW systems are observed.

Of these faults of NNW-SSE system parallel to the folding structure are most conspicuous. The thrust fault in the eastern part of the Oyon area belongs to this fault system. The block of west side, consisting of Chimu formation leans on that of east side, consisting Jumash and Celendin formations, along the thrust fault.

The faults belonging to the NNW-SSE system are observed in the western and central parts of the Oyon area (henceforth called Picoy fault and the Puñun fault, respectively). The nature of Picoy fault is similar to that of the thrust fault mentioned above, and the Chimu formation of the western side leans on the Jumasha formation of the eastern side. The vertical dislocation attains up to 1-2 km. The Calipuy volcanic rocks of the west side and the Chimu formation of the east side are bounded to each other by the Puñun fault. The fault is different in nature from the thrust fault mentioned before, and the west side block is depressed relative to the east side block. From the correlation between the strata, the vertical dislocation in this fault is estimated to be at least 2 km.

The faults belonging to the NE-SW and WNW-ESE systems cross obliquely with the folding structure and characterized by the horizontal displacement. Of these, the faults belonging to the WNW-ESE system are developed in the Viroc area, 3 km west of Oyon, and the Pucayacu area, 12 km southeast of Oyon, (henceforth called Viroc fault and Pucayacu fault, respectively). Both faults are accompanied mainly by horizontal displacement and the east side block is displaced westward. The apparent displacements are 1 km and several hundred meters in the Viroc fault and Pucayacu fault, respectively. The Viroc fault is developed in echelon and the strata are drugged by this echelon fault. The faults of this type are also developed in the Parquin area, southern part of the surveyed area. On the other hand, the faults of NE-SW system are not observed within the Oyon area, but well developed out of the surveyed area, 20 km northwest of Oyon. These faults as well as the Viroc fault are echelon fault, displacing the east block toward west. From the observations mentioned above, the faults belonging to these two fault systems are typical conjugate shear faults, which are

closely related to the formation of the fold structure.

The faults of ENE-WSW system are observed to cross with the fold axis at right angle in the Cochaquillo area, 19 km southeast of Oyon. The faults have the nature of tension fracture and the displacement are in different directions. The dikes in the Iscay Cruz area intruded mainly along the cracks of this system.

At the part received violent folding, since many bedding plane faults are developed, although the displacement by each fault is small, the displacement as a whole appears to be large. This caused saw-shape structure at the axial part of the fold. The horizontal fractures are develop at the intervals of several ten to several hundred meters, sometimes causing the displacement of several meters.

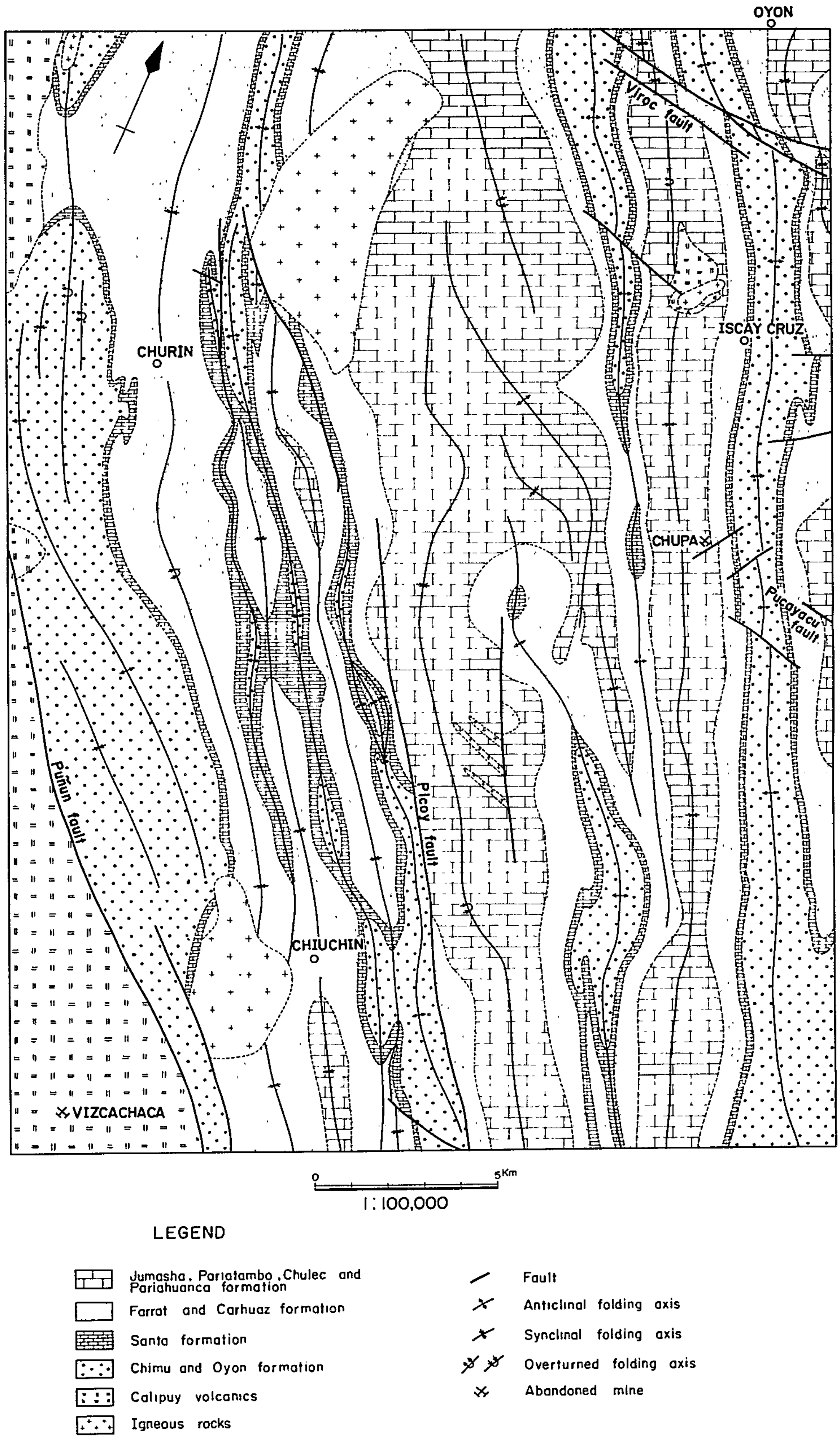


Fig. 6. Generalized Geological Map of the Surveyed Area

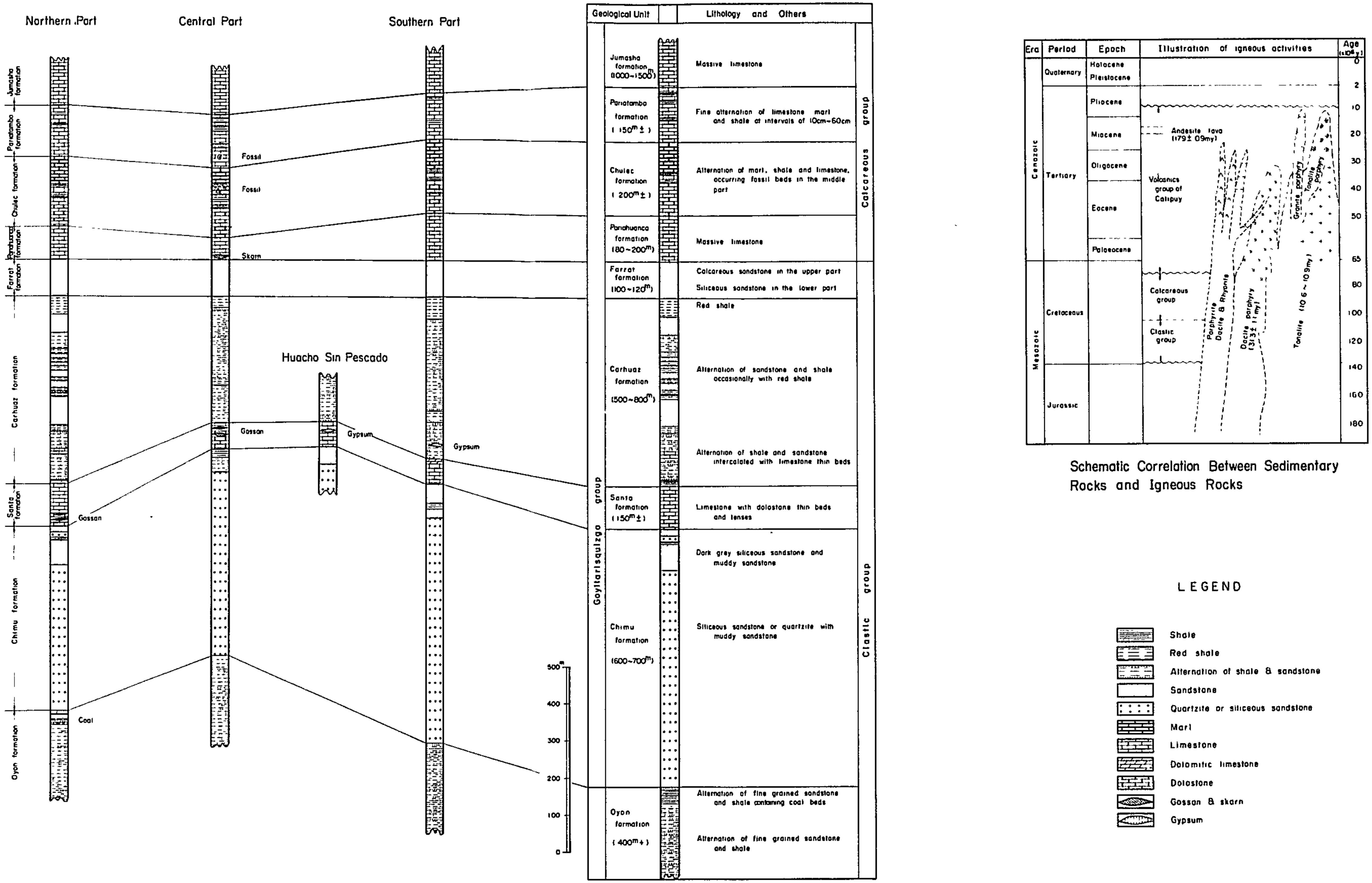
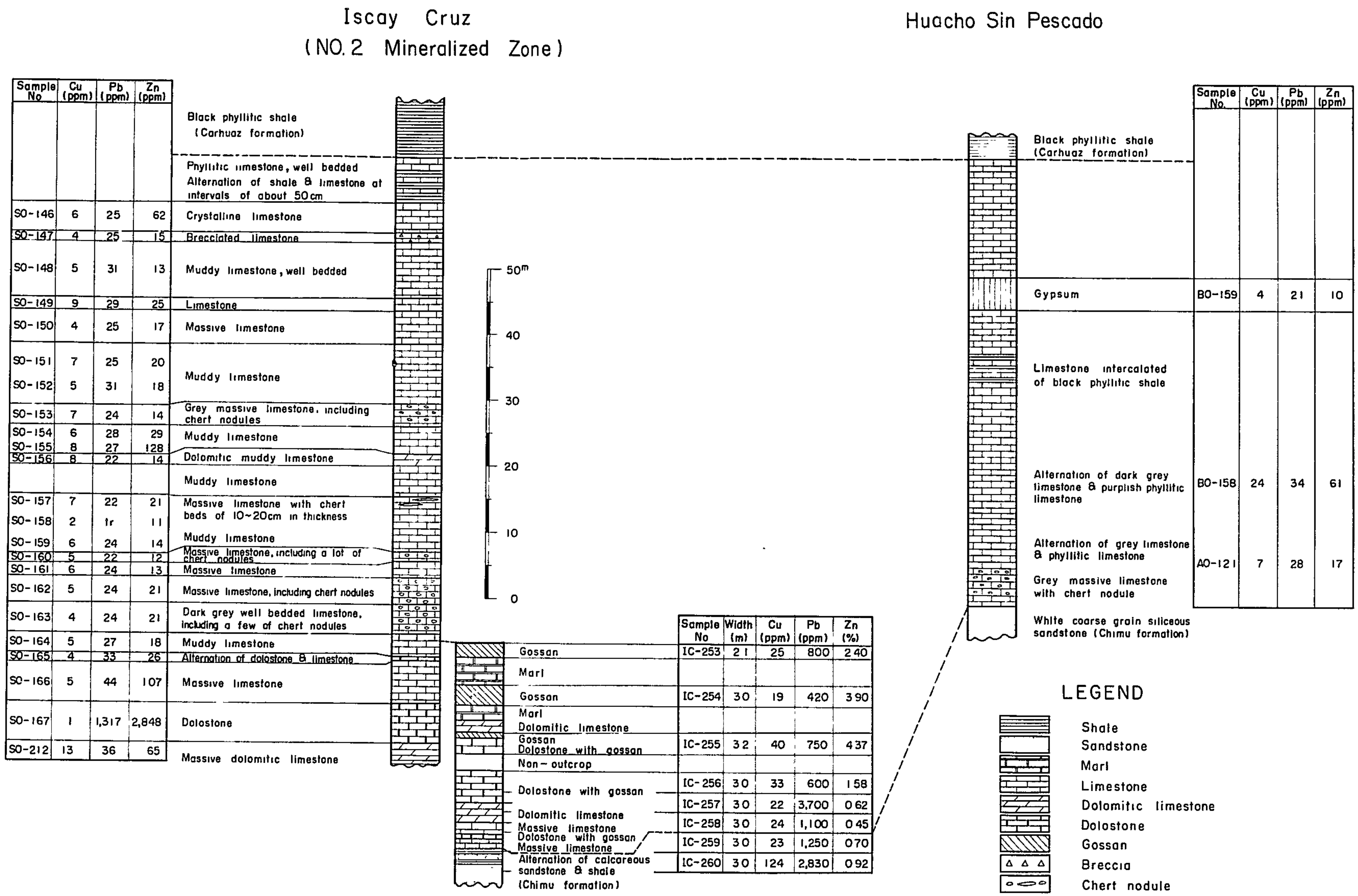


Fig. 7. Geological Columns and Igneous Activities in the Surveyed Area



Iscay Cruz (NO. 2 Mineralized Zone)

Sample No	Cu (ppm)	Pb (ppm)	Zn (ppm)	Lithology
				Black phyllitic shale (Carhuaz formation)
				Phyllitic limestone, well bedded; Alternation of shale & limestone at intervals of about 50cm
SO-146	6	25	62	Crystalline limestone
SO-147	4	25	15	Brecciated limestone
SO-148	5	31	13	Muddy limestone, well bedded
SO-149	9	29	25	Limestone
SO-150	4	25	17	Massive limestone
SO-151	7	25	20	Muddy limestone
SO-152	5	31	18	
SO-153	7	24	14	Grey massive limestone, including chert nodules
SO-154	6	28	29	Muddy limestone
SO-155	8	27	128	
SO-156	8	22	14	Dolomitic muddy limestone
				Muddy limestone
SO-157	7	22	21	Massive limestone with chert beds of 10~20cm in thickness
SO-158	2	tr	11	
SO-159	6	24	14	Muddy limestone
SO-160	5	22	12	Massive limestone, including a lot of chert nodules
SO-161	6	24	13	Massive limestone
SO-162	5	24	21	Massive limestone, including chert nodules
SO-163	4	24	21	Dark grey well bedded limestone, including a few of chert nodules
SO-164	5	27	18	Muddy limestone
SO-165	4	33	26	Alternation of dolostone & limestone
SO-166	5	44	107	Massive limestone
SO-167	1	1,317	2,848	Dolostone
SO-212	13	36	65	Massive dolomitic limestone

Lithology	Sample No	Width (m)	Cu (ppm)	Pb (ppm)	Zn (%)
Gossan	IC-253	2 1	25	800	2 40
Marl					
Gossan	IC-254	3 0	19	420	3 90
Marl; Dolomitic limestone					
Gossan; Dolostone with gossan	IC-255	3 2	40	750	4 37
Non-outcrop					
Dolostone with gossan	IC-256	3 0	33	600	1 58
	IC-257	3 0	22	3,700	0 62
Dolomitic limestone	IC-258	3 0	24	1,100	0 45
Massive limestone; Dolostone with gossan; Massive limestone	IC-259	3 0	23	1,250	0 70
Alternation of calcareous sandstone & shale (Chimu formation)	IC-260	3 0	124	2,830	0 92

Huacho Sin Pescado

Lithology	Sample No.	Cu (ppm)	Pb (ppm)	Zn (ppm)
Black phyllitic shale (Carhuaz formation)				
Gypsum	BO-159	4	21	10
Limestone intercalated of black phyllitic shale				
Alternation of dark grey limestone & purplish phyllitic limestone	BO-158	24	34	61
Alternation of grey limestone & phyllitic limestone	AO-121	7	28	17
Grey massive limestone with chert nodule				
White coarse grain siliceous sandstone (Chimu formation)				

Fig. 8. Geological Columns of the Santa Formation in the Iscay Cruz and Huacho Sin Pescado Area

Table 1 Assay Values and Normative Composition of Igneous Rocks

Component	Field No. / Rock Name	AO-116 Andesite	CO-121 Tonalite	CO-122 Tonalite	SO-176 Dacite-Porphyry
Assay Values	SiO_2	57.44 (%)	64.57 (%)	68.22 (%)	63.86 (%)
	TiO_2	1.02	0.65	0.44	0.61
	Al_2O_3	18.62	17.49	15.67	15.73
	Fe_2O_3	4.36	1.53	1.09	1.27
	FeO	3.22	2.87	2.30	6.33
	MnO	0.21	0.09	0.08	0.08
	MgO	1.94	1.96	1.19	1.21
	CaO	4.88	3.54	2.87	4.09
	Na_2O	4.01	4.05	3.77	2.38
	K_2O	2.11	2.68	3.33	2.94
	P_2O_5	0.30	0.20	0.16	0.18
	H_2O^+	1.61	0.26	0.53	1.27
	H_2O^-	0.47	0.07	0.12	0.23
	Total	100.19	99.96	99.77	100.18
Normative Composition	Q	13.33	19.48	25.05	24.61
	C	1.62	1.98	1.04	1.65
	Or	12.71	15.90	19.85	17.61
	Ab	34.58	34.39	32.18	20.41
	An	22.68	16.31	13.31	19.37
	Sub-Total	84.92	88.06	91.43	83.64
	En-Hy	4.92	4.90	2.99	3.05
	Fs-Hy	1.04	3.11	2.77	9.85
	Mf	6.44	2.23	1.59	1.87
	Il	1.97	1.24	0.84	1.17
	Ap	0.71	0.47	0.37	0.42
	Sub-Total	15.09	11.94	8.57	16.36
Ratio	Q	16.00	22.63	27.71	30.01
	Or	15.26	18.47	21.96	21.47
	Ab+An	68.74	58.91	50.33	48.51

Table 2 Isotopic Age of Igneous Rocks

Field No. (Rock Name)	Location	Mineral	Isotopic Age (m.y.)	$Ar^{40R}/gm \times 10^{-5}$	% Ar^{40R}	% K
AO - 116 (Andesite)	G3	whole rock	17.9 ± 0.9	0.113	52.1	1.57
				0.108	55.3	1.59
CO - 121 (Tonalite)	G1	biotite	10.9 ± 0.5	0.215	43.8	5.17
				0.225	51.0	5.16
CO - 122 (Tonalite)	G1	biotite	10.6 ± 0.5	0.267	56.6	6.36
				0.258	47.8	6.32
SO - 176 (Dacite-Porphyry)	G1	biotite	31.3 ± 1.6	0.133	39.2	1.09
				0.129	36.2	1.04

Constants used

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

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

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

Notes

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

m.y. : million years

Analysis performed at Teledyne Isotopes, Westwood, New Jersey, USA.

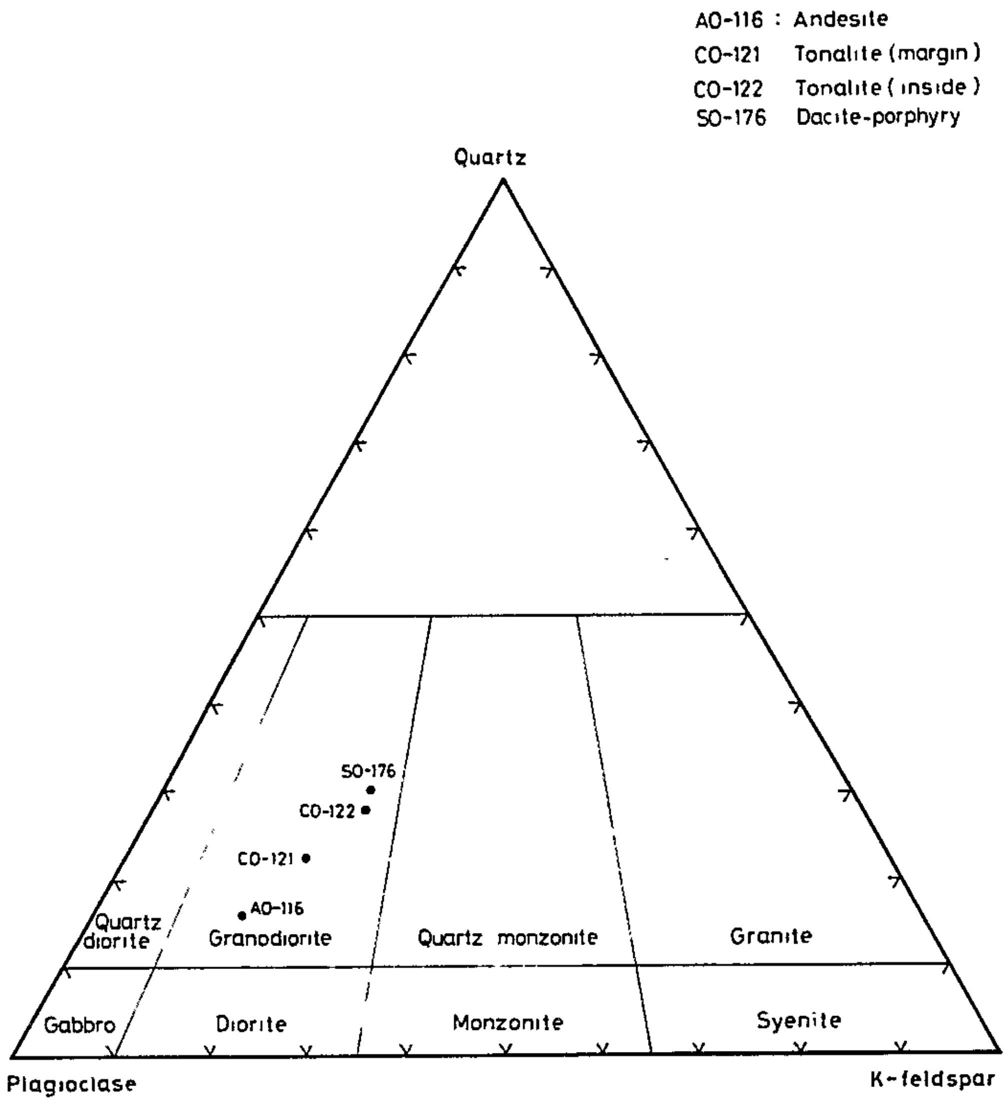


Fig. 9. Triangular Diagram of Quartz, K-Feldspar and Plagioclase for Normative Composition of Igneous Rocks

Chapter 4 Ore Deposits

4-1 Outline of the Ore Deposits

4-1-1 Metal Ore Deposits

In the Oyon area, there is no metal ore deposit being worked at present, but a few deposits were once investigated and operated; e.g. the Iscay Cruz mine, the Chupa mine, and the Viscachaca mine. On the other hand, the Raura mine, the Chauca mine and the Uchucchacua mine in the neighboring area to the north and east of the surveyed area are now worked.

These ore deposits belong to "la Sub-Provincia Polimetalica del Altiplano", according to the classification of ore deposits in the Republic of Peru (Bellido, et al., 1967). This ore belt is divided into two types; one occurs in Mesozoic sediments along the eastern side of the "Altiplano", and the other is found mainly in Mesozoic and Cenozic volcanics along the western side. The ore deposits in and around the surveyed area are distributed over these two zones and are situated in the southern part of Huallanca-Oyon area and surounded by Cerro de Pasco and Huaron-Carhuacayan areas.

The ore deposits are classified into the following three types, based on the occurrence and ore species (refer to Table 3).

(1) High temperature metasomatic ore deposits (copper, lead, and zinc), formed at the contact zone between intrusive rocks and Cretaceous limestones.

Raura ore deposit

Chupa ore deposit

(2) Fissure-filling type ore deposits (silver, lead, and zinc) in Cretaceous limestone and Tertiary volcanic rocks.

Raura ore deposit

Uchucchacua ore deposit

Chanca ore deposit

Viscachaca ore deposit

(3) Stratified or massive ore depooits in Cretaceous limestones.

Iscay Cruz ore deposit

4-1-2 Non-metal Ore Deposits

In the sedimentary rocks distributed in this area, coal and gypsum are found as a non-metal ore deposits. Some of them are worked on a small scale.

The coal is embedded in the Oyon formation which is the lowest formation of this area and crops out at the axial part of anticinal structure. The coal deposits are worked on a small scale at two localities in the southeastern and southwestern parts of Oyon.

Gypsums are embedded in the Carhuaz formation which is located in the Churin and Chiuchin areas in the western part of the surveyed area. The gypsums occur as lenses, about 5 m in maximum thickness and 50 to 70 m wide, within the lowest sandstone bed, and are mined on a small scale. Such gypsums are also found in the Santa formation exposed near Huacho sin Pescado. However, they are not workable.

4-2 Ore Deposits in the Surveyed Area

4-2-1 Iscay Cruz Ore Deposits

(1) Outline

The ore deposits are situated at about 10 km SSE of Oyon, and are distributed around the Lago Mancacucha. To attain the mine from Oyon, about 10 km by car and then about 8 km by horse are needed.

The ore deposits occur in the Santa formation occuping a west wing of anticline whose axial part consists of the Chimu formation. Iron-quartz gossans and lead-zinc sulphides occur in carbonate rocks such as limestone and dolostone and are distributed intermittently for 11 km long.

(2) Progress of surveys up to date

The surveys carried out in a part but their results on the Iscay Cruz deposit have not been made clear. Only the results of the electromagnetic survey for gossan zone by Evans et al. (1968) and description on the geology by Cobbing (1973) have been known. Although tracks of drilling are found at several points throughout this deposit, the results have never been recognized.

(3) Geology near the deposit

Cretaceous sediments, from the Chimu to Jumasha formations, are distributed in the Iscay Cruz area. These rocks are intruded by dacite and porphyrite stocks or dikes. The sediments strike NNW-SSE and dip ranging from 70° west to 80° east.

The Santa formation, a country rock of the ore deposits, overlies the Chimu formation and ranges from 60 to 105 m in thickness. Based on the above lithology, the Santa formation is divided into three members such as dolostone, limestone with nodules, and massive limestone in an ascending order. The dolostone is dark gray to yellowish brown and do not show a clear bedding plane because of their massive occurrence. Near the ore deposits, the dolostone attains about 20 to 25 m in thickness, but tends to become thin outword. The limestone with chert nodules ranges from 20 to 35 m in thickness and partly forms an alternation together with massive limestone. The nodules occur as plaly lenses about 10 cm thick. The uppermost massive limestone averages about 35 m in thickness. In some cases, dolomitic limestone seams are found in the upper and lower parts of the massive limestone.

Stratigraphy of the Santa formation in the Iscay Cruz area is shown in Fig. 8 (Chapter 3).

Sedimentary rocks near the deposit are distributed between the Chimu formation showing an anticlinal structure along the eastern side of the deposit and the Jumasha formation showing a synclinal structure along the western side. The Santa formation shows a monoclinal structure with dip to west. In some localities, however, the formation is partly overturned, and then dips eastward.

Fault and fissure systems are grouped as follows: one is a system showing the same trend as the strike of the formation and the other system crosses the strike. The former is difficult to be recognized on the surface. In the Chimu quartzite, however, a small scale displacement of several centimenters is recognized. Most axes of folding in the Oyon area dip westward. Accordingly, it is indicated that these foldings resulted from a strong compression and thrusting from west to east. Especially, where a prominant difference of competency such as between quartzite and limestone exists, it can be estimated that there are thrust faults parallel to the bedding plane. It appears from the above evidences that the dacite dikes showing a sheet-like structure within the Santa formation was formed by intrusion along such strike-trending fractures.

On the other hand, the faults and fractures cutting the sedimentary rocks are observed easily on the surface. Their systems are made up mainly of NW-SE and NWW-SEE trends. They are characterized by a small dislocation of the formations.

Some faults and fractures of the NE-SW system are accompanied by dacite dikes.

(4) Minerals indications

The Iscay Cruz ore deposits embedded in the Santa formation extend sporadically over about 11 km. For the convenience of consideration, the deposits are called No. 1 minerals indication, No. 2 minerals indication, ... and No. 6 minerals indication from north to south. The No. 1 to 4 minerals indications have been surveyed in detail.

1) No. 1 minerals indication

No. 1 minerals indication is the largest among all the indications, and is distributed around the Cumbre de Iscay Cruz in the northern end of Iscay Cruz area. Lead and zinc are contained in gossans.

Because the rocks near the minerals indication are covered by talus deposits composed of quartzite, gossans and carbonate rocks are partly exposed as country rocks. Therefore, the whole occurrence of the Santa formation and relationships to the overlying and underlying formations have never been made clear. Gossans occur in two parallel rows. The lower row (eastern side), approximately 1.2 km long and about 25 m maximum wide, crops out successively near the pass. In some cases, this row is separated into two or three rows. Accordingly, the mean width is about 12 m. On the other hand, the upper row is smaller than the above one, and is exposed intermittently for about 300 m along its strike. The maximum width is 7 m and the average width attains about 6 m.

Gossan shows massive and black to dark brown, preserving a original texture of country rocks, and is composed mainly of quartz and limonite with subordinate amounts of goethite and hematite. No sulfide minerals are observed by naked eyes. Also most of the lead and zinc minerals included in the gossan appear to occur as oxides. According to the results of X-ray diffraction and electron probe microanalysis, chalcophanite ($ZnMn_3O_7 \cdot 3H_2O$) are recognized as one of zinc minerals (Sample Nos. SO-137, IC-103, -234). As for the only one example, a few sphalerites replaced largely by chalcophanite occur in calcite veinlets which is observed in dolostone in contact with the gossan (Sample No. SO-135). Lead minerals have never been found.

The result of chemical analysis for the gossan is shown in Fig. 2 etc. Both of the lead and zinc contents are the highest in the samples from the pass, and their grades tend to decrease toward south. Analyses of the upper and lower gossans are summarized as follows:

	Average length of sampling (m)	Cu (ppm)	Pb (%)	Zn (%)
Lower row	12.9	31	0.78	4.83
Upper row	5.7	24	0.09	4.02
Average	11.6	30	0.71	4.76

2) No. 2 minerals indication

No. 2 minerals indication appear in the southern area about 700 m south of the southern border of the No. 1 minerals indication. The No. 2 minerals indication, approximately several to 50 meters long and 1 to 23 m wide, is dotted within an area about 650 m long. This indication is smaller than the No. 1 minerals indication, and is poorly traced on the surface. Furthermore, the gossan is not well developed as it is observed in the No. 1 minerals indication, but is of a network remaining the country rocks of dolostone.

Similar to the No. 1 minerals indication, the No. 2 minerals indication is black to dark brown, and contains mainly quartz, goethite, and hematite. Most of lead and zinc ores appear to be oxidized. In the old drift which is in contact with the overlying Carhuaz formation, a vein-form white clay zone, parallel to the strike and about 0.5 to 1.0 m wide, is found. Sphalerite is recognized in quartz-kaoline zone. A small amount of chalcophanite is also detected (Sample No. IC-2) by the X-ray diffraction.

The average grade of samples from the gossan is 35 ppm for Cu, 0.14% for Pb, and 2.59 for Zn, and those from the old drift is 34 ppm for Cu, 0.13 % for Pb, and 6.93 % for Zn in width of 1.9 m.

3) No. 3 minerals indication

No. 3 minerals indication is situated about 600 m south of the No. 2 minerals indication and arranged along Lago Quellaycocha. The minerals indication appears only in five exposures of dolostone which is isolated in an area, about 800 m long, and near the indication talus deposits composed mainly of quartzite is remarkably developed. Therefore, the continuity and relationship to the overlying and underlying rocks have never known, but the scale of the indication is probably a little smaller.

The No. 3 minerals indication is characterized by presence of significant amounts of sulfides, contrary to the Nos. 1 and 2 minerals indications. The indication is devided into two types by the occurrence; one is a disseminated type in dolostone and the other is a concentrated type around the massive pyrite. The former type is main in this indication, whereas the latter type is found only near the southern end of this area.

Dolostone in the former type is gray and a little coarse-grained. On the surface of dolostone iron oxides are disseminated, but the core remains comsiderably fresh. Network type gossans similar to those in the No. 2 minerals indication are also found. Sphalerites occur as pale brown to pale yellow and irregularly granulated crystals about 0.5 to 1.0 cm in diameter. The third exposure from north extends over about 30 m with a width of 5 m and the other exposures are rather small. At the exposures, sphalerite is found in a scattered pattern. Galena exhibits more irregular form than that of sphalerite, and occurs in fissurs.

The average grade of samples from four localities is 53 ppm for Cu, 0.12 % for Pb, and 0.73 % for Zn in average width of 5.0 m.

As for the latter type, a massive pyrite ore body replacing the dolostones is recognized. Ore minerals such as mainly galena are found in druses and cracks on the outer side of the massive pyrite. Chemical analysis shows that the rock specimen of about 4.2 m in width contains 30 ppm for Cu, 12.33 % for Pb, and 2.65 % for Zn.

4) No. 4 minerals indication

No. 4 minerals indication is distributed around the Cumbre de Huanda. The Santa formation near the indication is made up of dolostone and limestone. Judging from the relation to the overlying and underlying formation, the Santa formation is about 70 m in thickness and tends to thin southward. Near the contact with the underlying Chimu formation, acidic intrusive sheet of about 10 m in thickness is found.

Two rows of the No. 4 minerals indication exhibit a linear arrangement. The lower indication appears at the central part of the Santa formation with a width of about 12 m near the pass. At the other locality the indication thins out and shows an intermittent distribution within an area of about 800 m in length, where the dolostone is partly metasomatized. In the southern area of the pass, the indication is covered by talus deposits of quartzite. The upper indication is composed of several layers about 100 m long and 1 m wide near the pass. In the southern area of the pass the indication has never been found.

The main ore minerals in the No. 4 minerals indication are sphalerite and galena. Sphalerite in the lower indication is concentrated and embedded as a small lens, about 2 to 5 cm thick, in crystalline dolostones. Futhermore, the dolostones are also impregnated by a small amount of sphalerite. The sphalerite is pale brown to pale yellow, coarse-grained (2 to 5 mm in diameter). A small amount of chalcopyrite dotted in form are observed in the sphalerite by the microscopic observation. (Sample No. IC-301, -342).

In the upper indication, dolostones as a country rock are composed of alternation of thin layers of limestone and shale. Near the contact with shale they are subjected to hydrothermal alteration. Sphalerite near the contact is scattered, and are pale brown and coarse-grained (5 to 7 mm in diameter). Galena is about 2 to 3 mm in diameter. A small amount of pyrite is rarely found in dolostone.

The minerals indication observed in talus deposits at the southern end of this area is characterized by massive pyrites. The pyrite is fine-granined and compact. Limonite formed by oxidation is occasionally found. Galena occurs impregnatedly in pyrite ores. Occurrence of sphalerite has remained unclear.

The grade of smaples from the No. 4 minerals indication is as follows:

	Average length of sampling (m)	Cu (ppm)	Pb (%)	Zn (%)
Lower indication	7	916	0.16	2.10
Upper indication	7	601	0.08	1.31
Average	7	811	0.13	1.84

5) No. 5 minerals indication

No. 5 minerals indication is situated about 4 km south of the Cumbre de Huanda. In this area, actinolite, garnet and epidote represent as main constituent minerals of skarn in limestones of the Santa formation. The skarn zone, approximately 20 m wide and 100 m long, shows a parallel arrangement to the bedding plane.

Ore mineral in the No. 5 minerals indication is magnetite, idiomorphic crystal of 2 to 3 mm in diameter. Another ore minerals are not observed. A chemical analysis for this skarn shows 10 ppm Cu, 22 ppm Pb, and 3,455 ppm Zn. (Sample No. NO-161).

6) No. 6 minerals indication

No. 6 minerals indication is situated at the southern end of the Iscay

Cruz ore deposits. The indication, about 1.5 km south of the No. 5 minerals indication, is scattered intermittently within an area of about 2 km long and about 20 m wide. This minerals indication similar to those of Nos. 1 and 2 is characterized by iron minerals and quartz. A chemical analysis for grab samples is as follows:

	Cu (ppm)	Pb (%)	Zn (%)
Northern part	2	11	2,006
Southern part	8	120	4,429

4-2-2 Chupa Ore Deposit

This ore deposit is situated 500 m west of the No. 5 minerals indication of Iscay Cruz. The deposit assciated with zinc and copper is a contact metasomatic deposit produced by replacing the Pariahuanca limestone which forms upper part of the Santa formation, and the underground prospectings for this deposit have already been performed at 2 or 3 levels. According to Evans et al. (1968), the deposit was called the Fiel deposit and was prospected by Cerro de Pasco Corporation, but the details of results have not been made clear. Fig. 10 is a schematic map of the deposit.

The ore deposit and its surrounding area is lain in the west wing of anticline structure, whose axial part consists of the Jumasha formation, and are composed of Farrat sandstone and Pariahuanca limestone. The sandstone is distributed to the east side of the ore deposit, medium to coarse-grained, white in color, and becomes calcareous at the contact with the limestone. The limestone is massive, compact and gray to bluish gray. The both strata are in the relation of conformity, and the strike and dip of boundary between them are NWW-SEE and about 75°E, respectively, and appear to be overturned slightly. The faults of E-W system are well developed and the displacement of strata of several maters are observed.

The distribution of skarnization zone is controlled by this fault system; that is, the skarnization zone stretches along the strike direction and its development is marked at the places where the faults of E-W system are also marked. The skarn at the upper part (4,620 m on the sea level) is estimated to attain up to about 40 m in width and about 200 m in length, while at the lower part (4,560 m) less than 20 m in width and 90 m in length are confirmed. The skarn minerals are composed mainly of hedenbergite, actinolite, and garnet, and epidote and lievrite are observed in places.

The ore minerals consist mainly of sphalerite, chalcopyrite, and hematite with subordinate amount of magnetite, pyrrhotite, and galena. These minerals are not homgeneously disseminated in the whole skarn zone. It seems to be existent the complicate control and zonal arrangement of mineralization, such as the dominant dissemination of only sphalerite in places or chalcopyrite in other places, judging from the grab sampling in the lower drift (refer to Fig. 10; average grade is 1.56% Cu, 0.03% Pb, and 13.89% Zn). Igneous rocks related to the skarnization and mineralization in this ore deposit are not found.

4-2-3 Viscachaca Ore Deposit

The ore deposit is located at the southwestern corner of the surveyed area, 15 km southwest of Chiuchin. The mine from which silver was mined exist, but are not worked at present.

The neighbouring areas of ore deposit consist of andesitic lavas and tuffs of the Calipuy volcanic rocks intruded by syenite porphyry. The rocks, however, poorly are exposed because of weathering, and therefore the details of shapes and extents of the porphry is not clarified. porphyry is abundant in potash-feldspar phenocryst (Sample No. AO-117) and are received argillization and sericitization to become white and brittle.

The ore deposit is vein-type, precipitating in the part of vertical fault with the strike of N 80° E and 1 m in width. In the ore pipe at the pit mouth, two layers of ores, 12 cm and 16 cm in width respectively, consisting of galena, sphalerite, and pyrite are observed. Main gangue minerals are sericite, clay minerals, and quartz. The analyses of the specimens from the ore pipe are as follows:

Sample No.	Ag (g/t)	Cu (%)	Pb (%)	Zn (%)
AO-117	6.75	0.05	7.6	11.0

4-3 Main Mines in the Peripheral Area

4-3-1 Outline of the Mining Industry

Although there are no mines in the Oyon area, in the neighboring areas Roura silver-lead-zinc mine, Chanca silver-lead mine, and Uchucchacua silver mine are being worked. The productions in these mines are 1,100 t/day, 200 t/day, and 200 t/day and the employees are 800, 450, and 200, respectively. The production scale of these mines are small to moderate, but about 10,000 peoples including the employees' families are depending their life on these mines.

The development of these mines gives a great impact to the local economy and makes the mountainous area active, where peoples are carrying on old-fashioned farmings and cattle breedings, through the improvements of infrastructures such as road and stable earning.

Coal minings are also operated, though they are in small scale and remains in old-fashioned handiwork. Their contribution to the local economy therefore is not so great.

4-3-2 Raura Mine

(1) Present condition

The mine belongs to Cia. Minera Raura S.A. and produces silver, lead, and zinc. It was opened in 1961 and has been worked for 18 years since that year. The production per day is 1,100 tones. The employees are about 800.

(2) Location and geography

The mine is located 20 km north of Oyon, at 4,700 m above the sea level in the Condillera Raura belonging to the Continental Devide, very close to the higher mountains such as Cerro Santa Rosa (5,706 m) and Cerro Caudalosa (5,685 m), and surrounded by glaciers. It takes about an hour and a half to attain the mine from Oyon by car.

(3) Outline of the geology (Fig. 11)

Cretaceous limestones belonging to the Jumasha and Machay formations are distributed around the mine. The composite stocks consisting of diorite, dacite, and dacitic prophyry intruded into these limestones. This composite intrusive spreads over 2 km east to west and 7 km north to south and gives the metasomatism and alteration to the surrounding limestones, such as marblization, silicification, epidotization, and garnetization. The brecciations are also observed in places.

The mine lies in the thrust zone, where the main thrust fault of NNW-SSE trend runs and the fault fractures of E-W direction, which are associated with the mineralization, are also densely developed.

(4) Ore deposits

There are two types of the ore deposits, the ore veins filling the fractures of E-W direction mentioned above and the metasomatic skarn deposits replacing the limestones. The veins occur in the intrusive bodies as well as in the replaced or altered limestones.

The main ore deposits are distributed in the areas of Hada, Catuva, and Flor de Loto from the south to the north. The type and property of the ore deposits are considerably different according to each area.

Hada area: Several echelon veins with the strike of E-W and steep dip to south occur in the dacite. Usually they are about a meter in width and sometimes attain up to about 4 m, and extend ranging 200 to 400 m. The ore minerals consist of galena, sphalerite, and pyrite, while the gangue minerals are quartz, calcite, and rhodochrosite. The ore deposits in this area are characterized by the dominant occurrence of galena.

Catuva area: A skarn type metasomatic ore deposit occurs in the limestone sro'.nding the diorite. The ore body with 40 m in width extends over 60 m and 300 m in the horizontal and vertical directions, respectively.

The ore minerals consist mainly of sphalerite, galena, pyrite, and argentite, while the main gangue minerals are garnet, green skarn minerals, quartz, and calcite. The ore body is characterized by the presence of sphalerite rich in the Fe content, so-called marmatite.

Flor de Loto area: The vein type ore deposits with E-W direction and 0.9 m in the average width occur in the altered limestone suffering silicification, epidotization, and garnetization. Many paralled veins exist. The ore minerals consist mainly of galena, sphalerite, and chalcopyrite with subordinate amounts of tetrahedrite and freibergite. The main gangue minerals are quartz, calcite, and gypsum. The ore deposits in this area are characterized by cupper and lead.

The total ore reserves in these three areas attain to 2.9 million tones and their grades for Cu, Pb, Zn, and Ag are 0.34 %, 4.86 %, 5.44 %, and 5.64 oz/t, respectively.

(5) Outline of the operations

The ores are being mined mainly by cut and fill method. The capacity of mineral dressing is 1,200 t/day. The crude ores from the three areas are treated in the different systems respectively and the concentrate ores of seven kinds are produced.

The recent results of production in each area are as follows:

Area	Production amounts (t/month)	Ag (oz/t)	Pb (%)	Zn (%)	Cu (%)
Hada	10,300	3.23	9.12	2.92	0.12
Catuva	14,500	4.00	2.61	6.01	0.30
Flor de Loto	5,500	8.74	2.69	3.44	0.76

In the Flor de Loto area, the Cu-concentrates are produced in addition to the Zn- and Pb-concentrates. Silver is concentrated into the Cu-concentrate ores whose grade for Ag is 300 oz/t. On the other hand, in the other areas, since Cu occurs as an exsolution form of chalcopyrite in sphalerite, the separation is difficult. Therefore, only the Pb- and Zn-concentrates are produced. In this case, silver concentrates into the Pb-concentrate ores in which the Ag grades are 80 oz/t and 23 oz/t in the Catura and Hada areas, respectively.

The mine owns a water-power station with the ability of 1,000 KWH.

The investigation on this mine was carried out in the cooperation with the following persons:

Superintendente General,	Ing° Roland Tejada
Assist. Superint. y Jefe de Planta,	Ing° Octavio Ochoa Torres
Departmento de Geologia,	Ing° Victor Vizcarra
	Ing° Fernando Zuloaga

4-3-3 Chanca Mine

(1) Present condition

The mine belongs to Cia. Minera Raura S.A. and produces silver and lead. It has been operated since 1975 and is producing 180-200 t/day at present. The employees are about 450.

(2) Location and geography

The mine is located at 4,700 m above the sea level and lies 10 km northeast of Oyon. Rio Gorgor, a branch of Rio Pativilca, has its source near the mine. The surrounding area shows plateau as a whole, although the glacial landform is developed. It takes about an hour to attain the mine from Oyon by car.

(3) Outline of the geology (Fig. 12)

Andesitic, dacitic, and basaltic agglomerates, tuff breccias, and lavas belonging to the Calipuy volcanic rocks are distributed in the surrounding area.

The dikes and stocks of dacite intrude these volcanic rocks which covers unconformably the Cretaceous sediments. In the northern part, the Pariahuanca, Farrat, and Carhuaz formations crop out, having an unconformable abut relation with the volcanic rocks.

Many faults of the NNW-SSW direction by which the volcanics are dislocated develop at the intervals of 200 m. The direction of these faults are in coincidence with that of folding axis of the Cretaceous sediments, reflecting the structure of underlaying strata. This structure appears to controll not only the over-laying volcanics, but also the directions of the dacite intrusives. The fissures developing between these faults are associated with mineralization.

(4) Ore deposits (Fig. 13)

The silver veins of the ENE-WSW direction occur over a wide area in the volcanics, and mineralized area extends over 700 m in E-W direction and 2,000 m in N-S direction. There are 18 veins in total, of which 7 veins such as Canaderia and Sirvia etc. are worked. The Canaderia vein extends over 1,800 m, but the workable shoot extends about 600 m. The vein varies considerably in the width and attains 2 m in the maximum, but usually less than 1.5 m. The average width is 0.85 m. The dislocations of the veins by the faults of NNW-SSW direction, up to 100 m, and several merters dislocations by the fissures with gentle dip make the vein system complicate.

The main ore minerals are galena, pyrite, proustite, pyrargyrite, and tetrahedrite, while the gangue minerals rhodochrosite, rhodonite, calcite, quartz, and siderite.

Near the surface sulfide minerals are oxidized and leached. The extensions of ore shoots in vertical direction are usually about 400 m and the following zonal arrangement of ore minerals is observed:

(upper) Sb - Ag - Zn - Pb - Cu - Fe (lower)

The ore reserve is estimated to be 360 thousand tones. The average width of the veins is 1.04 m and Ag- and Pb-grades are 15.9 oz/t and 2.14%, respectively. The cut-off width of veins is 60 cm and cut-off grade is 9 oz/t.

(5) Outline of the operation

The ore bodies are being mined by the methods of cut and fill and shrinkage. The mill capacity is 250 t/day and the concentres of silver and lead are produced. The recent production is as follows:

	Production amounts (t/day)	Grade	
		Ag (oz/t)	Pb (%)
Crude ore	180	11.5	0.90
Ag-Pb concentrate	5-8	290	17

The investigation on this mine was performed in cooperation with Ing° Jose Canales Ruiz and Ing° Jujo de la Cruz of Departmento de Geologia.

4-3-4 Uchucchacua Mine

(1) Present condition

The mine belongs to Cia. de Minas Buenaventura S.A. and produces silver. It has been operated since 1974 and is producing crude ore of 180-200 t/day at present. The employees are about 200. To increase the production up to 500 t/day after 1980, the production facilities are being reinforced.

(2) Location and geography

The mine, which is located 10 km east of Oyon, lies at 4,600 m above sea level. In the east of the mine the peaks higher than 5,000 m stretch, forming the Continental Devide. The typical glacial topography develops in the surrounding areas of the mine. It takes an hour to reach the mine from Oyon by car.

(3) Outline of the geology (Fig. 14)

The mine lies in the thrust fault zone of the Cretaceous sedimentary rocks. The Jumasha formation consisting of limestone, is widely distributed in the surrounding area. In the north of the mine Calypuy volcanics covers the limestones unconformably, and in the west of the mine the middle and upper Cretaceous formations crop out and are bounded on the volcanics by the thrust. Many small intrusive bodies of dacite, associated with brecciation and skarnization, occur in the Jumasha limestone near the mine.

The thrust faults parallel to the folding structure extend from north to south, reflecting the geological structure in this area. Near the mine many faults and fissures with the NE-SW and E-W directions, the branches of the main thrust faults, are well developed and a part of them forms the ore veins of this mine.

(4) Ore deposits (Fig. 14)

The veins, carrying mainly Ag with subordinate amounts of Pb, Zn, and Mn, are found in the Jumasha limestones. These veins with the NE-SW and E-W directions occur in the fault-fracture zone. The widths are usually 1-1.5 m but are very variable, and the shoots vary their width at an interval of several ten meters.

The ore minerals consist of argentite (plata roja), galena, sphalerite, tetrahedrite, pyrite, and are characterized by the abundance of Ag- and Mn-minerals. The gangue minerals are mainly composed of calcite and rhodochrosite, and quartz is absent. The ore minerals disseminate in the fracture zone and the boundaries with the limestones are obscure.

The three veins, Socorro, Luz, and Casualidad are mainly worked at present.

Socorro vein: It occurs on the south side of the Uchucchacua fault of NE-SW direction. The strike is ENE dipping 50° - 60° to north and horizontal extension is 400 m with vertical extension of 300 m.

Luz vein: Located south of the Socorro vein, the vein occurs in the Socorro fault fracture zone of E-W direction. The horizontal extension attains 700 m and the vertical extension is 300 m. In the lower part it intersects the Soccoro vein.

Casualidad veins: Located south of the Luz vein, the veins consist of the pairs of veins with the E-W and ENE-WSW directions: one is 60° N in dip and 300 m in extension, and the other is 70° N and 500 m. The horizontal extensions of the both veins are 300 m.

Zona Nueva: Several veins with about 1 m in width occur to the east of the Socorro and Luz veins and are now under prospecting. Many small veins of 20-30 cm width are also found.

In addition to the ore deposits mentioned above a new minerals indication is found in the northern part of the Socorro vein.

The ore reserves in the Luz, Socorro, Casualidad, and Zona Nueva are estimated to be a million ton, a half million ton, a half million ton, and three million tones, respectively. The Ag-grade is inferred to be 13-14 oz/t.

(5) Outline of the operation

The ores are being mined mainly by the cut and fill, and partly by the shrinkage methods. Since the ores contain considerable amounts of manganese, the final concentrates are obtained by removing the manganese from the flotation bulk through the sulfate leaching process. The recent results of productions are as follows:

	Production amount (t/day)	Grade Ag (oz/t)	Pb (%)	Zn (%)	Mn (%)
Crude ore	180	13-15	1	2	5
Bulk concentrate	15-25	120	9	3-4	20
Leaching concentrate	5-10	200-230	200-230	5-10	1

The invesrigation in this mine was performed in cooperation with the following persons:

Superintendente,	Ing^{o} Carros Guzman Arpa
Assistente de la Superintencia,	Ing^{o} Luis Guzman
Departamento de Geologia,	Ing^{o} Flavia Paz

4-3-5 Coal in the Oyon Area

(1) Outline

The occurrence of coal in the Oyon area has been known among the inhabitants from old time. They have dug the coal at the outcrops and used as fuel for their own use. However, the detailed survey has not been carried out until middle of the nineteenth Century. The coke production was attempted and good quality cokes were obtained late nineteenth Century. Recently the comprehensive surveys and studies have been carried out by the SIDERU PERU. However, since the structure of strata carring the coal beds is complicate and the coal beds are small scale and complicated, the development of coal mines has not yet progressed. At present the coal at the outcrops is being dug in small scale using picks, shovels, and handcarts.

Many small coal mines exist in the Pampahuay area along Rio Pampahuay, 7 km southeast of Oyon. Many pit mouthes are distributed over

7 km, but most of them are unworked. The coal productions in this area are only about 200 t/month and about one hundred people are engaging in the coal mining.

(2) Occurrence

The coal occurs in the alternation beds of sandstone and shale in the Oyon formation along the anticlinal axis. There are 4 beds of about 1 m in width. As the folding angle in the axial part usually is acute, the dips of coal beds become steep. The coal beds are also dislocated by many faults and fissures. Receiving the influence of orogenic movement, the extension and thickness of the coal beds are remarkably variable.

The outcrops of the Oyon formation carrying the coal beds are restricted only in the small extent. Nevertheless, since the Oyon formation lies widely beneath the surface, the coal reserves in this area are considered to count for remarkable amounts. Further surveys are expected to clarify the forms, scales and condition of occurrences.

(3) Property of coal

The property of coal is antracitic (antractas) or bituminous (Hulla seca and Hulla negra). The antracites are lusterous black, while there are two types in the bituminous coal: one is black with conchoidal fracture and resinous luster, and the other is black with poor luster. This may be caused by the removal of volatile components and concentration of fixed carbon during the orogenic movement associated with regional metamorphism. The property of coal is very variable. The representative analyses (Luis et al., 1921) are as follows:

Property	Area	Components (%) Water	Volatile	Carbon	Ash	Calory (Kcal/kg)
Anthracite	Gazuna & Quichas	2.85	9.00	79.00	9.15	7,371
Bituminous	Saquicocha & Conocpata	1.00	19.40	70.50	9.10	7,876
Bituminous	Gazuna & Quichas	3.20	22.70	62.50	11.60	7,486

In general, the coal in this area are poor in volatile components, rich in carbon, slightly rich in ash content, and low in calory.

Table 3 List of Mineralized Zones in the Surveyed Area

No.	Area	Location	Kind of Ores	Host Rock		Type of Miner-alization	Mode of Occur-rence	Scale of Mineralized Zone	Scale of Unit Ore Body		Direction	Grade of Ore	Ore Minerals	Gangue Minerals	Remarks
				Formations	Lithology				Length	Width					
1	Iscay Cruz	IC-No. 1	Pb, Zn	St	Ls, Do	rep	mas-band	Length 1,200m	140m	25m	NNW-SSE	Cu 30ppm Pb 0.71% Zn 4.76%	Zn-Ox (Cph)	Qt, Gt, Hm, Dm	
		IC-No. 2	Pb, Zn	St	Ls, Do	rep	mas-band	Length 650m	50m	23m	NNW-SSE	Cu 35ppm Pb 0.14% Zn 2.81%	Zn-Ox (Cph)	Qt, Gt, Hm, Dm	
		IC-No. 3	Pb, Zn	St	Ls, Do	rep	mas-band	Length 800m	30m	5m	NNW-SSE	Cu 49ppm Pb 2.24% Zn 1.06%	Sp, Gl	Dm, Hm	
		IC-No. 4	Pb, Zn	St	Ls, Do	rep	mas-band	Length 800m	80m	12m	NNW-SSE	Cu 811ppm Pb 0.13% Zn 1.84%	Sp, Gl	Dm, Hm, Gt	
		IC-No. 5	Pb, Zn	St	Ls	skarn	dis	Length 100m	100m	20m	NNW-SSE	Cu 10ppm Pb 22ppm Zn 3,455ppm	Mt	Ac, Gn	
		IC-No. 6	Pb, Zn	St	Ls, Do	rep	mas-band	Length approx2,000m	-	approx 20m	NNW-SSE	Zn 3,200ppm	Zn-Ox	Qt, Gt Hm, Dm	
2	Iscay Cruz	Chupa	Cu, Zn	Ph	Ls2	skarn	dis	Length approx 170m	90m	22m	NNW-SSE	Cu 1.56% Pb 0.03% Zn 13.89%	Sp, Ccp Po	Gn, Hd, Qt	Under Explo-ration
3	Chiuchin	Visca-chaca	Ag, Pb Zn	Cp	Vol	fra-fill	vein	Length approx 100m	50m	1m	N80°E	Cu 0.05% Pb 7.6 % Zn 11.0 %	Gl, Sp	Qt	Abandaned
4	Raura	Raura	Ag, Pb, Zn	Jm, Cp	Ls, Vol	fra-fill	vein	4,000mx2,000m	300m	1~3m	E-W	Ag 5.6 oz Cu 0.3 % Pb 4.9 % Zn 5.4 %	Ag, Gl, Sp	Qt, Cal, Rdc	In Operation (1,100 t/d)
						skarn	dis		60m	40m			Sp	Gn, Qt, Cal	
5	Chanca	Chanca	Ag, Pb	Cp	Vol	fra-fill	vein	2,000mx 700m	600m	0.6~2m	ENE-WSW	Ag 16 oz Pb 2.1 %	Gl, Ag	Rdc, Rd, Cal, Qt	In Operation (200 t/d)
6	Uchuc-chacua	Uchuc-chacua	Ag, Pb	Jm	Ls	fra-fill	vein	2,000mx1,200m	300m~ 700m	1~3m	NE-SW E-W	Ag 14 oz Pb 1~2 %	Ag, Gl	Cal, Rdc	In Operation (200 t/d)

Abbreviations

St: Santa formation
Ph: Pariahunca formation
Jm: Jumasha formation
Cp: Calipuy volcanics
Ls: Limestone

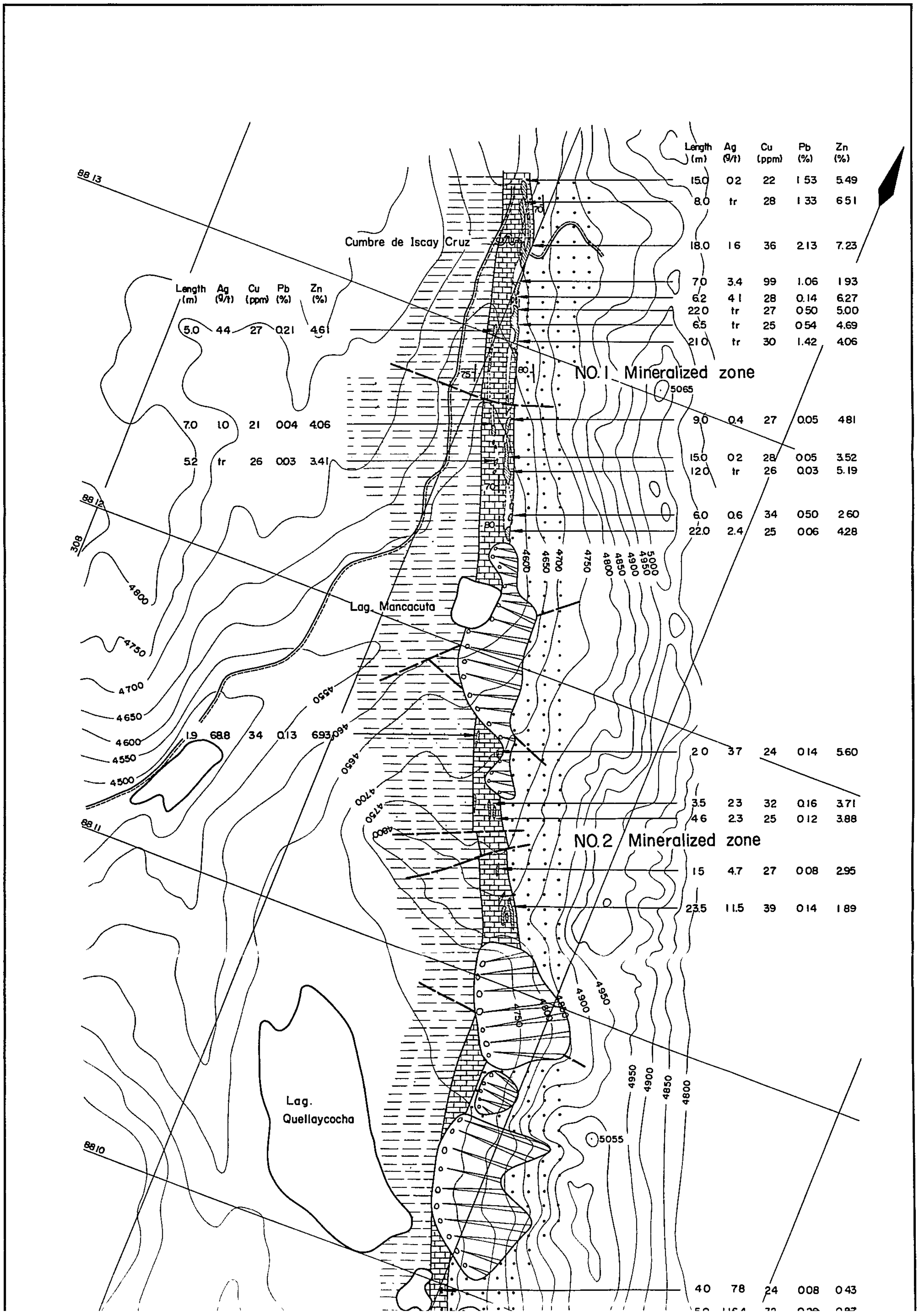
Do : Dolostone
Vol : Volcanic rocks
rep : replacement
fra-fill: fracture-filling
mas-band: massive-banded

dis : dissemination
Zn-Ox: Zn-Oxide
Cph : Chalcophanite
Sp : Sphalerite
Gl : Galena

Mt: Magnetite
Ccp: Chalcopyrite
Po: Pyrrhotite
Ag: Silver Minerals
Gt: Goethite

Hm: Hematite
Dm: Dolomite
Ac: Actinolite
Gn: Garnet
Hd: Hedenbergite

Qt : Quartz
Cal: Calcite
Rdc: Rhodocrosite
Rd : Rhodonite


Length (m) Ag (g/t) Cu (ppm) Pb (%) Zn (%)
15.0 0.2 22 1.53 5.49
8.0 tr 28 1.33 6.51
18.0 1.6 36 2.13 7.23
7.0 3.4 99 1.06 1.93
6.2 4.1 28 0.14 6.27
22.0 tr 27 0.50 5.00
6.5 tr 25 0.54 4.69
21.0 tr 30 1.42 4.06
NO.1 Mineralized zone
9.0 0.4 27 0.05 4.81
15.0 0.2 28 0.05 3.52
12.0 tr 26 0.03 5.19
6.0 0.6 34 0.50 2.60
22.0 2.4 25 0.06 4.28
2.0 3.7 24 0.14 5.60
3.5 2.3 32 0.16 3.71
4.6 2.3 25 0.12 3.88
NO.2 Mineralized zone
1.5 4.7 27 0.08 2.95
23.5 11.5 39 0.14 1.89
4.0 7.8 24 0.08 0.43
Length (m) Ag (g/t) Cu (ppm) Pb (%) Zn (%)
5.0 4.4 27 0.21 4.61
7.0 1.0 21 0.04 4.06
5.2 tr 26 0.03 3.41
1.9 68.8 34 0.13 6.93
Cumbre de Iscay Cruz
Lag. Mancacuta
Lag. Quellaycocha
88 13
88 12
88 11
88 10
308
5065
5055
4500
4550
4600
4650
4700
4750
4800
4850
4900
4950
5000

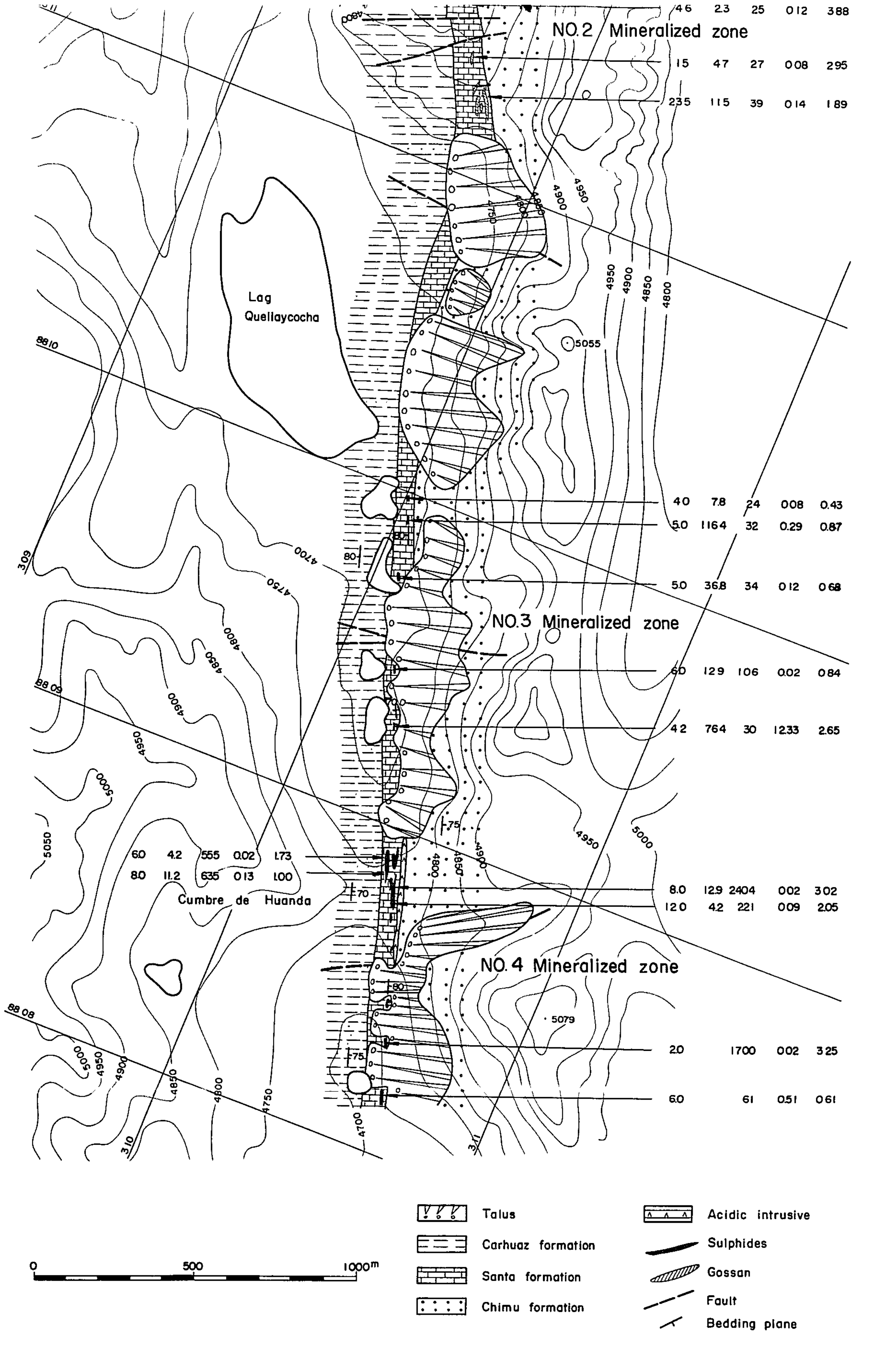


Fig. 2. Generalized Geological Map of the Iscay Cruz Area

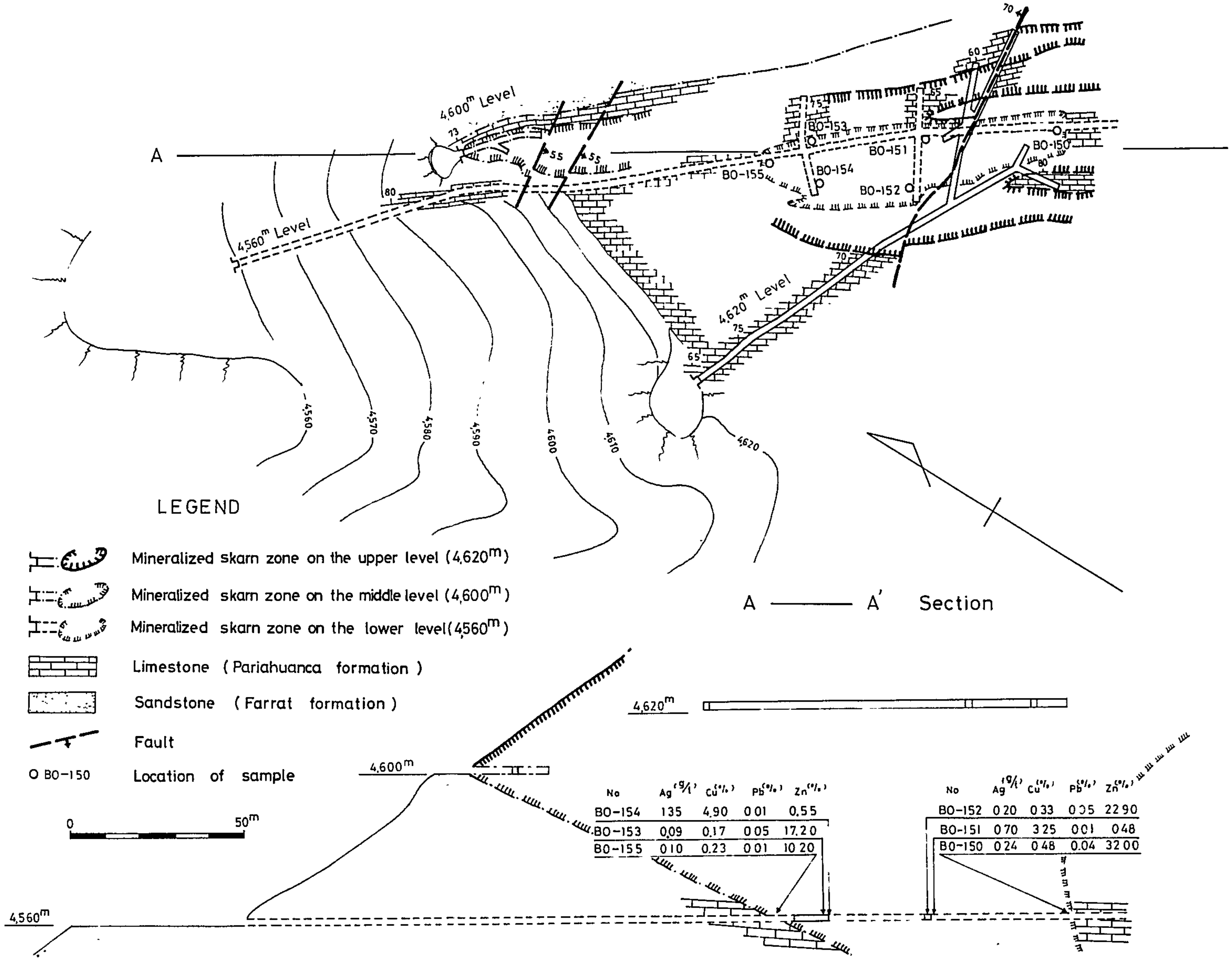


Fig. 10. Generalized Sketch Map of the Chupa Mine

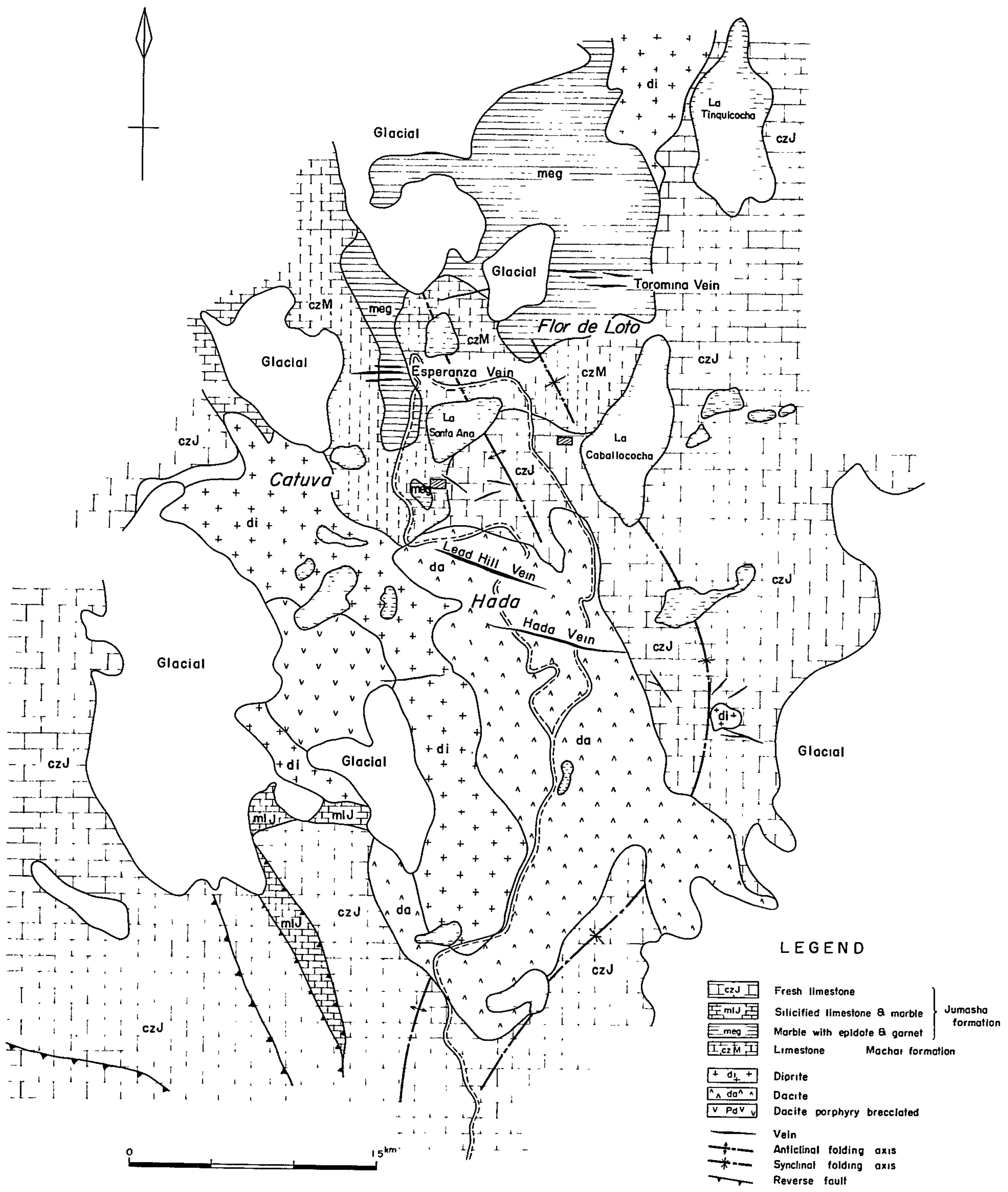


Fig. 11. Geological Map of the Raura Mine (from CIA. MINERA RAURA SA MINA RAURA)

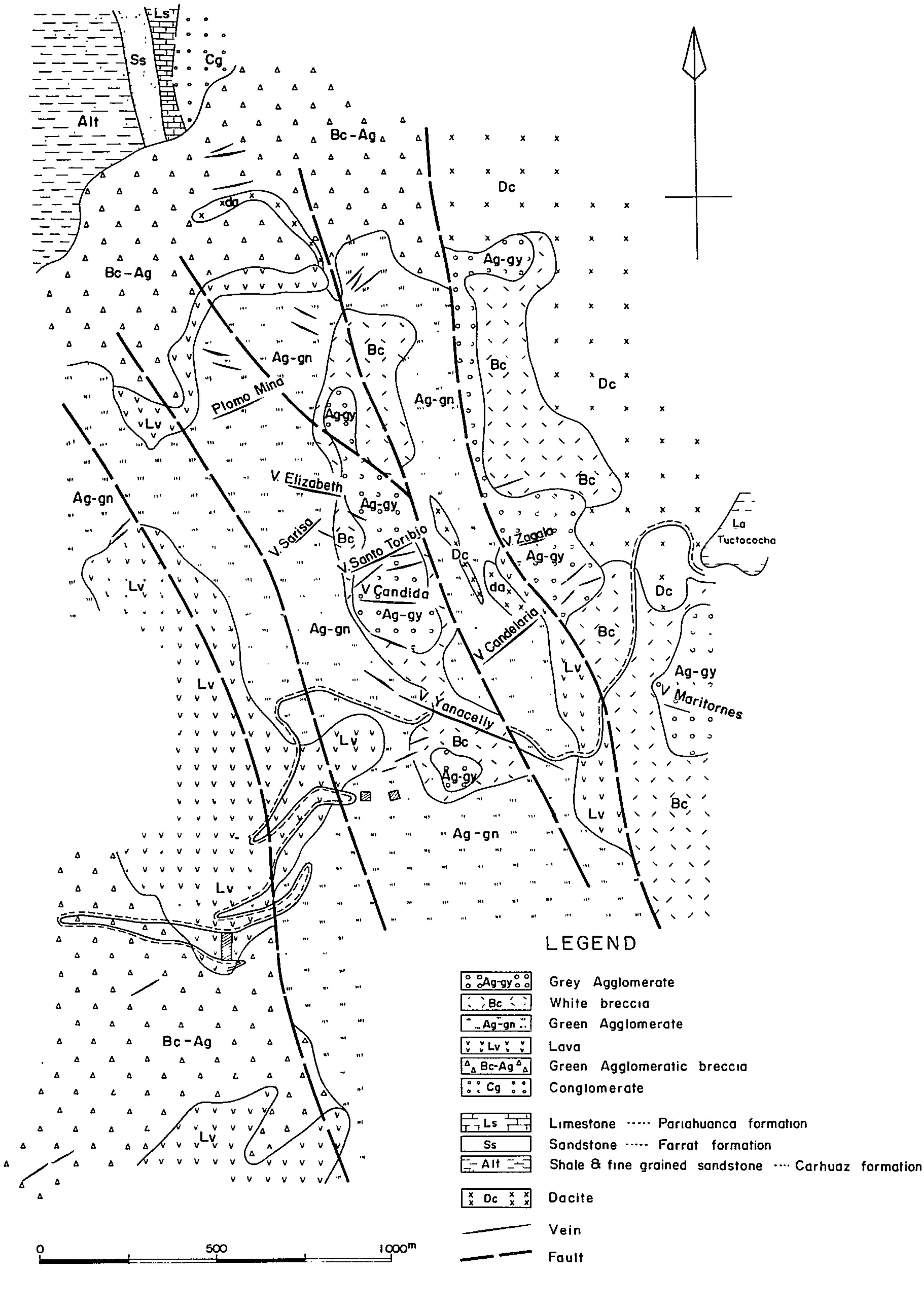


Fig. 12. Geological Map of the Chanca Mine
(from CIA MINERA RAURA S A
MINA CHANCA)

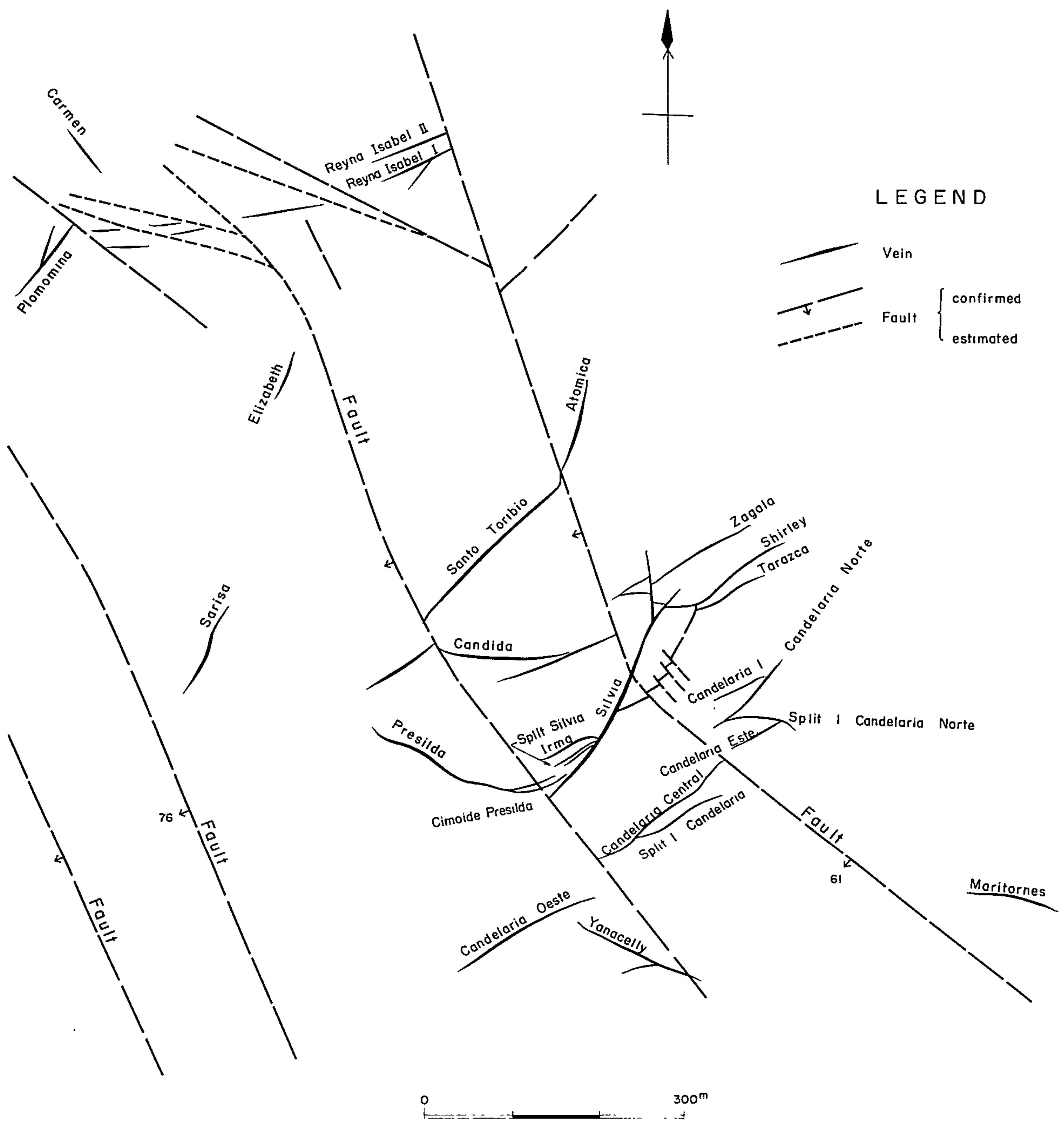


Fig. 13. Fracture Pattern of the Chanca Mine (from CIA MINERA RAURA S A MINA CHANCA)

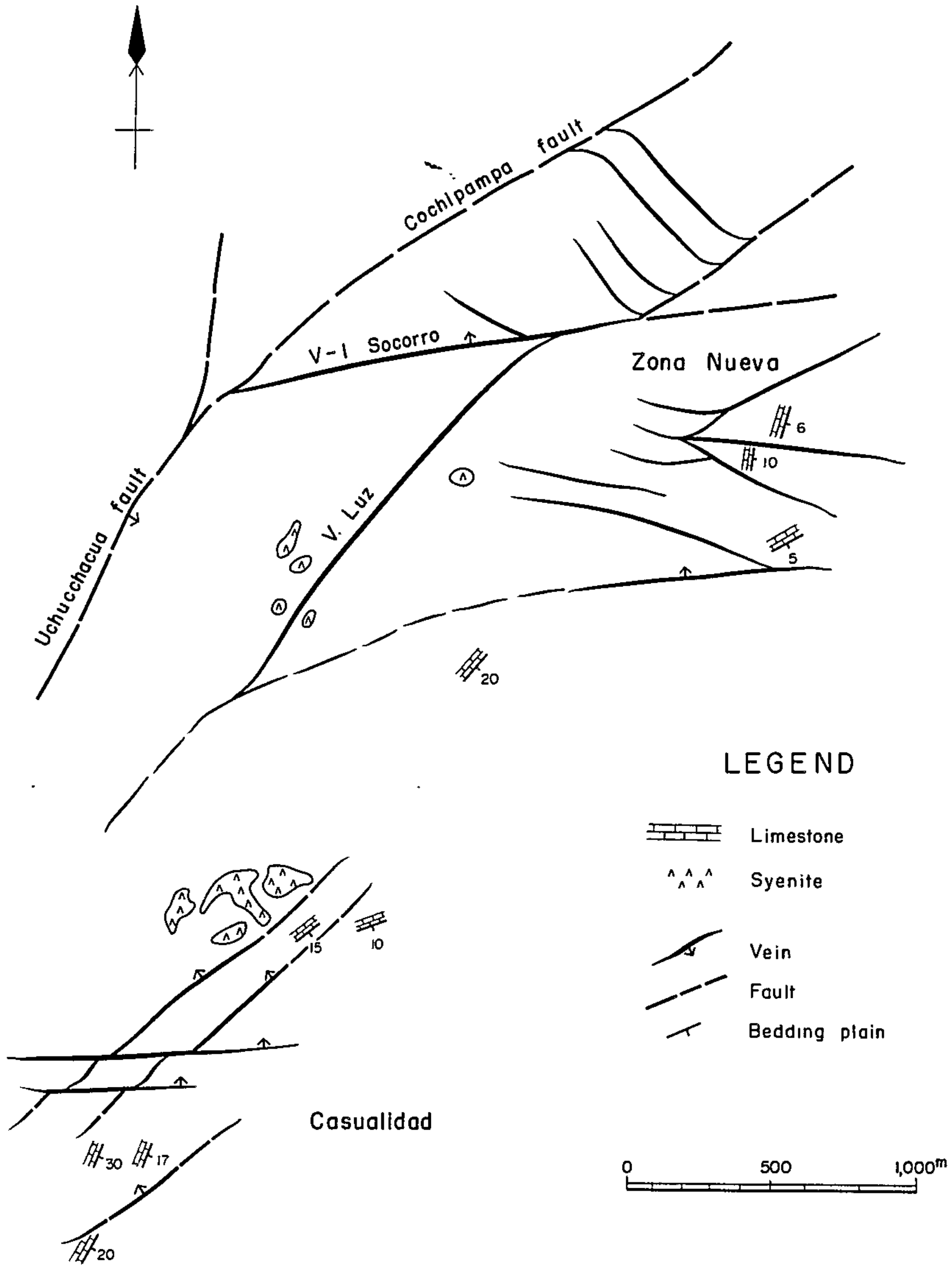


Fig. 14. Vein Pattern of the Uchucchacua Mine

(from CIA. DE MINAS BUENAVENTURA S.A. MINAS UCHUCCHACUA)

Chapter 5 Geochemical Survey

5-1 Purpose and Method

This survey was conducted for the purpose of detecting anomalous concentrations of metallic elements contained in rocks and stream sedements in the surveyed area, and clarifing the mineralization and the relationship between anomalies and ore deposits. It is assumed that ore deposits of hydrothermal origin in Santa limestone are principal mineralization in the surveyed area, however, there is a possibility that the mineralization is of syngenetic origin. Therefore, samples were mainly collected from rocks, including gossan in the Iscay Cruz area. Stream sediments were also sampled to obtain a wide-range information on ore deposits in the surveyed area.

Rock samples were collected from exposures which were encountered during the geological survey. Santa limestone was mainly sampled, but samples were also collected from other rocks and layers so many as it could be compared with the Santa limestone samples. Gossan was collected by means of the channel sampling in which 2 to 4 m long and perpendicular to the strike of the stratum. Stream sediments were collected from rivers which were encountered during the survey. However, the sampling from areas which are dried up and dangerous to access was not performed. Therefore, sampling locations is lacking in equidensity. Collected samples were screened in water through an 80 mesh screen and at the same time, mud and organic materials were removed. Materials that passed through the screen were used for analysis.

The samples of gossan and stream sediment that passed through the screen, were directly sent to the laboratory for the further processing. Each rock sample was crushed and quatered, at the base camp, so that each sample was adjusted to be about 10 g for analysis.

The chemical analysis of the rocks and stream sediments was conducted for three elements (Cu, Pb, and Zn) by atomic absorption method. For the samples from gossan, composite samples were prepared and chemical analysis for Ag element was also conducted in addition to the above analysis.
For rock samples, chemical analysis for the elements of Ca, Mg, Sr, Ba, Fe, and Mn was conducted to elucidate the properties of carbonate rocks.
The results of these chemical analyses are shown in A.10, etc.

5-2 Analysis on Assay Data and Discussion on the Results

(1) Data processing

The analysis data were statistically processed by computer (IBM 370-145). The data were classified into 3 populations-- rock, gossan and stream sediment. The rock and gossan populations were further classified into several sub-populations according to the formation, rock type (lithology) and area where the samples were collected, etc. before analysis. The results of the analyses are shown in Table 4, Figs. 15 and 16.

(2) Dispersion of samples

Table 4 shows the average value, maximum value and minimum value of contents of each population. These are shown in Fig. 15. Fig. 16 shows histograms for the values of the samples which were roughly classified by lithology. The Table and Figures give use to the following discussion on the dispersion of samples. The following analysis and discussion were made according to the method presented by Lipertier in 1969.

1) Rocks

The Cu contents in most samples were around 5 ppm, only one sample exceeded 100 ppm. In each group by lithology, the samples did not show much sample was adjusted to be about 10 g for analysis.

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1) Rocks

The Cu contents in most samples were around 5 ppm, only one sample exceeded 100 ppm. In each group by lithology, the samples did not show much difference in values. This population has a relatively clear bell-shaped lognormal distribution.

The Pb content of the majority of samples was about 30 ppm. It can be said that the population has a lognormal distribution, like Cu. However, the population contains high values, even though these were few samples, and a bend in the positive direction is seen in the cumulative frequency curve. Therefore, it may be said the population shows a multi-existence of high values.

For Zn content, many samples, about 75 % of the total, had 10 to 50 ppm. A similar tendency is observed for each group by lithology. This tendency is distinct in calcareous rocks in which many samples were collected. It can be said that the histogram shows a dispersion of the multi-existence of high values. This is because the histogram gradually slopes for values exceeding 30 ppm, and includes a small lognormal distribution which indicates the existence of a small anomalous population. For samples from the Santa formation, the same can be observed.

2) Gossans

The average values for 117 samples were 48 ppm for Cu, 1,523 ppm (0.15 %) for Pb, and 21,872 ppm (2.2 %) for Zn. For Pb and Zn, there are many high value samples. In Chapter 4 relationship between ore grade and mineralization is described considering the results of the geochemical survey, therefore, detailed discussions are excluded from this Section.

3) Stream sediments

These were only 44 samples in total. The sampling locations are not distributed uniformly, as mentioned above. Therefore, the population is not always representational of the tendency of all areas surveyed. However, it can be said that the population has a large value frequency of 20 ppm Cu, 20 to 30 ppm Pb, and 80 ppm Zn.

(3) Average value (Background value)

The average value of Cu for rocks is 5.3 ppm. For each formation, the value is in a range of 4 to 11 ppm.

The average value of Pb is 22 ppm. There is such a large difference for each group by lithology that the value is high in calcareous rocks and low in clastic rocks and igneous rocks. The average value for calcareous rocks is in a range of 25 to 30 ppm. The horizon containing the Iscay Cruz ore deposit in the Santa formation has a slighly high value of 45 ppm.

The average value of Zn is 35 ppm. The difference of mean values for each group by lithology is indicated in a slightly different way from Pb. The average value for the Santa formation in which the numbers of samples are largest (138) is 35 ppm which is the same as for all rocks. However, the average value for the Iscay Cruz ore deposit horizon is 77 ppm, but that for both sides of the horizon is in a range of 20 to 25 ppm, which is lower than that for all rocks. The average value for the upper calcareous formations in which the numbers of samples (89) are next to the Santa formation is 35 ppm. However, a large difference can be observed for each horizon such as 25 ppm for the Pariatambo formation and 45 ppm for the Pariahuanca formation. The average values for Carhuaz clastic formation and igneous rocks are 50 ppm and 75 ppm respectively.

From these facts, the background values of Cu, Pb, and Zn contained in rocks in the surveyed area are considered to be 5 ppm, 22 ppm, and 35 ppm, respectively. For each group by lighology, background values are estimated to be as follows.

	Cu (ppm)	Pb (ppm)	Zn (ppm)
Calcareous rocks	5	30	35
Clastic rocks (mainly sandstone)	5	10	30
Igneous rocks	7	5	55

Turekian et al. (1961) reported of heavy metals contained in the earth crust. From this report, Cu, Pb, and Zn contents in the rocks of each type related to the surveyed area are summarized as follows.

	Cu (ppm)	Pb (ppm)	Zn (ppm)
Basaltic rocks	87	6	105
Granodiorite	30	15	60
Granite	10	19	39
Shale	45	20	95
Sandstone	-	7	16
Carbonate rocks	4	9	20

From the above table, the backgound value of Cu in the surveyed area is slightly lower than the above, that of Pb and Zn is slightly higher for carbonate rocks and the values for igneous rocks are almost the same as the Turekian's data. Especially, the Zn content in calcareous rocks is almost double. It may be said that this phenomenon indicates the difference of Pb and Zn concentration in the surveyed area when rocks and formations were formed. However, this Zn content is slighly lower than that in the Mesozoic, Jurassic Pucara Group distributed in the Oxapampa area of the Cordillera Oriental, Peru (mainly consists of limestone, etc.). In the Oxapampa area, Cu is 7 ppm, Pb is 39 ppm, and Zn is 66 ppm (JICA and others, 1977 and 1978). The Cu value is the same as that in the surveyed area, but Pb and Zn values are almost 3 to 4 times.

It can be estimated that the background values of stream sediments are 22 ppm for Cu, 30 ppm for Pb, and 80 ppm for Zn.

(4) Threshold value

According to the research by Lipertier (1969), the threshold value can be simply determined from the histogram and cumulative frequency curve which indicate the tendency of dispersion of the population. For samples from the surveyed area, Zn, for example, has the histogram which indicates bell-shaped normal distribution, however, the right-side slope of the curve is somewhat gradual; so, the histogram has the tendency of multi-existence of higher values. A bend in the cumulative frequency curve indicates the same tendency. The point of this bend corresponds to slightly less than 200 ppm at 60 % of the total numbers of samples. However, it is proper that the point of this bend should not be taken as the threshold value for anomaly from the standpoint of the exploration on metal ore deposits. The same can be said for Pb. Therefore, the threshold value of Zn and Pb cannot be simply determined. Consequently, the value of general average value plus twice of standard diviation corresponding to 2.27 % of the population is used as the threshold value in this survey. Because the dispersion type is not clear, the threshold value of stream sediments is determined by the same method as that for rocks. The values are as follows.

	Cu (ppm)	Pb (ppm)	Zn (ppm)
Rocks	100	220	500
Stream sediments	120	270	500

When using the same method above, the threshold value of Cu is 25 ppm which is out of the discussion. Therefore, average value plus four times of standard deviation is used as the thereshold value of Cu.

(5) Discussion on anomaly

1) Rocks

The numbers of samples with anomaly are 1 for Cu, 7 for Pb, and 15 for Zn. Table 5 shows the content, geological data, etc. for samples with anomaly. Comparatively many anomalies are found in the Iscay Cruz horizon of the Santa formation. Anomaly is locally found in the Santa formation, except the Iscay Cruz horizon, and Pariahuanca formation.

Anomaly in the Iscay Cruz horizon exists in the following (from the north);

(1) Dolostone, which was altered to gossan, in the north of the Iscay Cruz mineralized area,

(2) Limestone and dolostone in the Iscay Cruz area,

(3) No. 5 and No. 6 Iscay Cruz mineralized areas.

Dolostone, which was altered to gossan, is in the area 2 km northward from the Iscay Cruz mineralized zone, forming 3 layers, 10 m wide and 50 to 100 m long. This dolostone contains 2,000 to 4,000 ppm Zn, therefore, it may be considered that this dolostone should be classified in the gossan category.

Anomaly in the mineralized area is for (2) and (3) above. The above (3) is determined by the sample collected from gossan; so, this belongs to the gossan category, same as (1). However, (1) is located close to gossan and found in the limestone and dolostone which were not altered into gossan. In each case, calcite veinlets are found and sometimes fine-grained sphalerite is included. From this fact, it can be said that the dolostone was influenced by the mineralization before altered into gossan, in other words, this is the indication of mineralization influenced by sulfides.

In the Iscay Cruz horizon, anomaly is found only in the above 3 areas. In other areas, the content is extremely low. The average content in this horizon is 5.0 ppm for Cu, 44.7 ppm for Pb, and 77.4 ppm for Zn. When excluding 10 samples with Zn anomaly, the average content is as low as 5.4 ppm for Cu, 24.6 ppm for Pb, and 21.7 ppm for Zn. Those values are lower than the grand average and other average grades.

Except the Iscay Cruz horizon, anomaly is notable in the Pariahuanca and Santa formations located eastward from the Iscay Cruz mineralized area and 15 km south-eastward from Oyon. Anomaly in both formation is found in limestone. However, no alteration is found in the limestone and only a very small amount of calcite veins is observed in the Pariahuanca layer. From the standpoint of the geological structure, the layers with anomaly are located in the extension of the strike of stock (this is probably an aggregate of dikes) of Iscay Cruz dacite and there is a small stock in the north of the anomaly. Accordingly, in this area, the mineralization in conjunction with the igneous activity exists possibly. Also, this area needs the further survey to clarify the origin of anomaly and the geological background.

In other areas, in general, anomaly only exists independently. Furthermore, no distinct transformation into gossan is found. The anomaly may result from the influence by igneous rocks, but the details are not clear. However the content and size of anomaly are far smaller than those of the Iscay Cruz mineralized area and out of the discussion.

(2) Stream sediments

The numbers of samples with anomaly is one for each of Cu, Pb, and Zn. For stream sediments from the standpoint of sedimentation, it is necessary to discuss not only the comparison between absolute values but also the comparison of contents and geology of the sampled area to those of the stream sediments taken in adjacent rivers on the basis of the flow quantity and flow area of the river where the samples were collected. From the point of view described above, the contents of stream sediments are as follows (refer to Fig. 17).

1) The right bank of the Rio Huaura and the left bank of the Rio Checras are possible existence area of the mineralization, similar to the Chanca, Viscachaca and other ore deposit areas. Stream sediments are possibly

influenced by the above mineralization. High values are found in the samples No. SD-16 (742 ppm Cu), No. SD-28 (182 ppm Cu, 103 ppm Pb), etc. In other areas, about 100 ppm Zn contents are frequently measured. Therefore, the further wide-range survey will be necessary to clarify the origin in detail.

2) In sedimentary rocks, the sample No. SD-32 can be said the Pb anomaly (content: 2,500 ppm). Granite porphyry penetrating into sedimentary rocks is found in the area where No. SD-30 was sampled. The Zn anomaly is probably influenced by granite porphyry which contains Zn in comparatively high value (575 ppm Zn for sample No. NO-113).

3) Samples, No. SD-14 and No. SD-33 were collected from the extension of the strike of the Iscay Cruz mineralized area and the Zn contents are 310 ppm and 395 ppm respectively. In the down stream area of the Santa formation, the value is generally low. There are only 2 samples, but it can be said that the Iscay Cruz horizon is an important area for the exploration of ore deposit. Anomaly of Zn in also found in tonalite stock (1,905 ppm Zn for sample, No. SD-30).

Table 4 Results of Statistical Analysis on the Geochemical Samples

	Population	Number of Samples	Average Value			Maximum Value			Minimum Value		
			Cu(ppm)	Pb(ppm)	Zn(ppm)	Cu(ppm)	Pb(ppm)	Zn(ppm)	Cu(ppm)	Pb(ppm)	Zn(ppm)
1	Type of Samples										
	Rocks	289	5.3	22.3	35.2	176	5,580	20,938	0	0	5
	Gossan	117	47.8	1,523.1	21,877.6	90,000	33,500	122,000	15	100	100
	Stream sediments	44	22.6	40.8	123.9	742	2,500	1,905	6	0	42
2	Formations										
	Jumasha formation (Jm)	17	3.9	27.6	26.9	12	39	153	3	19	11
	Pariatambo formation (Pt)	22	5.5	24.3	29.6	21	35	110	3	17	13
	Chulec formation (Cl)	21	7.2	28.4	36.2	36	42	307	2	16	15
	Pariahuanca formation (Ph)	29	6.0	28.0	45.0	40	40	3,383	3	7	12
	Farrat formation (Fr)	7	3.6	5.5	10.2	26	25	37	4	0	5
	Carhuaz formation (Cz)	20	8.6	12.9	50.8	41	39	149	2	2	16
	Santa formation (St)	138	4.8	32.2	34.5	176	5,580	20,938	0	0	8
	Chimu formation (Cm)	14	4.5	10.8	29.6	63	92	184	0	0	7
	Oyon formation (Oy)	2	6.7	1.4	16.5	9	2	21	5	0	13
	Average	270	5.2	25.1	34.1						
	Calipuy volcanics (Cp)	10	4.8	6.8	41.6	16	74	101	0	1	13
	Intrusive rocks (Ig)	9	11.1	2.7	76.0	67	16	575	0	0	27
	Average	19	7.2	4.4	55.4						
3	Type of Rocks										
	Upper calcareous rocks (Jm, Pt, Cl, Ph)	89	5.6	27.1	34.9	40	42	3,383	2	7	11
	Upper clastic rocks (Fr, Cz)	27	6.8	10.3	33.6	41	39	149	0	0	5
	Lower calcareous rocks (St)	138	4.8	32.2	34.5	176	5,580	20,938	0	0	8
	Lower clastic rocks (Cm, Oy)	16	4.7	8.4	27.5	63	92	184	0	0	7
	Igneous rocks (Cp, Ig)	19	7.2	4.4	55.3	67	74	575	0	0	13
4	Sample Location on Santa Formation										
	Eastern side of Iscay Cruz horizon	34	4.7	24.5	19.9	16	37	523	1	6	9
	Iscay Cruz horizon (except gossan)	45	5.0	44.7	77.4	27	5,580	20,938	2	0	8
	Western side of Iscay Cruz horizon	59	4.7	29.4	25.6	176	553	366	0	0	11
5	Sample Location on Gossan										
	Northern part	63	27.4	2,773.3	45,603.7	158	33,500	82,500	15	122	15,500
	Central part	16	30.1	1,111.7	24,378.1	124	3,700	122,000	19	420	4,500
	Southern part	38	146.2	645.7	6,166.0	90,000	7,800	56,000	15	100	100

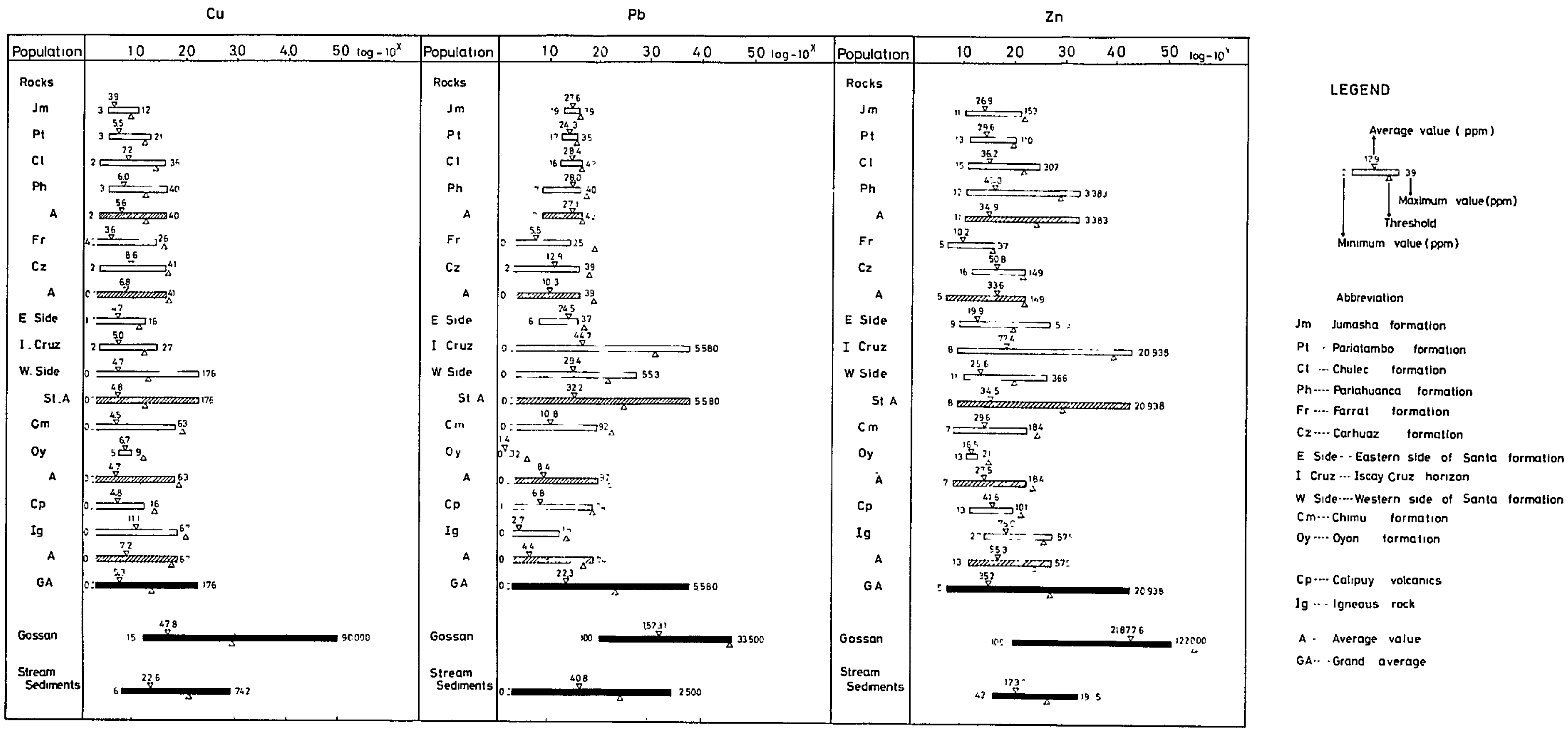
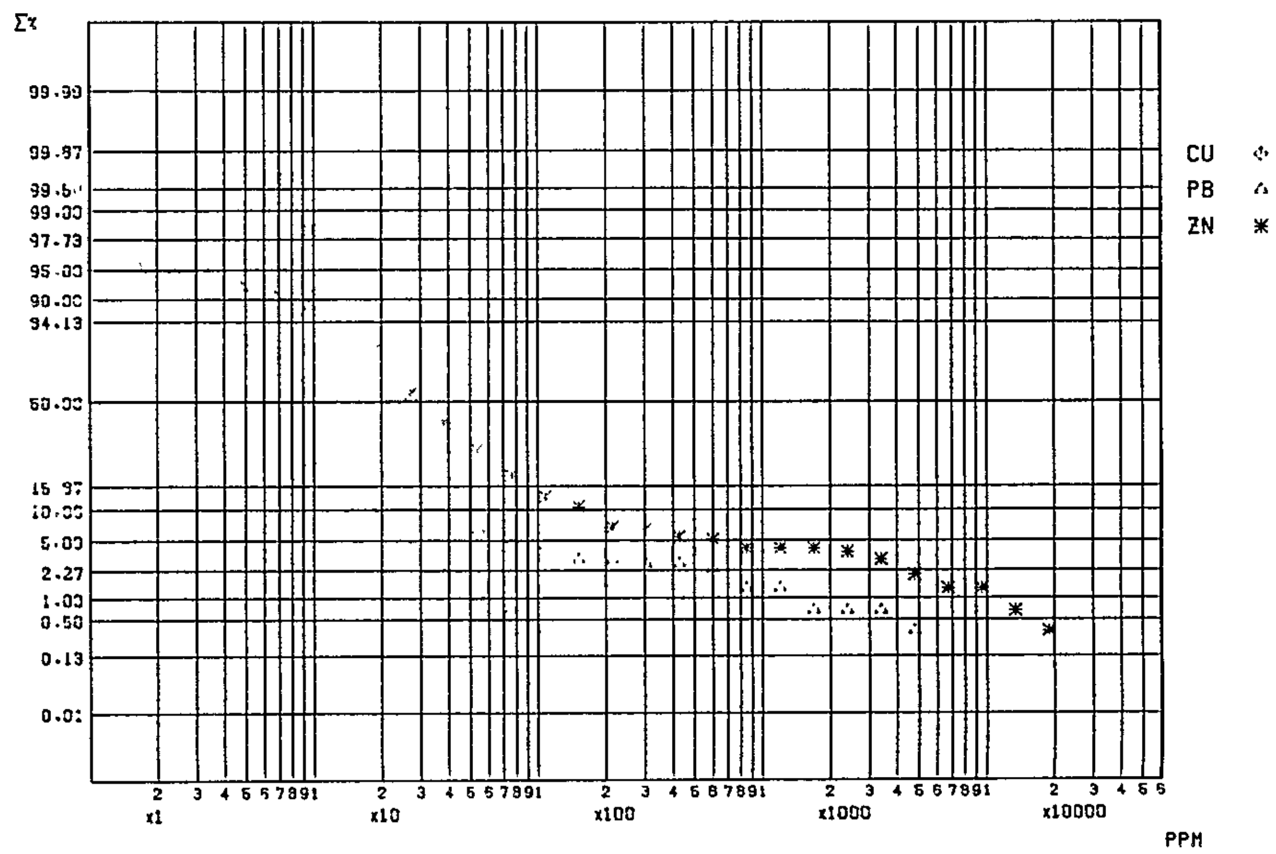
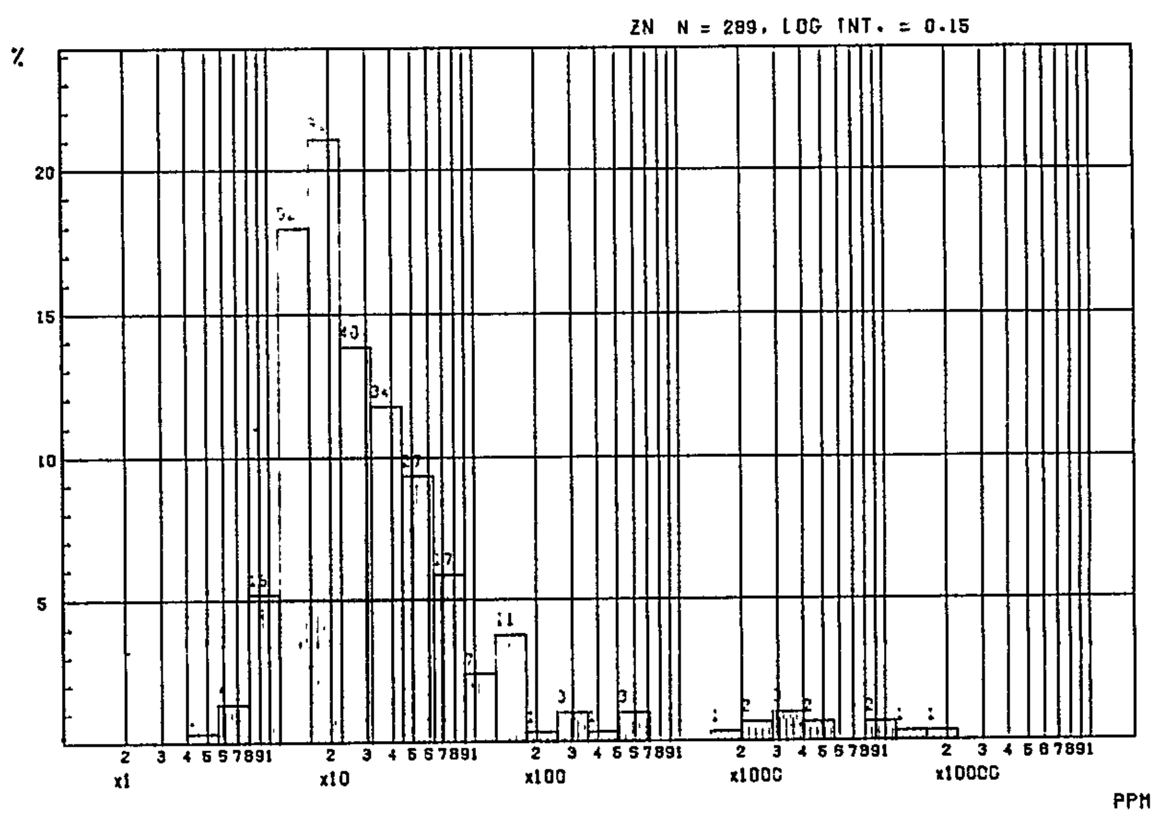


Fig. 15. Value Dispersion of Geochemical Samples Classified by Each Population in the Surveyed Area

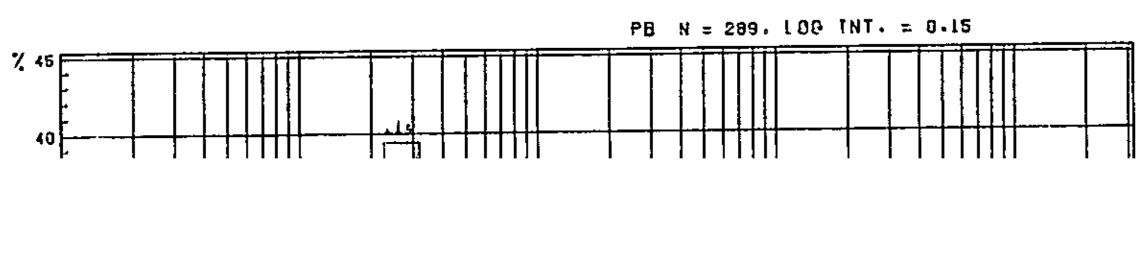
CUMULATIVE FREQUENCY DISTRIBUTION FOR CU, PB AND ZN

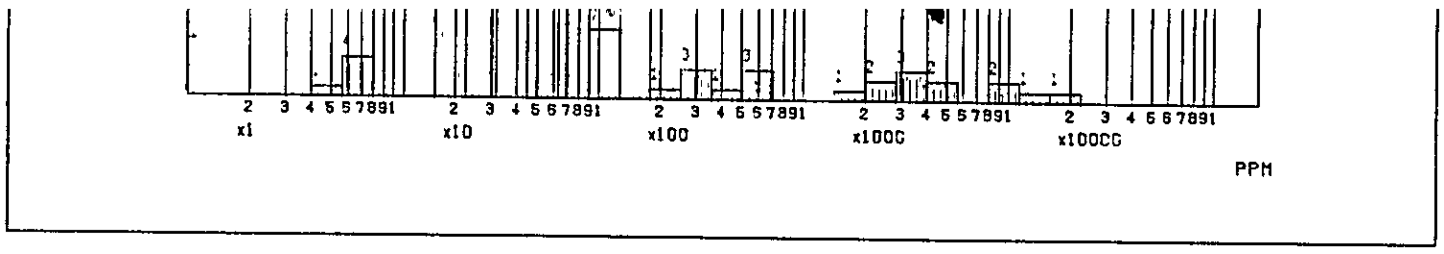


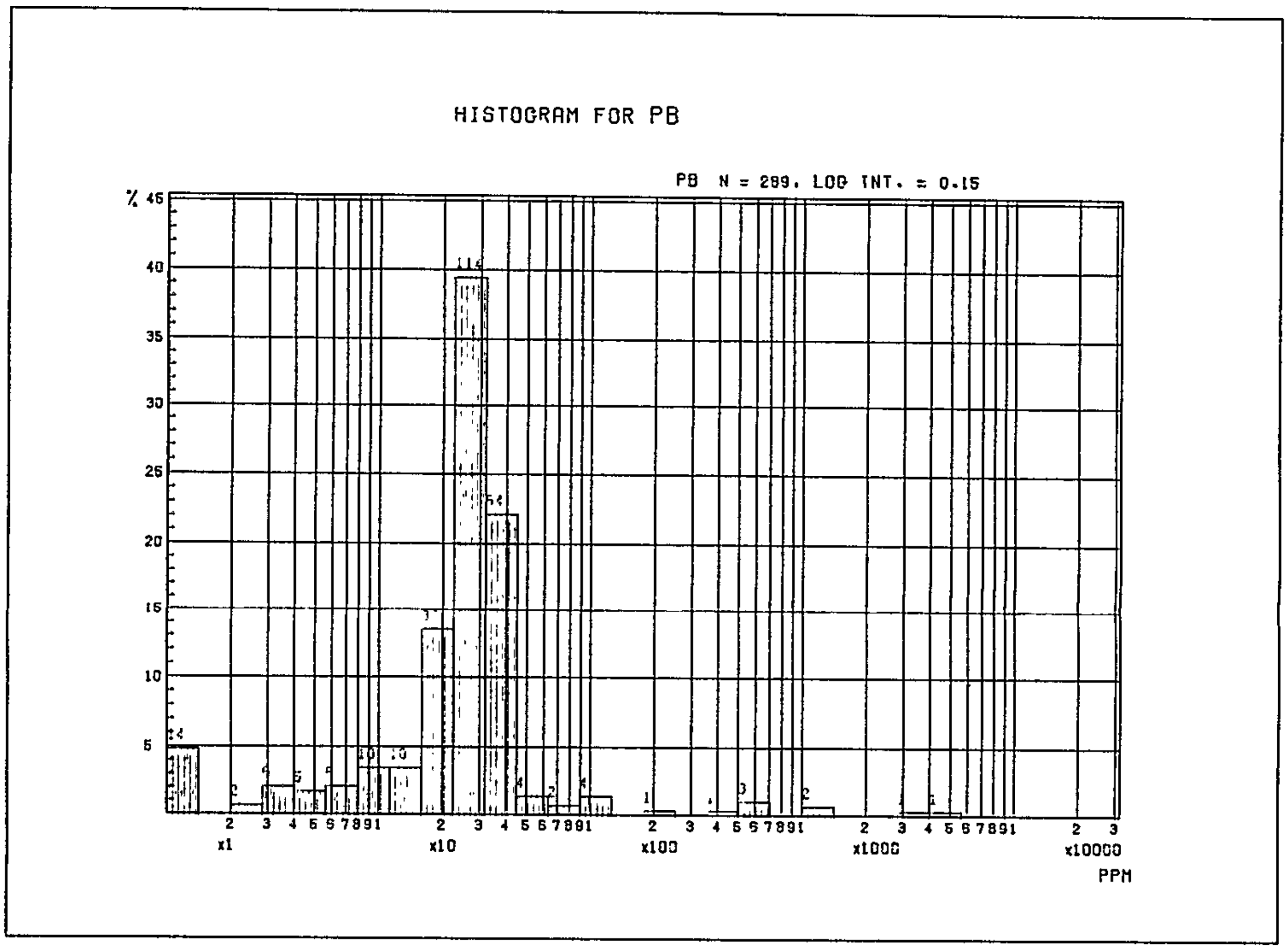
HISTOGRAM FOR ZN



HISTOGRAM FOR PB







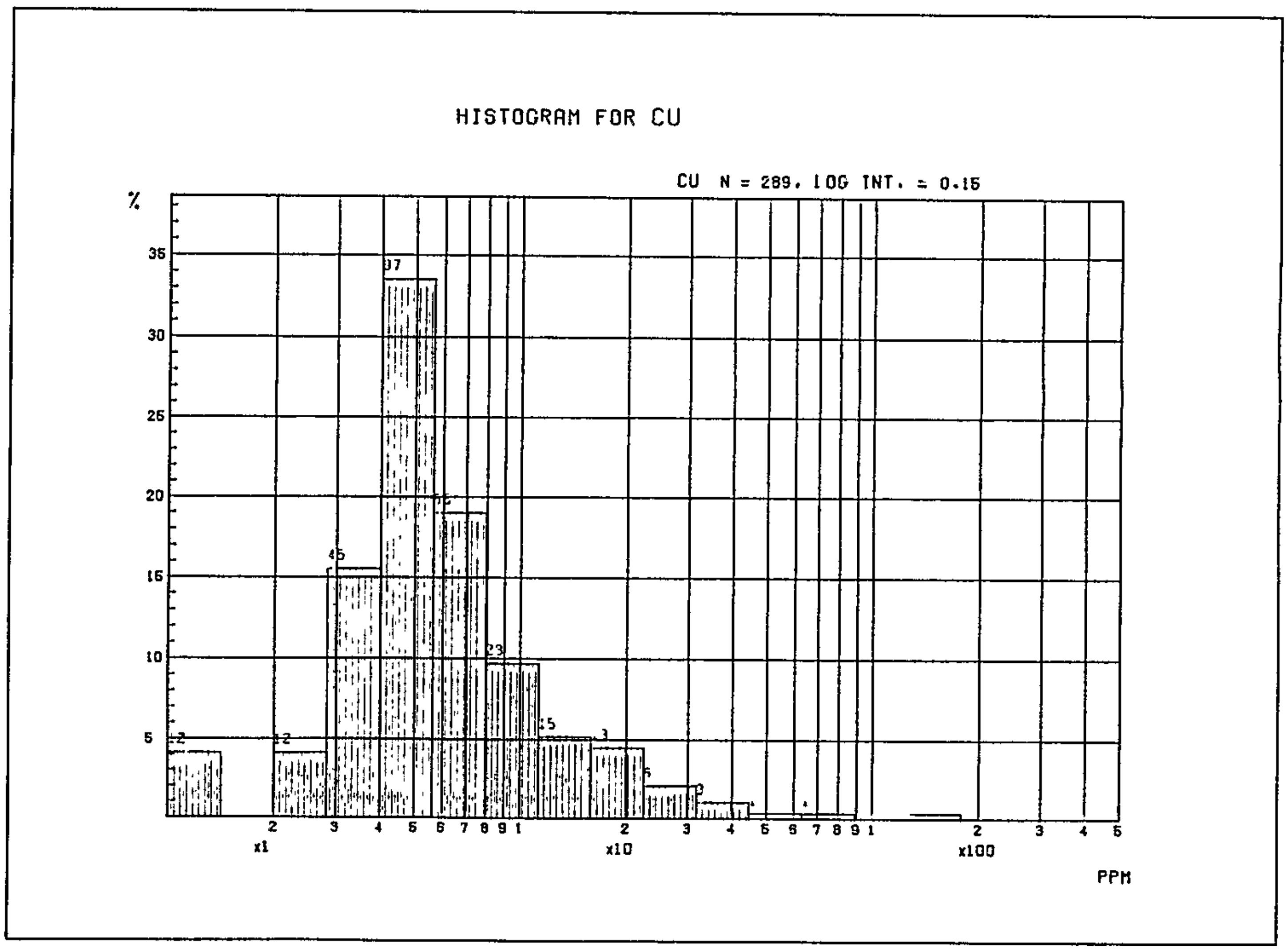
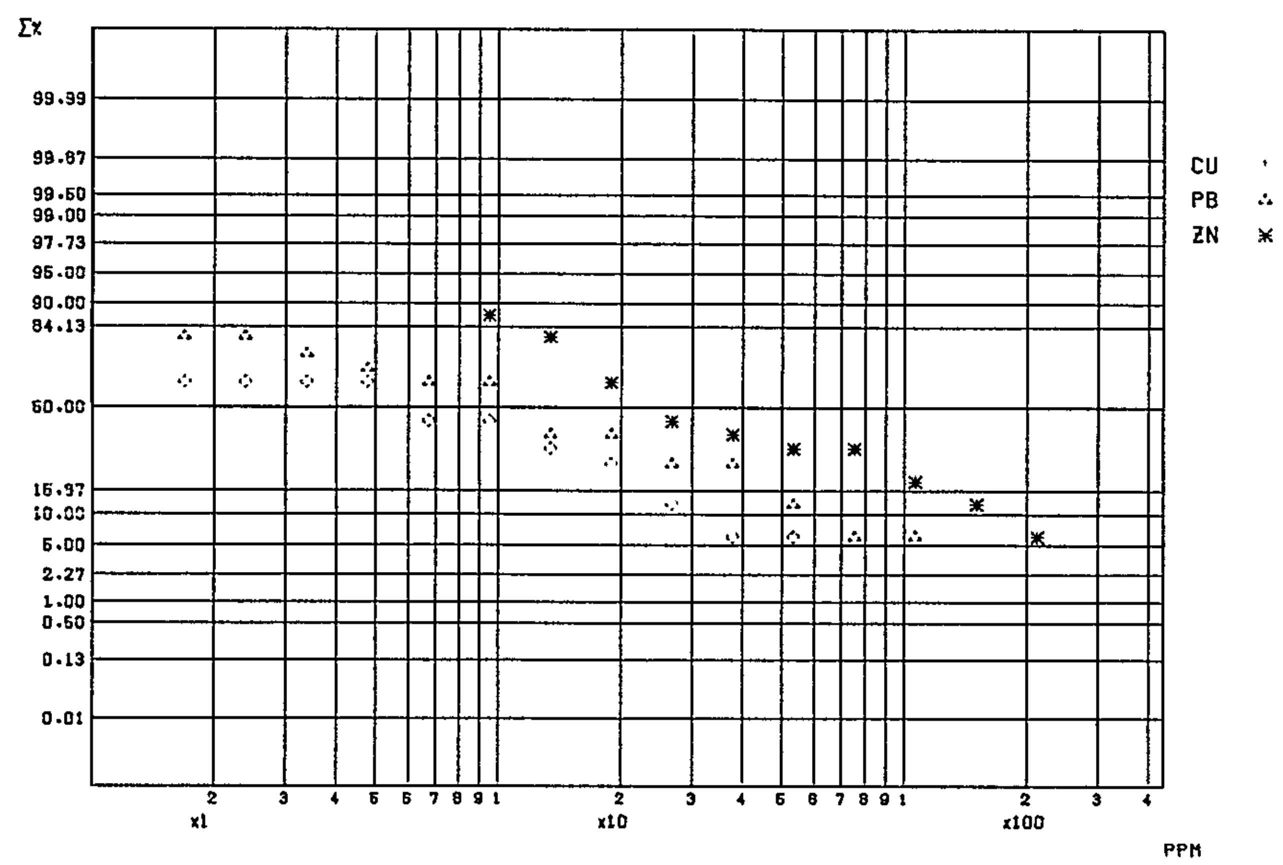
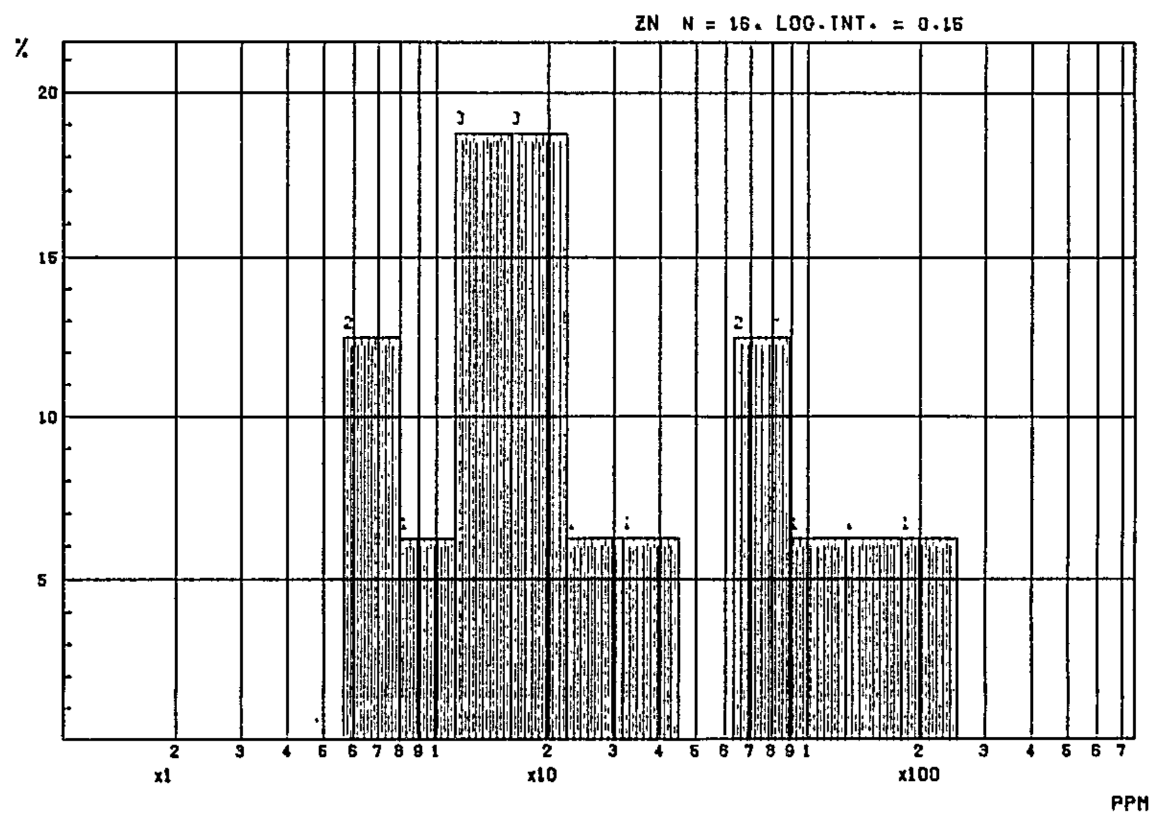


Fig. 16. Histogram and Cumulative Frequency Curve for Cu, Pb and Zn Contents in the Geochemical Samples (1) Total Rock

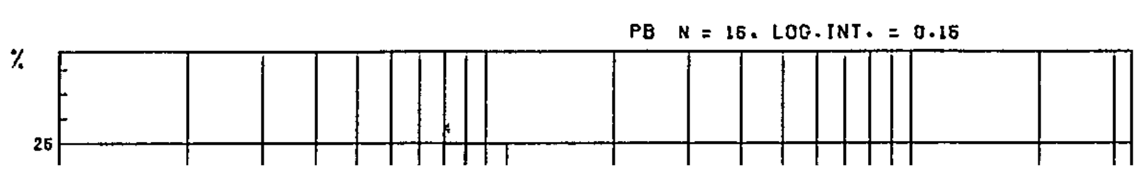
CUMULATIVE FREQUENCY DISTRIBUTION FOR CU, PB AND ZN

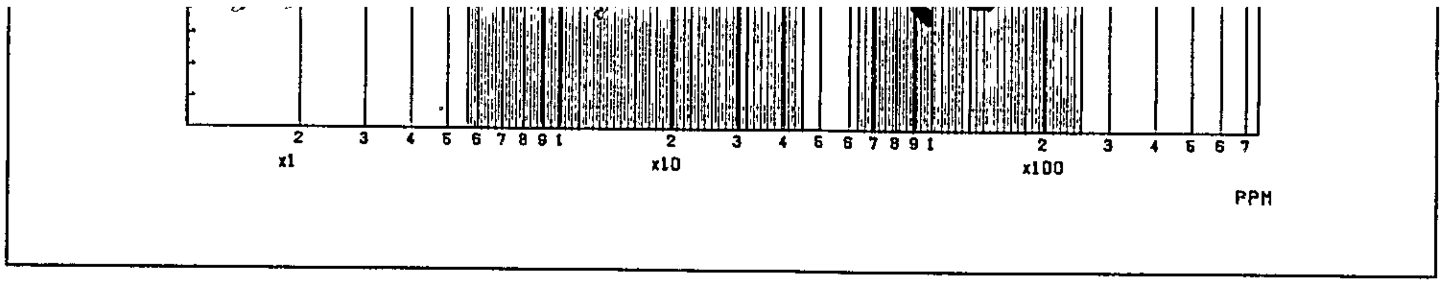


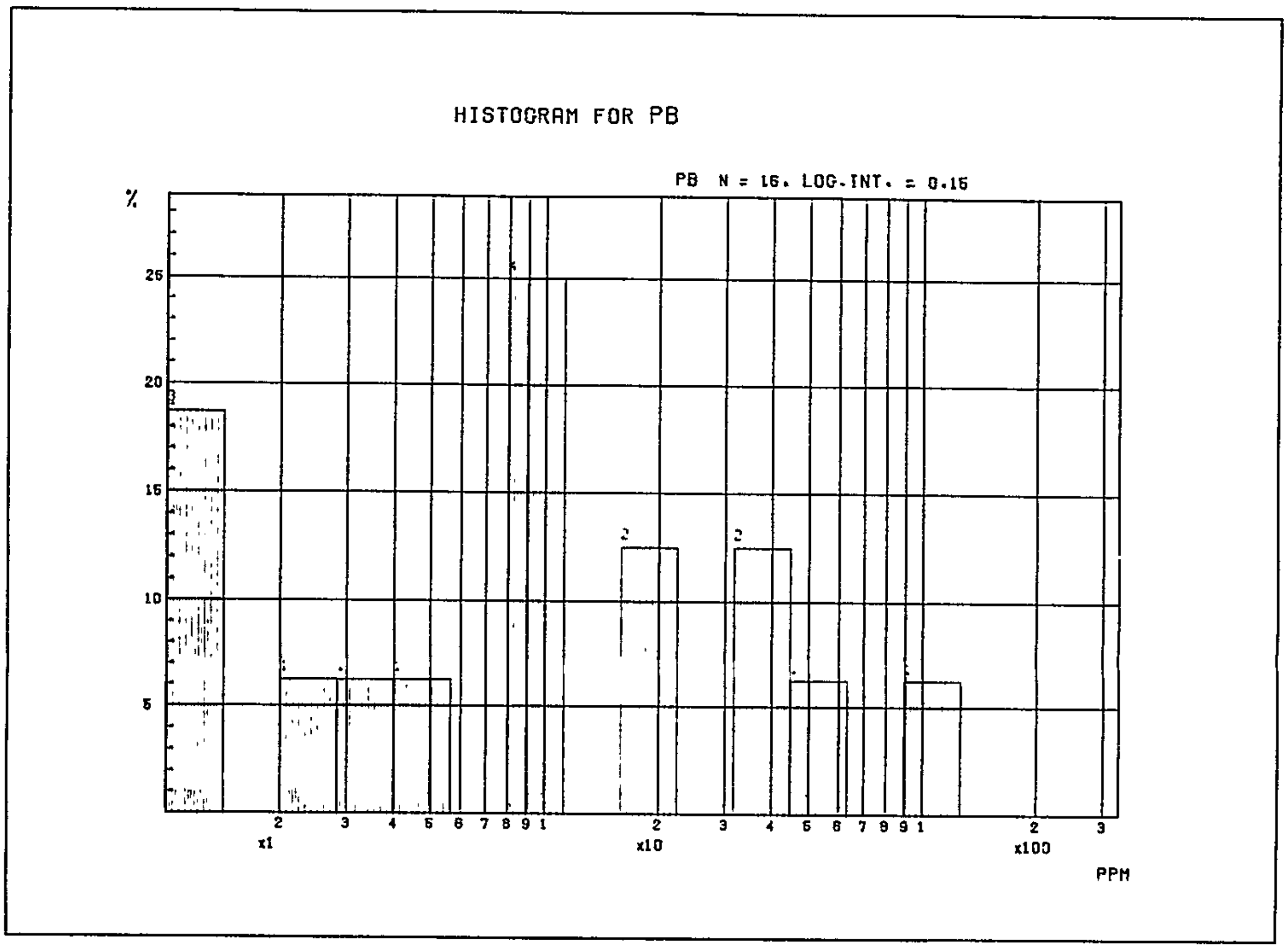
HISTOGRAM FOR ZN



HISTOGRAM FOR PB







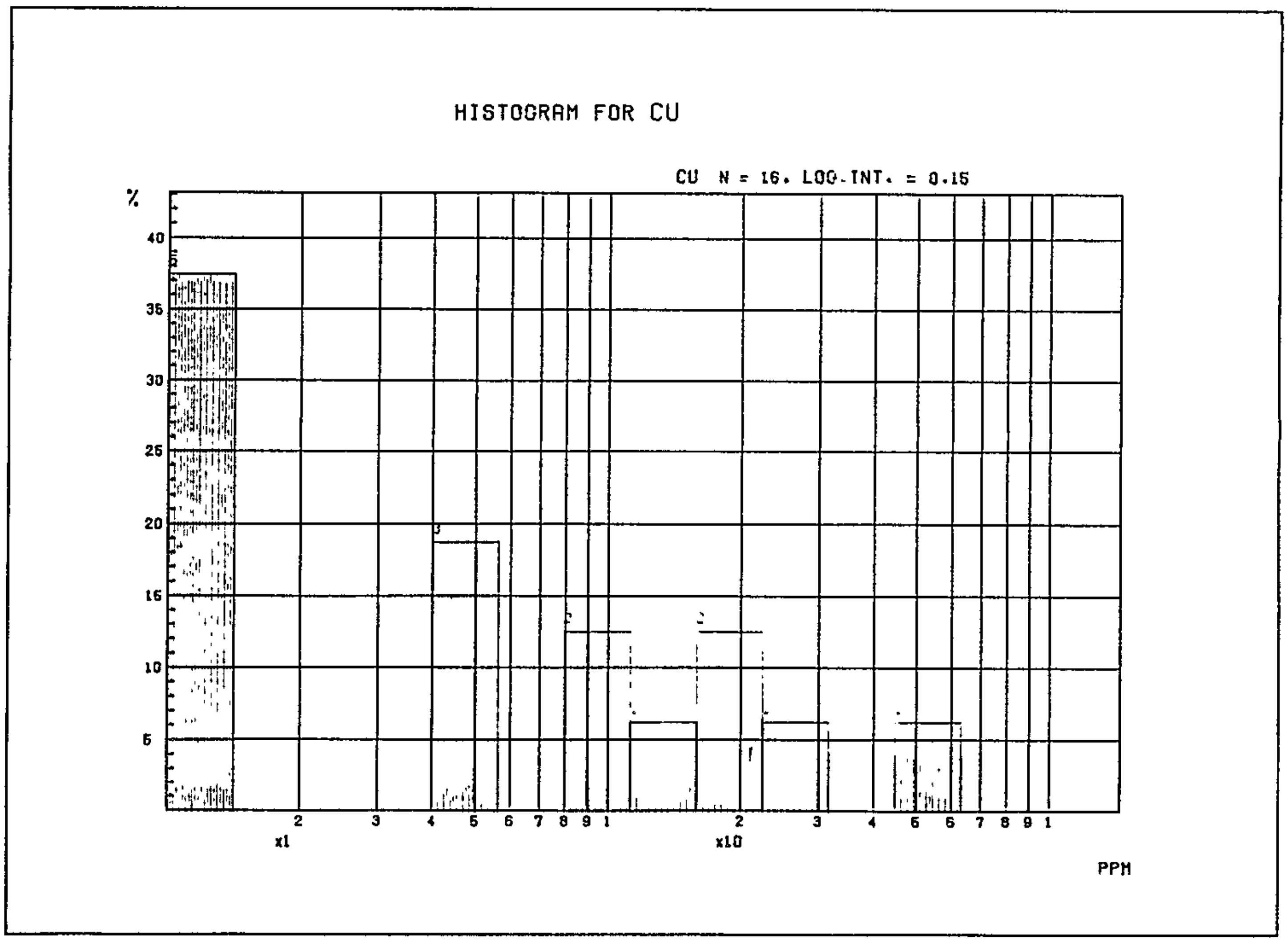
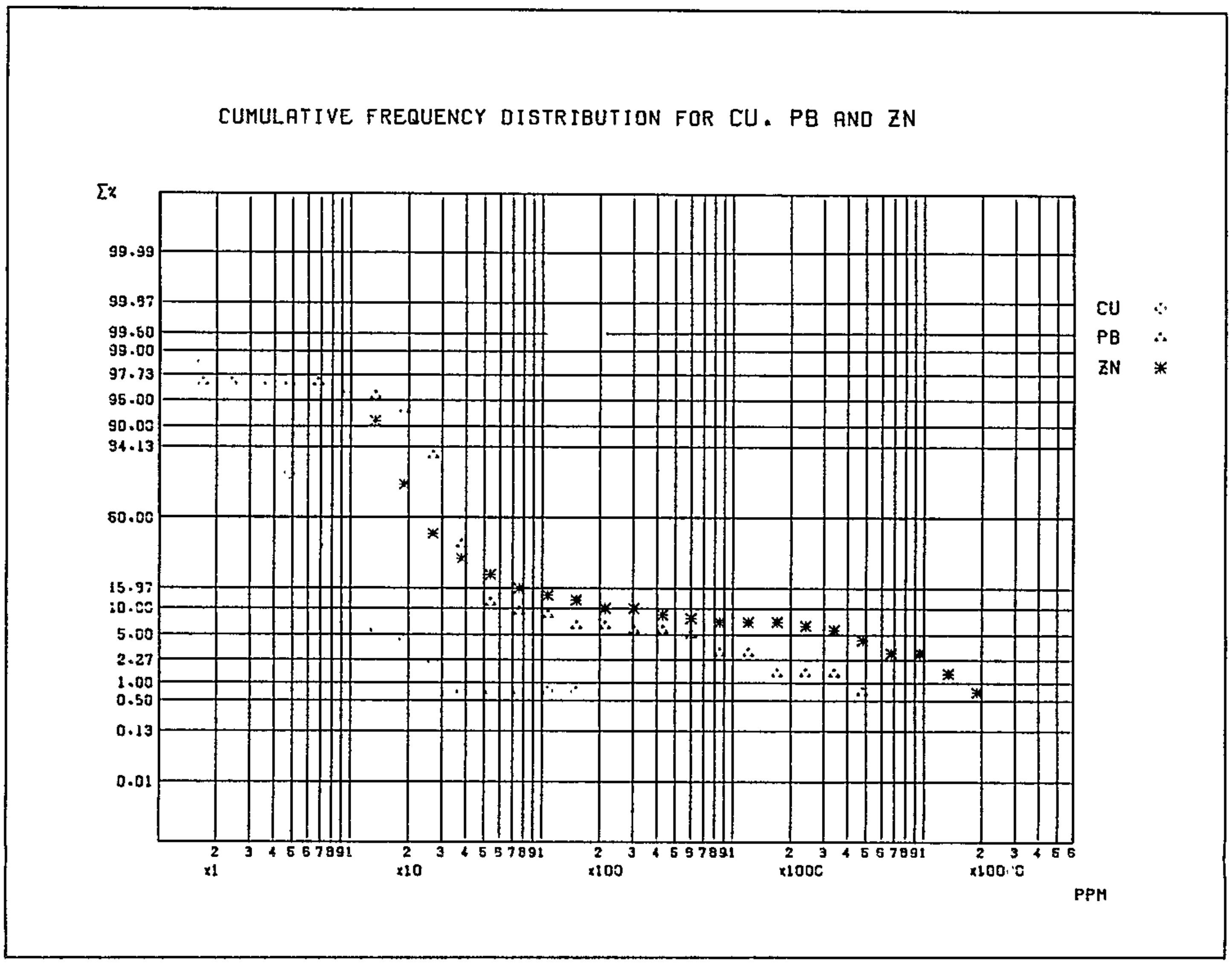
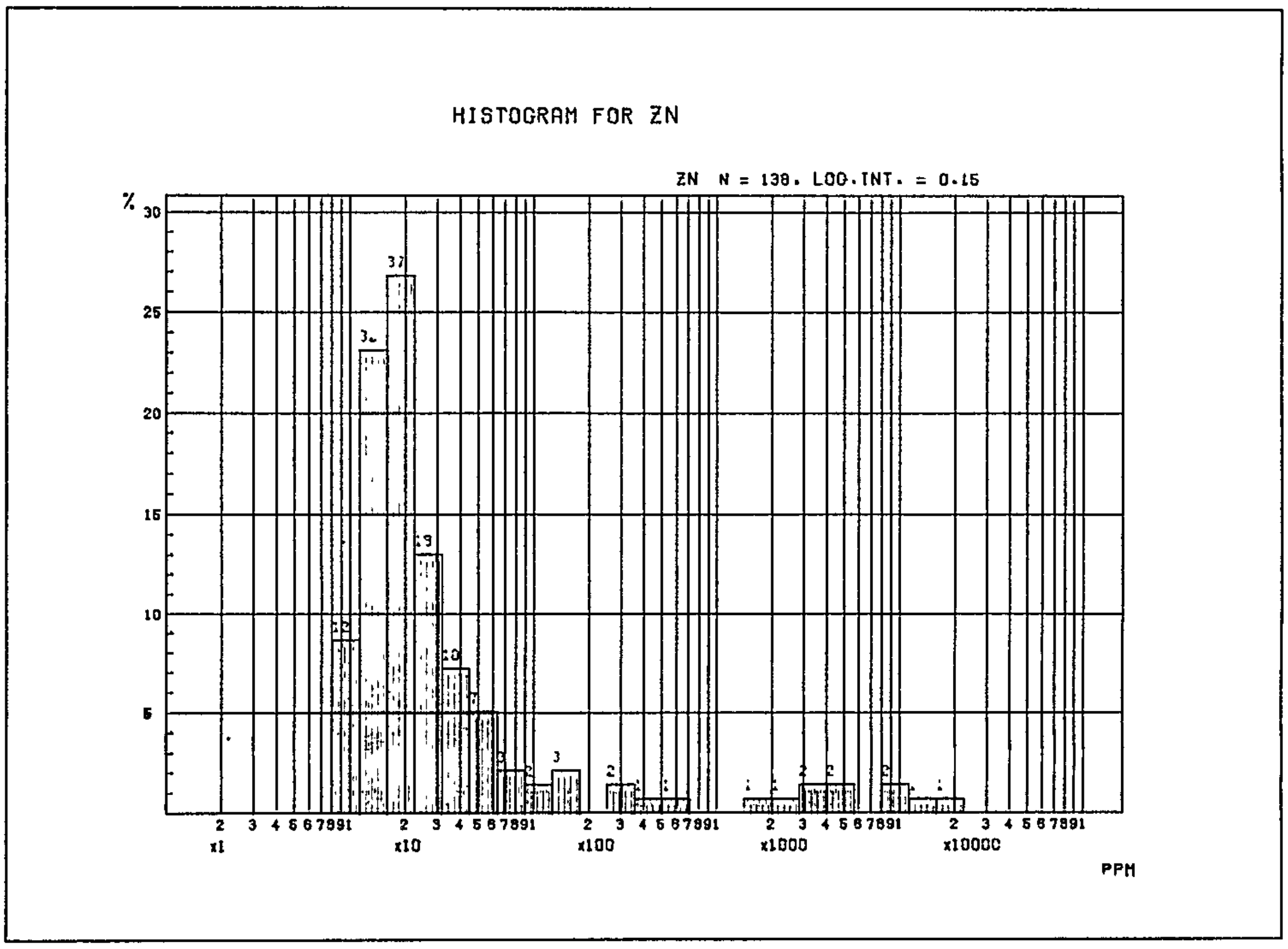
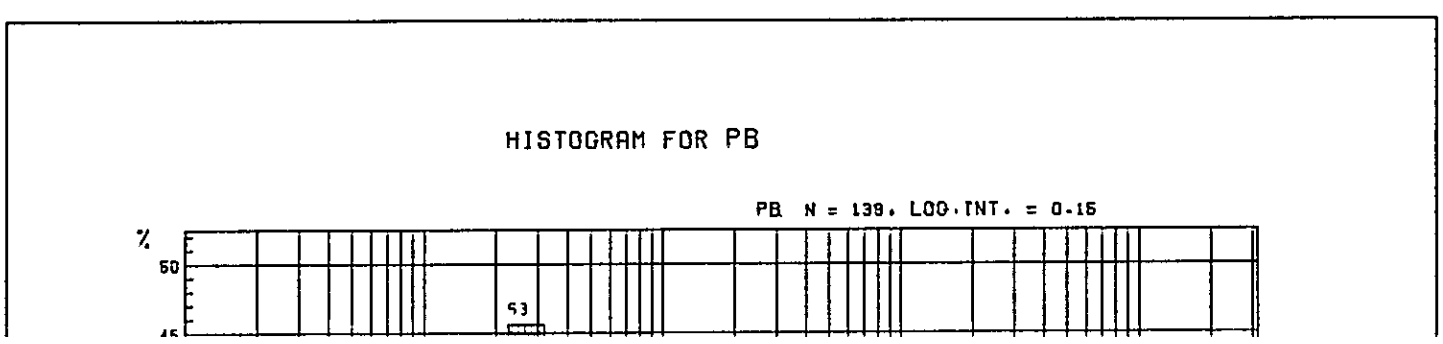
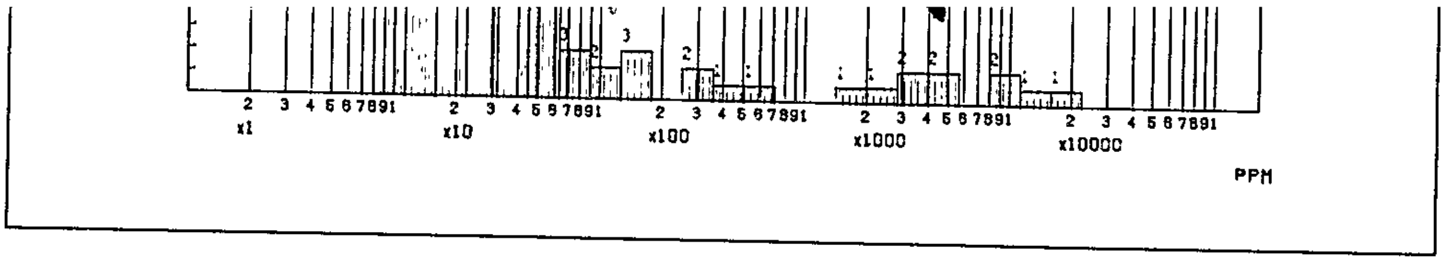


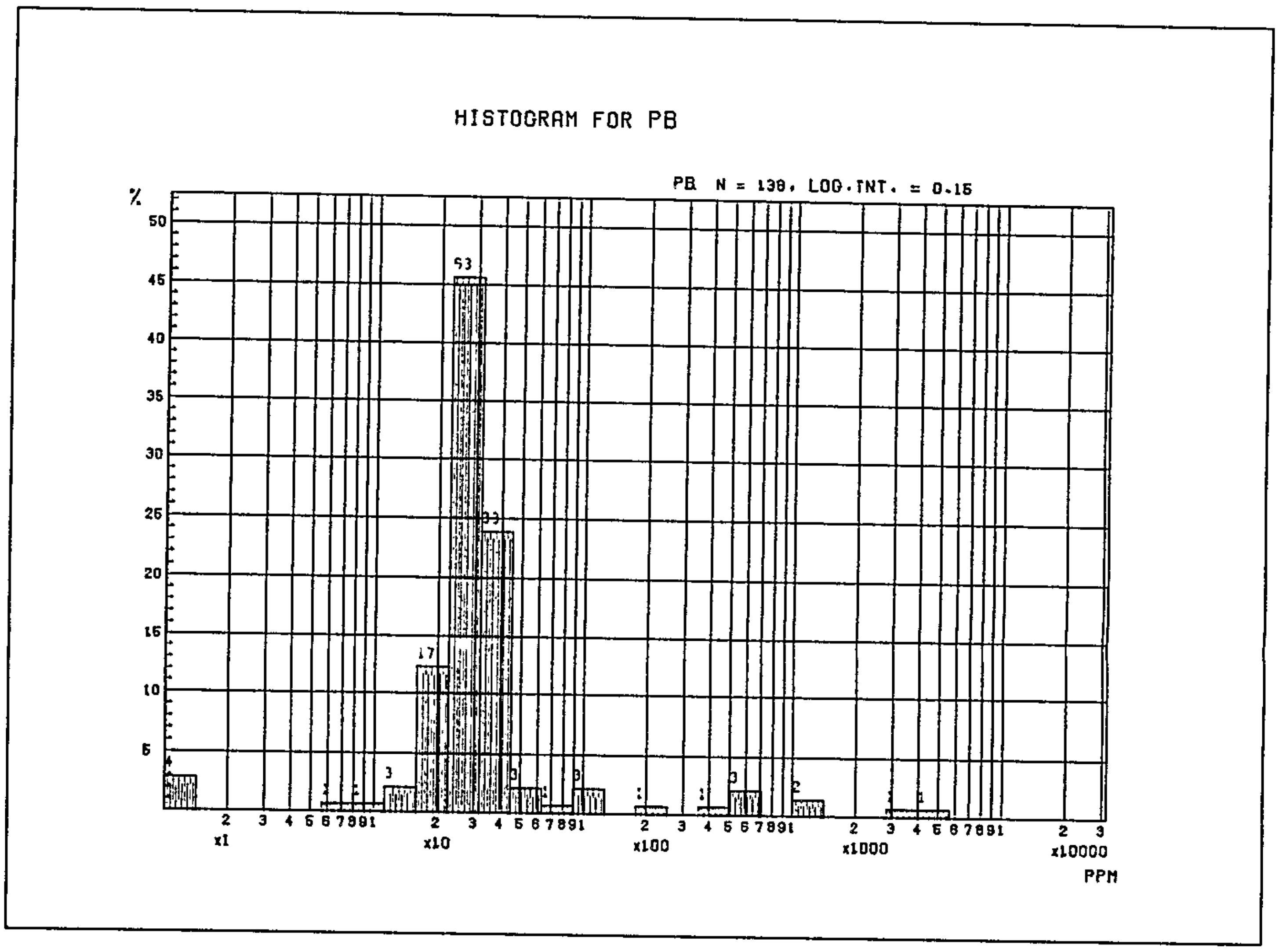
Fig. 16 Histogram and Cumulative Frequency Curve for Cu, Pb and Zn Contents in the Geochemical Samples (2) Chimu and Oyon Formations


CUMULATIVE FREQUENCY DISTRIBUTION FOR CU. PB AND ZN
Σ%
99.99
99.97
99.50
99.00
97.73
95.00
90.00
84.13
50.00
15.87
10.00
5.00
2.27
1.00
0.50
0.13
0.01
CU
PB
ZN
x1
x10
x100
x1000
PPM


HISTOGRAM FOR ZN
ZN N = 138. LOG.INT. = 0.15
%
30
25
20
15
10
5
37
13
10
3
x1
x10
x100
x1000
x10000
PPM


HISTOGRAM FOR PB
PB N = 139. LOG.INT. = 0.15
%
50
53





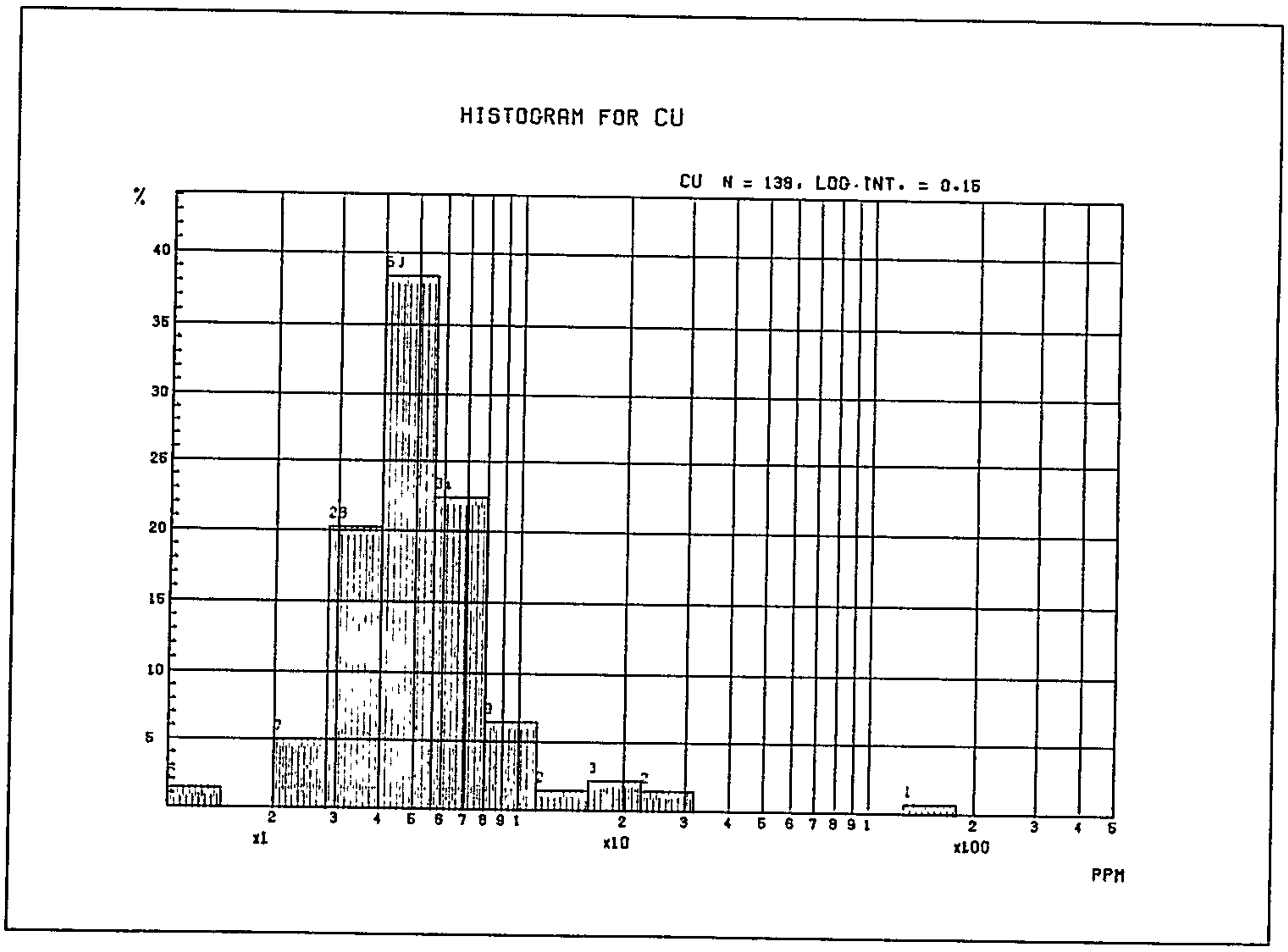
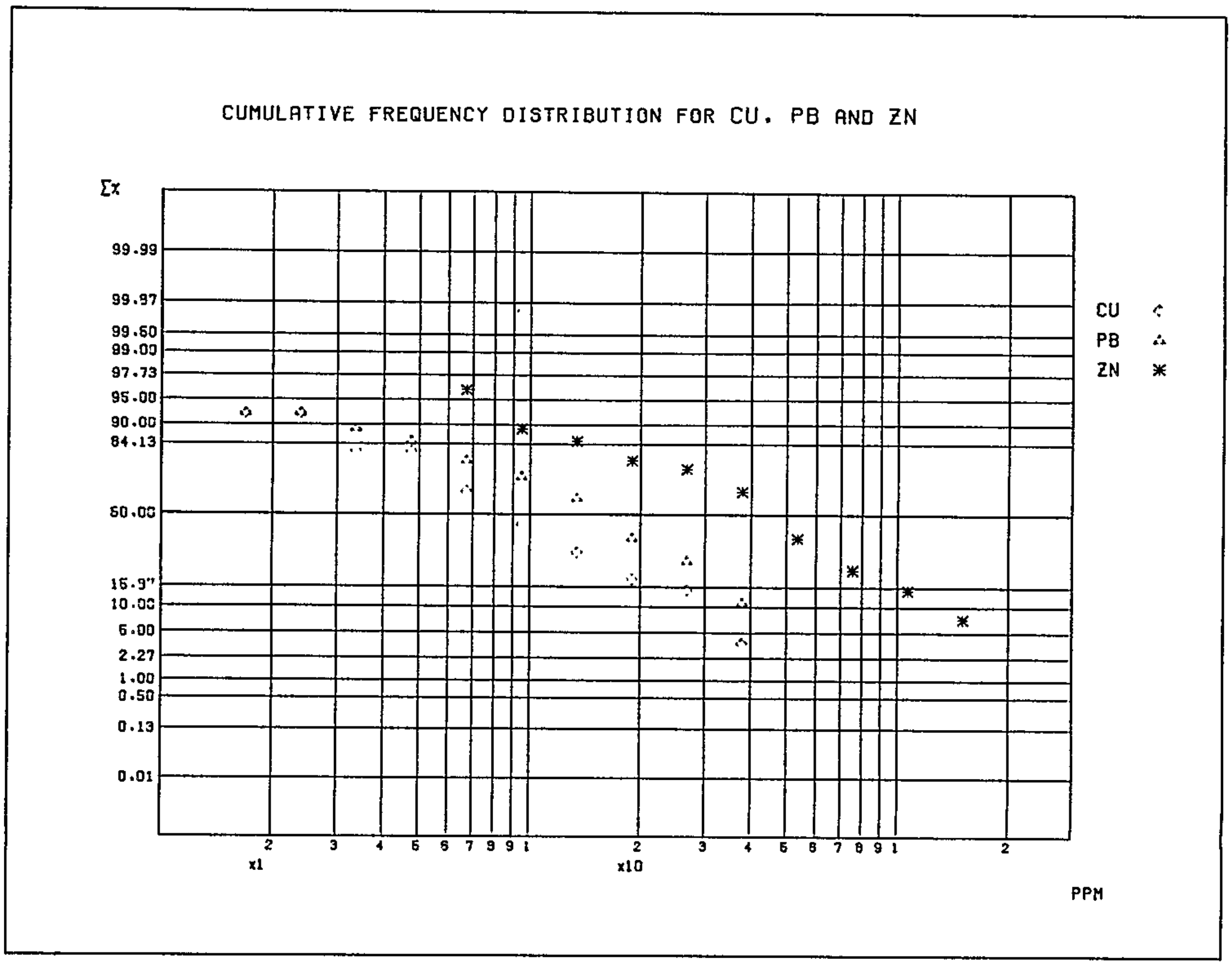
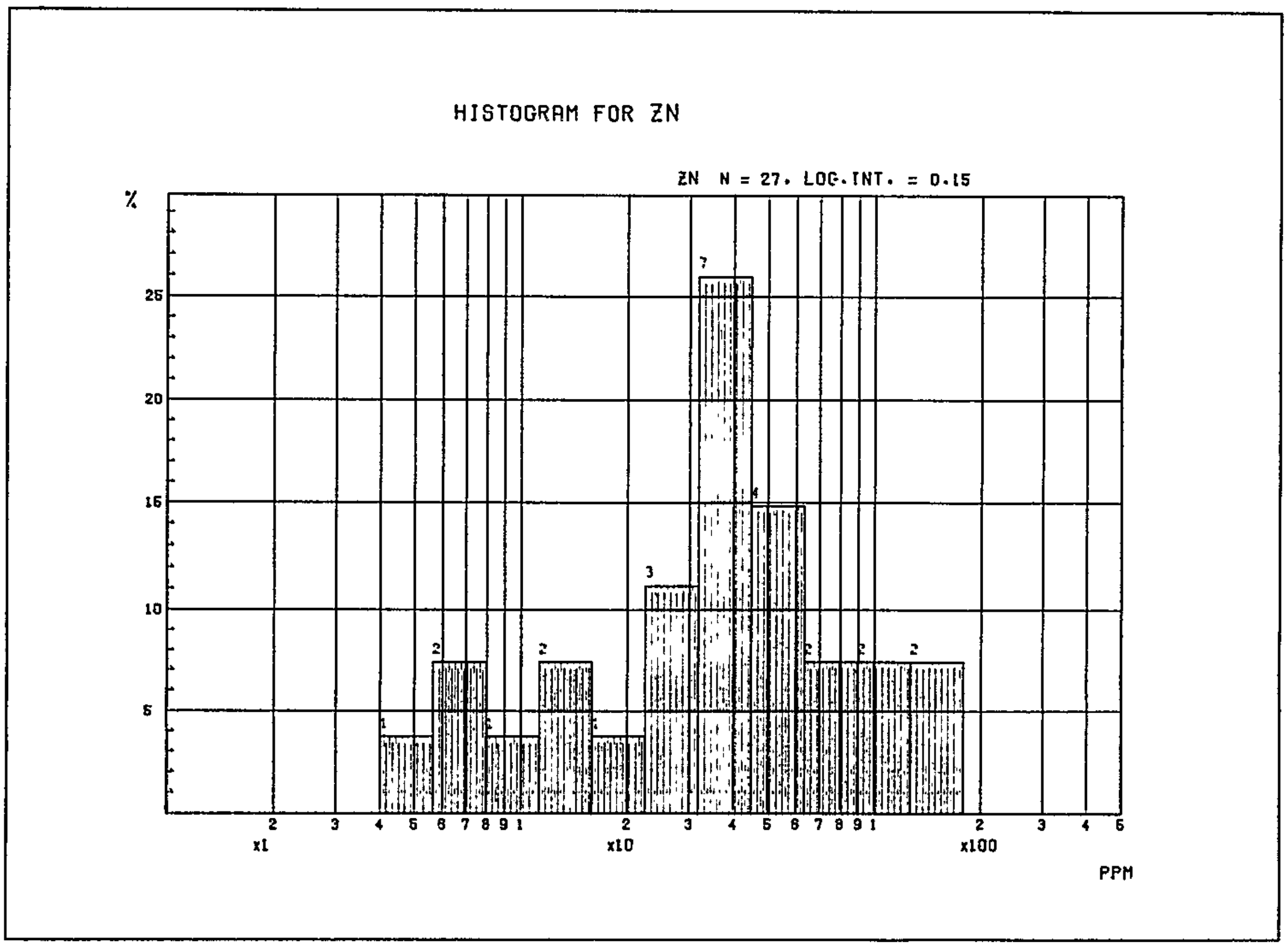
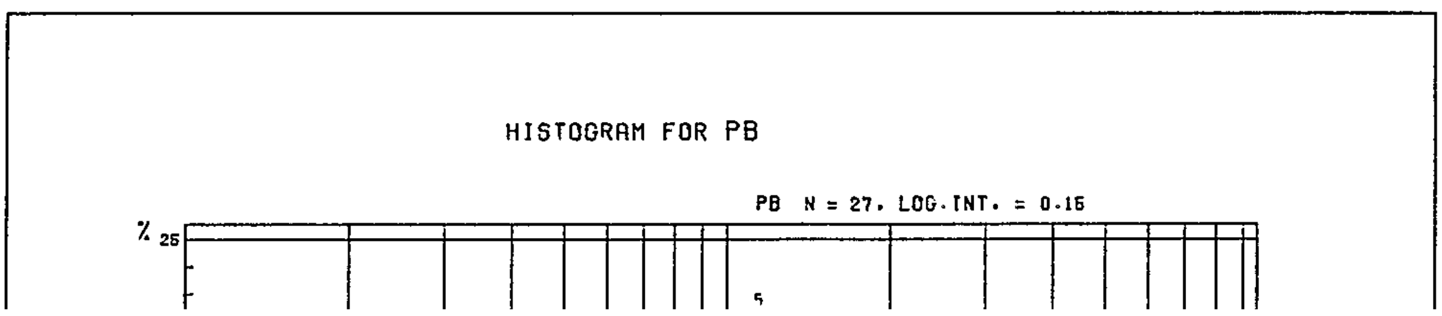
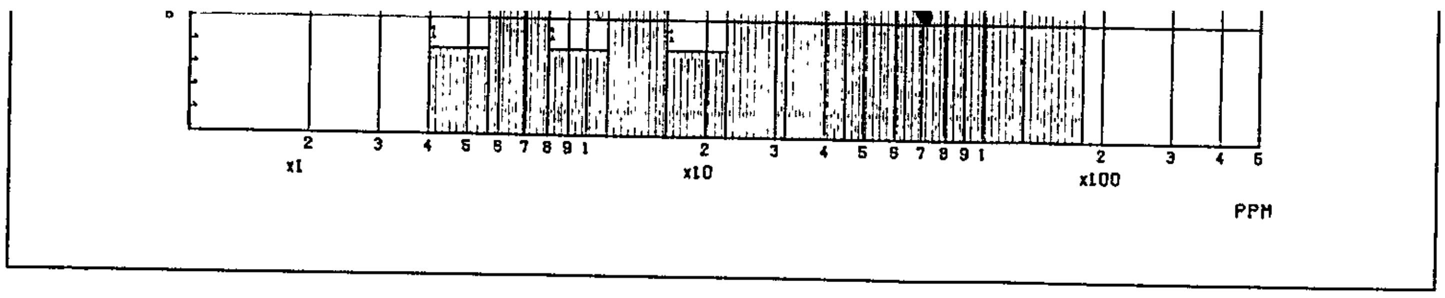


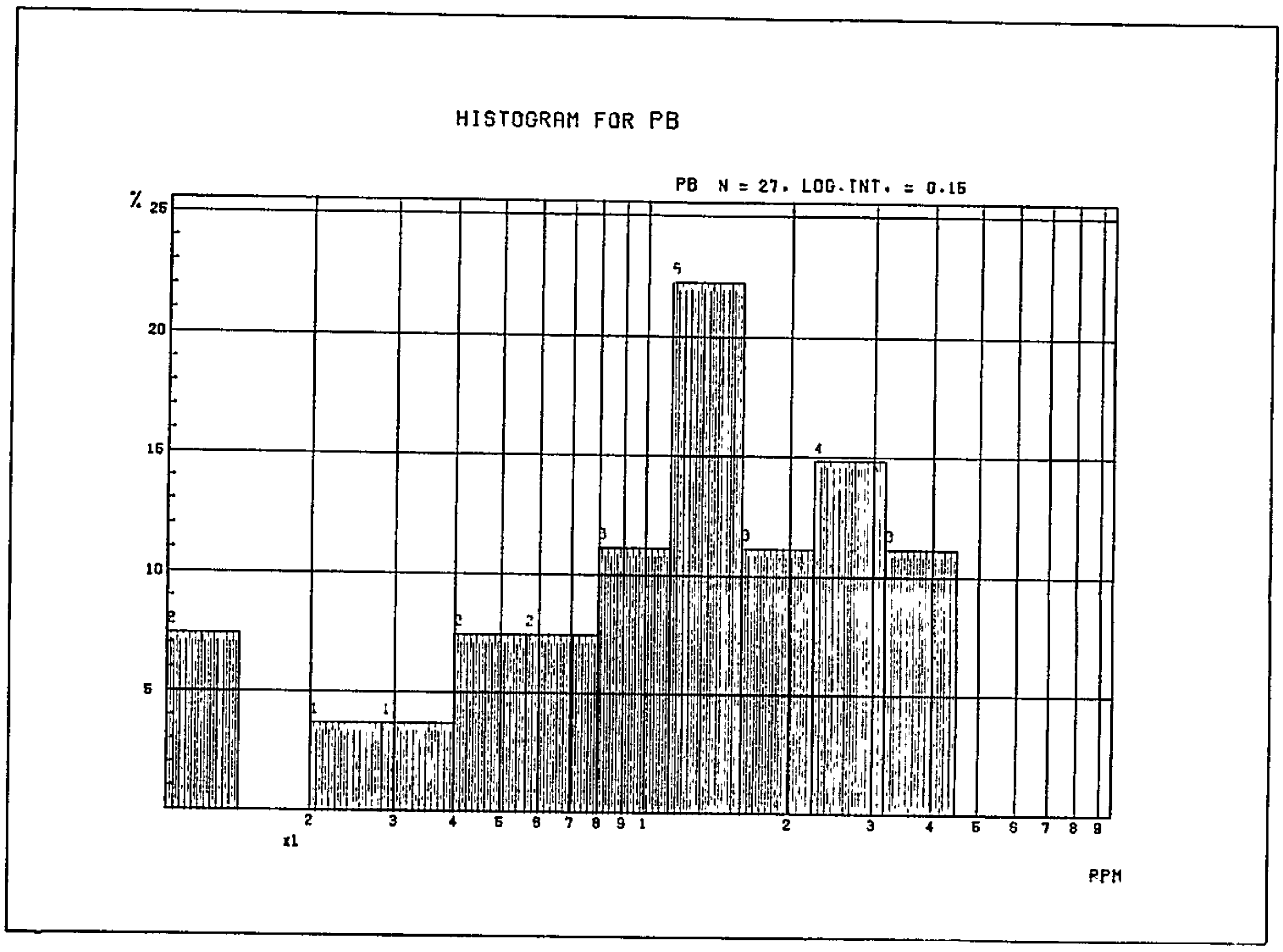
Fig. 16. Histogram and Cumulative Frequency Curve for Cu, Pb and Zn Contents in the Geochemical Samples (3) Santa Formation


CUMULATIVE FREQUENCY DISTRIBUTION FOR CU. PB AND ZN
Σx
99.99
99.97
99.60
99.00
97.73
95.00
90.00
84.13
50.00
15.9"
10.00
5.00
2.27
1.00
0.50
0.13
0.01
CU
PB
ZN
x1
x10
PPM


HISTOGRAM FOR ZN
ZN N = 27. LOG.INT. = 0.15
%
25
20
15
10
5
x1
x10
x100
PPM


HISTOGRAM FOR PB
PB N = 27. LOG.INT. = 0.15
% 25





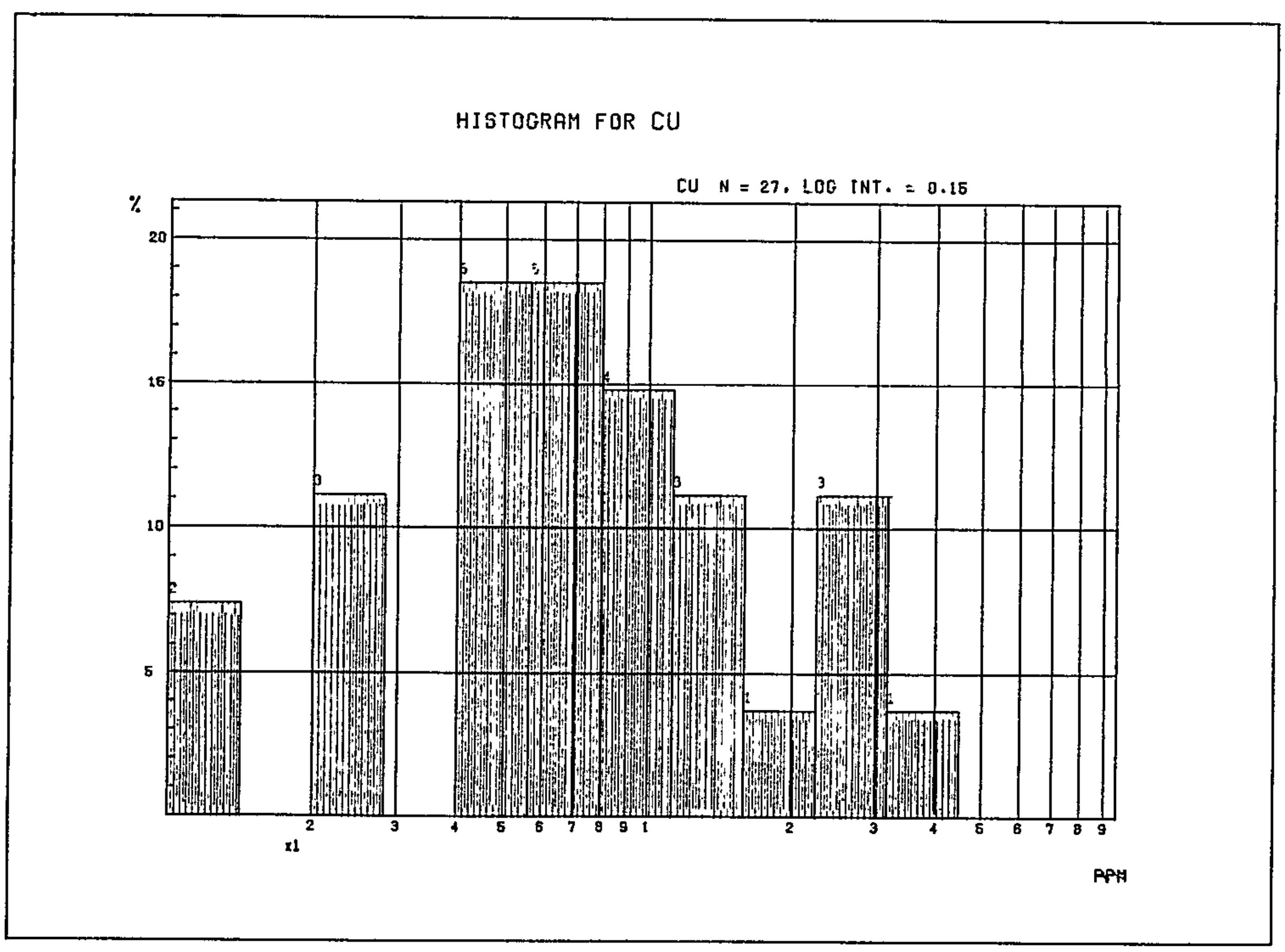


Fig. 16. Histogram and Cumulative Frequency Curve for Cu, Pb and Zn Contents in the Geochemical Samples (4) Carhuaz and Farrat Formations