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METAL MINING AGENCY
JAPAN INTERNATIONAL COOPERATION AGENCY
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PREFACE

The Government of Japan, in response to the request of the Government of the Republic of Peru, decided to conduct a geological survey for mineral exprolation in central part of Cordillera Oriental of Peru, and commissioned its implementation to the Japan International Cooperation Agency.

The Agency, taking into consideration of the importance of technical nature of the survey work, in turn sought the Metal Mining Agency of Japan for its cooperation to accomplish the task within a period of four years.

This year was for the third phase survey, and as for above-mentioned work, a Geological-Geochemical survey, geophysical survey and drilling survey teams were formed consisting of seventeen (17) members June 10 headed by Mr. Shigeaki Yoshikawa, MESCO, Inc., and sent to the Republic of Peru on June 10, 1977. The teams stayed there for one hundred sixty-four (164) days from June 10, 1976 to November 20, 1976. During the period of its stay, the teams, in close collaboration with the Government of the Republic of Peru and its various authorities, was able complete survey works on schedule.

This report submitted hereby summarizes the results of the Geological-Geochemical Survey, Geophysical Survey and Drilling Survey in the area, and Aerial Photogrammetric-mapping performed for the third-phase survey.

We wish to take this opportunity to express our heartfelt gratitude to the Government of the Republic of Peru and the other authorities concerned for their kind cooperation and support extended to the Japanese survey team.

February 1978

Shinsaku Hogen
President
Japan International Cooperation Agency

Yasuaki Hiratsuka
President
Metal Mining Agency of Japan

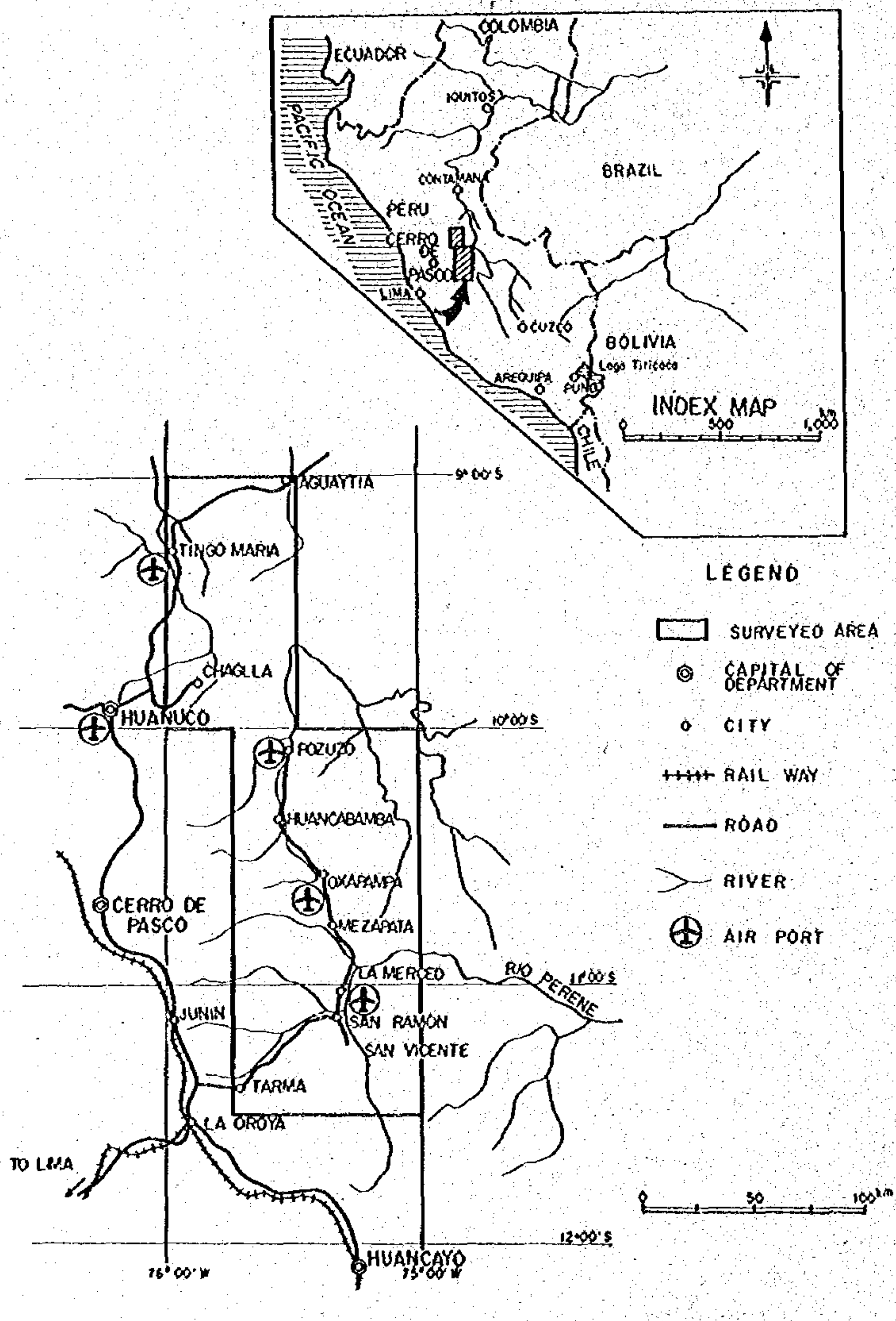

Fig. 1. Location Map of the Surveyed Area

GENERAL CONTENT

ABSTRACT

The present survey has been carried out comprising a part of the part of geological survey for the development of mineral resources in the central part of the Republic of Peru. The purpose of the survey is;

(1) To confirm the distribution of the Pucara Group in which strata-bound lead and zinc deposits are expected to have been emplaced, and to extract some areas of high potentiality for the mineral resources.

(2) To establish the most appropriate principle and the most effective methods for the exploration of strata-bound lead and zinc deposits.

The field works of geological survey, geochemical survey, geophysical survey and diamond drilling were carried out from June to November, 1977. The laboratory works were performed in the period between September 1977 and February 1978.

The rocks distributed in the surveyed area are Pre-Cambrian metamorphic rocks, the sedimentary rocks accumulated intermittently from Paleozoic Devonian to Cenozoic Tertiary period, and the igneous rocks of the several stages of activities between the end of Paleozoic and Cenozoic Tertiary period. These rocks show generally the trend of NNW-SSE. Macroscopically, the igneous rocks and the metamorphic rocks are distributed in the western part of the surveyed area and the sedimentary rocks are in the eastern part. Among the sedimentary rocks, the distribution of the Pucara Group is along the east of the zone of the igneous rocks, in the surveyed area. The trend of NNW-SSE is the major direction of the geological structures, and the synclines and the anticlines develop with the axes of this direction. Furthermore, the faults (normal faults and reverse faults) of the same bearing develop well with the faults corss-cutting them, of the trends of NWW-SEE and NEE-SWW.

In the surveyed area, strata-bound lead and zinc deposits, disseminated lead and zinc mineral indications, skarn-type copper, lead and zinc deposits, vein-type copper, lead and zinc deposits and indication of porphyryr copper type mineralization are found mainly in the southern part. The strata-bound deposits and the disseminated mineral indications recognized in the Pucara Group are thought to be the most important of them. These two types of mineralizations are emplaced in the dolomite of the Pucara Group. The strata-bound type mineralization is represented by San Vicente deposit, Pichita Caluga deposit and Tambo Maria mineral indication, and the disseminated type mineralization is represented by San Roque mineral indications. The distribution of strata-bound type mineralization is recognized to be remarkable in the dolomites showing banded structures, associated with structural disturbance such as folds and faults. The disseminated type mineralization at San Roque has been recognized on the surface and also lead and zinc dissemination has been confirmed, in the drill core of the four diamond drilling of the present year, in and/or on the muddy carbonate rocks. These mineralizations are thought to relate to the remobilization and the concentration of the metal elements, and also it is considered that the strata-bound lead and zinc deposit would have been formed as the development product of the disseminated type mineralization essentially precipitated as lead-zinc sedimentation.

For the above consideration, the results of the geochemical survey have participated, in addition to the geological and mineralogical analyses. That is, the analyses of the geochemical survey have been obtained by the extraction of the anomaly of San Roque type showing the high frequency in higher value than the average value, and the anomaly of Tambo Maria type showing high frequency in lower value. It is characteristic that the anomaly of the Tambo Maria type coincides roughly with the distribution area of the dolomite showing banded structure around the mineral indication at Tambo Maria, where strata-bound type mineralization has been recognized. This analysis method of the geochemical survey is thought to be very effective for the exploration of the mineralization of this sort. By the results of the geochemical survey by soil samples in the surveyed area, remarkable Zn anomaly has been confirmed in the Pucara Group, and Cu anomaly has been found in the area where diorite, prophyritic rocks, and vein type mineralization are distributed. Also, Ni anomaly has been detected in the area where the metamorphic rocks and diorite are distributed. It has been clarified from the above that Zn can be an indicator for the exploration of the strata-bound lead and zinc deposits and that Cu and Ni are effective for the classification of lithofacies as well as for the examination of the mineral indications.

As the geophysical survey, gravity survey and electric survey have been carried out. Through the gravity survey, the distribution and the structure of the dolomite, the most important rock, extending around Oxapampa area have been ascertained, as the density of the recrystallized dolomite is extremely high. Hovever, it has also become obvious that the electric survey is not effective for the exploration of this sort of mineralization.

Through the examination of the survey results as mentioned above, the high potential areas for the strata-bound lead and zinc deposits have been selected as Tambo Maria area and San Roque area situated near the Oxapampa in the southern part of the surveyed area. Also, in the northern part, the areas around Tambo de Vaca and in the valley of Rio Huallage, where Zn anomalies has been detected by the geochemical survey, would be high potential areas according to the favorable future survey results.

The following methods will be effective for the exploration of possible mineralizations in the above favorable areas.

(1) To check the geological structure and the stratigraphy of the Pucara Group, especially the paleo-environment of sedimentation of the dolomite and the muddy carbonate rock.

(2) The geochemical survey by rock sample, for the elements of lead and zinc.

Accordingly, the folloivng programme would be recommended.

(1) In the high-potential areas where subsurface mineral deposits are expected to exist,

1 geological survey and trenching

2 survey for the distribution of impurity elements

3 deep diamond drilling for geological structure

(2) Also, in the northern part of the surveyed area, introductory surveys corresponding to the surveys in Oxapampa area will be necessary in the areas of Rio Huallaga and Tambo de Vaca.

GENERAL

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Chapter 1 Introduction

1-1. Purpose of Survey

This survey was carried out in the area about 20,000 Km^2 planned for the project of geological survey for mineral resources development in the eastern parts of the departments of Junin, Pasco and Huanuco in central part of the Republic of Peru.

The purpose of the survey was to clarify the distribution and structure of the Pucara Group where so-called "Strata-bound lead and zinc deposits" are expected to exist, to extract some areas of high possibility of these deposits, and to determine the most suitable survey methods.

1-2. Progress of Survey

The 20,000 Km^2 area planned for the survey is rather underdeveloped except for the part of southern region. To expedite development of this area, in 1974, the Ministerio de Energia y Minas of the Republic of Peru set a Cordillera Oriental development plan covered Cordillera Oriental including this survey area by SLAR (side looking airborne radar) mosaics and conducted geological analysis on that basis. This survey was started in 1974 for the large 20,000 Km^2 area as a sequel to the ministrial plan. As there was not covered topographic maps and aerial photographs that were necessary for this project, the survey works, which is consisted of the checking of interpretation map by SLAR and this regional reconnaissance survey including with geochemical survey aimed to gain fundametal informations about ores, were carried out by the SLAR mosaics.

This reconnaissance survey was carried out in 1975 ~ 1976. As the result, it is clarified that the distribution of the Pucara Group, which is the principla purpose of this survey, and this group with which identified the country rock of the San Vicente mine in the southern part, is important for the deliberating on the country rock of the strata-bound lead and zinc deposits.

Therefore, the survey operations of 1976 in the southern part were limited in the area where Pucara Group is distributed by the semi-detailed survey and detailed survey, for investigating and studying many aspects included the stratigraphy of the Pucara Group and the appearance of ore deposits. Consequently, it were clarified that the "Strata-bound lead-zinc deposits" are closely related to the dolomite of the Pucara Group. Thereupon, in this year geological survey as well as geophysical survey and diamond drilling, purporting to gain more detailed data, were carried out.

The topographic maps were always used in this geological survey except for the initial reconnaissance. But, at the beginning, uncompleted maps which were plotted from aerial photographs that had been taken and were specially taken for this survey, were used in the area where no topographic map was published.

All works that have been done is shown in Fig. 2. and Table 1.

1-3. Outline of Survey

1-3-1. Extent of Survey

- Geological survey :		
Detailed survey	6 Areas Approx.	100 Km^2
Semi-detailed survey	4 Areas Approx.	300 Km^2
Reconnaissance	3 Areas Approx.	1,000 Km^2
- Geophysical survey	1 Area Approx.	400 Km^2
- Diamond drilling	4 holes, total	968.8 m

The detailes of this survey scope are shown in Fig. 2, and the routes to those areas are shown in Fig. 3.

1-3-2. Methods and Periods of Survey

(1) Field Survey

The geological survey was started on June 10, 1977 upon the completion of topographic mapping based on aerial photographs taken in 1976. The survey consisted of detailed survey, semi-detailed survey and reconnaissance conducted in each area. The existing and newly prepared topographic maps (1/10,000 or 1/25,000) were generally used; SLAR mosaics provided by the Institute de Geologia y Mineria (INGEOMIN), were used for reconnaissance in the northern part.

The geochemical survey was paralleled with the geological survey and geochemical samples by rocks and soil were sampled on the survey routes.

The geophysical survey consisted of gravity survey and electrical survey, was conducted in the vicinity of Oxapampa in the southern part.

The gravity survey was operated at intervals of about 500 m and 1,000 m in the surveyed area. The position of stations used in gravity measurement was determined on topographic maps prepared from aerial photographs. Bench levels for the stations were determined mainly by level survey. In the steep mountains, they were measured by the Paulin altimeter and based on the Oxapampa BM, which was measured by the Peruvian IGM (Institute de Geografico Militar).

The electrical survey was operated for studying its applicability in the future. Measurement was made by the method of in-situ measurement with respect to mineral indications that had been discovered. Four holes were bored by diamond drilling amounting to 968.8 m at the northwest of Oxapampa, continuously core logging was carried out.

All the above works were finished on 20th, November (Table 2).

(2) Analytical Work

The overall analitical works of the surveyed area, based on the data gained in this field survey and existed previously, were enforced after the end of field survey considering with the more precise or the more detailed survey method in the future.

This work was almost done in Japan, partly was done in Peru.

This analytical work took six months from September to February. The Peruvian engineer, Oscar Palacios, the Instituto de Geología y Minería (INGEOMIN) participated in this work.

1-4. Organization of Survey Team

The field works and data analysis were performed by MESCO, Inc., with cooperation of the geological survey of the Republic of Peru ((Instituto de Geologia y Mineria).

Members of field survey team are listed below.

Leader	Shigeaki Yoshikawa	MESCO, Inc.
General Affairs and Liaison	Kazutsugu Fuchimura	Japan International Cooperation Agency
	Shinsei Terashima	Metal Mining Agency of Japan
	Hisamitsu Moriwaki	"
Member (Geologist)	Hiroshi Sato	MESCO, Inc.
	Yasumasa Fukahori	"
	Yukichi Tagami	"
	Shin'ichi Doi	"
	Ikuhiro Hayashi	"
	Hideo Suzuki	"
	Minoru Saito	"
	Kezuyasu Sugawara	"
(Geophysist)	Shigeo Moribayashi	"
	Tomoyuki Takemura	"
	Kazuhiko Kinoshita	"
	Tomio Tanaka	"
	Masasamu Oyanagi	"
(Drilling Engineer)	Yoshinobu Sakamoto	"
	Katsumasa Tanigawa	"
	Ikuo Tanigawa	"
	Isamu Nakayama	"

General Affairs	Benjamin Morales A.	Instituto de Geologia y Mineria, the Republic of Peru
	Alberto Pool R.	
	Carlos Guevara R.	
	Julio Caldas V.	"
	Oscar Palacios M.	"
Counterpart	Victor Pecho G.	"
	David Davila M.	"
	Alberto Aranda V.	"
	Alberto Gamarra	"
	Alberto Garro	"
	Manuel Aldana	"
	Guillermo Diaz	"
	Luis Carrera	"
	Zenen de la Cruz	"

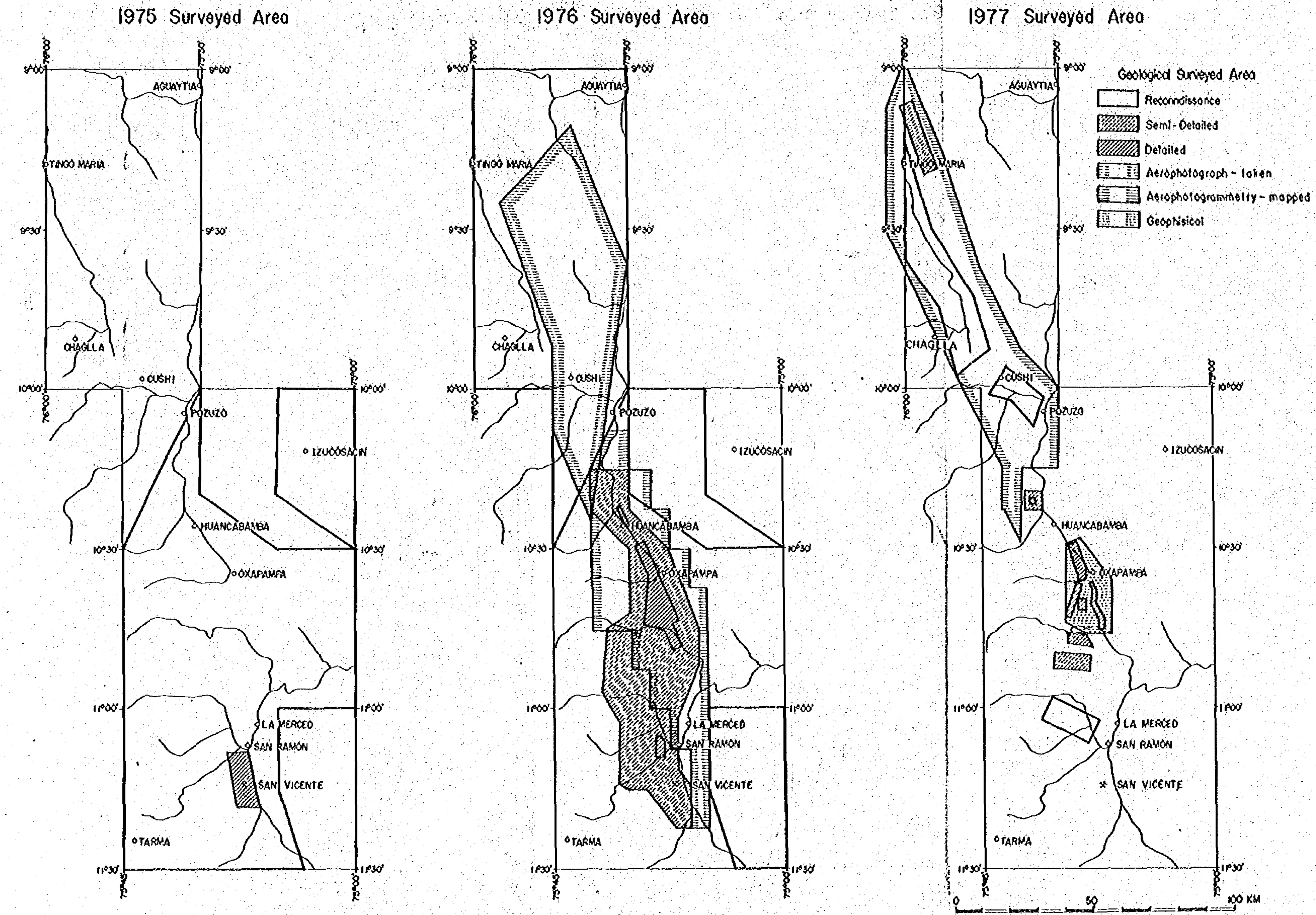


Fig. 2 Location Maps of the Field Works from 1975 to 1977

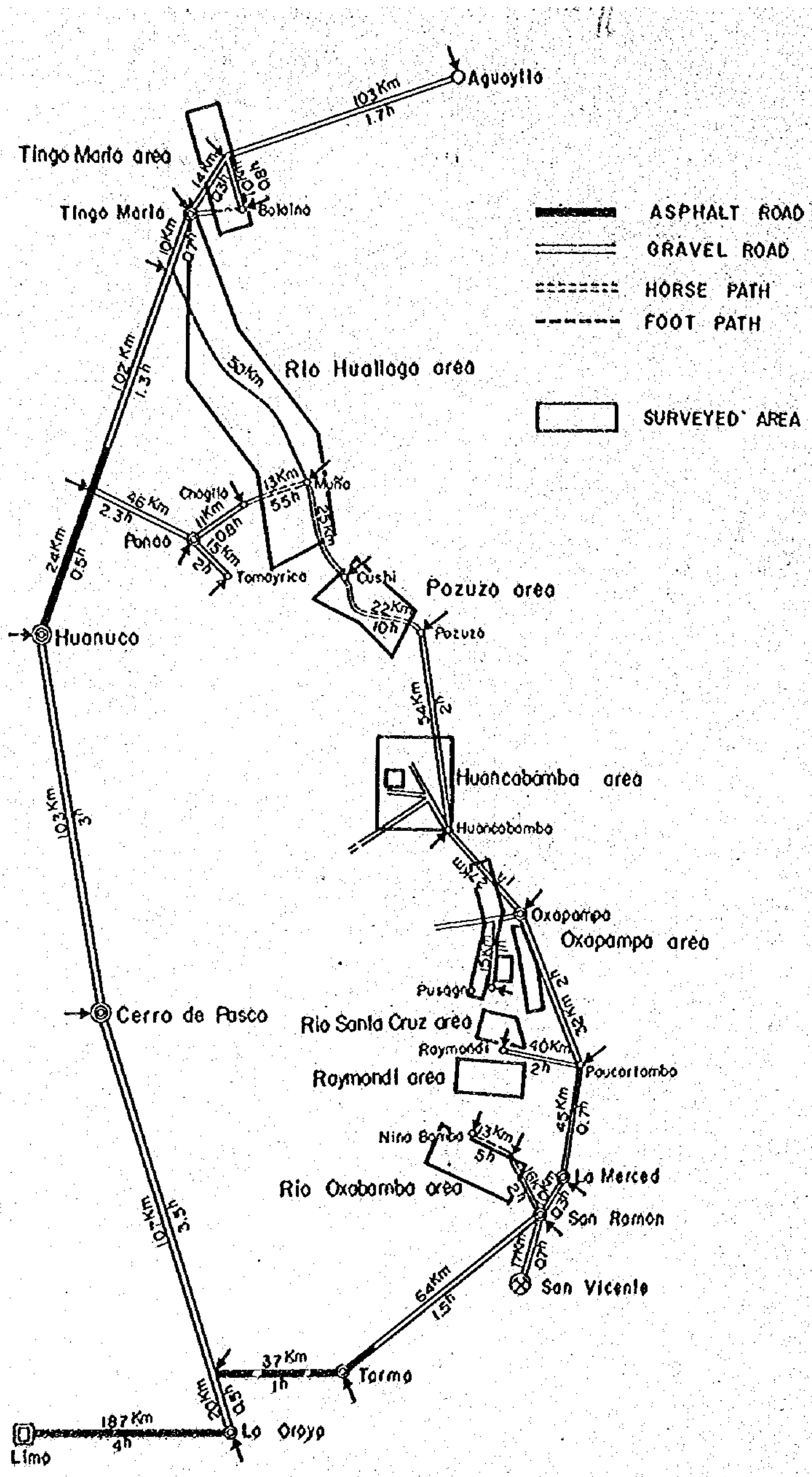


Fig. 3. Accessibility Map of the Surveyed Area

Table 1. Entire field works carried out from 1976 to 1977 in the surveyed area

Items	1975	1976	1977
Geological Survey (km^2)			
Reconnaissance	10,000	10,000	1,000
Semi-detailed survey	-	2,000	300
Detailed survey	100	259	100
Geochemical Survey (samples)			
Reconnaissance	2,595	1,702	262
Semi-detailed survey	-	2,622	315
Detailed survey	412	2,034	1,185
Geophysical survey (km^2)	-	-	400
Drilling (m)	-	-	(4 holes) 968.8
Aerophoto taking (km^2)	-	3,000	-
Topographic mapping	-	3,000	3,400

Table 2. Period of the surveyed works in 1977

Items	1977								1978	
	5	6	7	8	9	10	11	12	1	2
Geological and geochemical survey		10			10	(92 days)				
Geophysical survey			1		6	(68 days)				
Drilling Core logging				23			20	(90 days)		
Topographic mapping	- - - - - - - -	- -								
Analysis and Interpretation					7					10 (157 days)

Chapter 2 Summary of Survey Results

2-1. Results of the Geological Survey

The present year's surveys are constituted by the detailed geological survey in the southern part of the surveyed area, and by the semi-detailed geological survey and the supplemental geological reconnaissance in the southern and the northern parts. The synthetical elucidation of the survey results, including the results of the past year's surveys belonging to the basic geological survey in addition to those of the present year's surveys, are given below.

(1) In the surveyed area, the igneous rocks and the metamorphic rocks are distributed mainly in the western part, and the sedimentary rocks are found in the eastern part. The distribution of these rocks are following to the general trend of the geological structure, NNW-SSE, in the central part of the Republic of Peru.

(2) The metamorphic rocks are composed of schists and gneisses and are distributed mainly in the western part of the surveyed area as the base of the sedimentary rocks or as the roof-pendants of the granites intruded at the end of the Paleozoic Era.

(3) The igneous rocks distributed in the western part comprise followings.

- granites intruded at the end of the Paleozoic Era.
- diorites and granites intruded, in the Mesozoic Jurassic period, along the eastern margin of the Paleozoic granite mass.
- granite porphyry and quartz porphyry intruded, in the Mesozoic Cretaceous period, also along the eastern margin of the Paleozoic granite mass.
- volcanic rocks extruded, in Cenozoic Tertiary period, in the area occupied mainly by the Paleozoic granite.

And, along the fault running through the central part with the trend of NNW-SSE, there are monzonites intruded in Cenozoic Era, Tertiary period.

(4) As for the sedimentary rocks in the surveyed area, the older formations are distributed in the west and the younger beds are found eastward in succession of the order of their ages macroscopically. Their sedimentation have been deposited intermittently from Devonian period of Paleozoic Era to Tertiary period of Cenozoic Era in age. There are three interruption of the main sedimentation at the periods of the orogenic that is, at the periods prior to early Permian period of Paleozoic Era, prior to middle Jurassic of the Mesozoic Era, and in Paleogene of the Cenozoic Era.

(5) The Pucara Group, accumulated between the Triassic and the Jurassic of the Mesozoic Era, is distributed in the central part of the surveyed area, forming a narrow zone extending in NNW-SSE, and overlying the Mitu Group with unconformity. Along the west side of the zone of the Pucara Group, it is mostly intruded by the younger igneous rocks though in some places it is bounded with the Paleozoic granite by faults. On the other hand, along the east side of the zone, the group is bounded with the younger sedimentary rocks by faults or by unconformity.

(6) The Pucara Group is composed mainly of carbonate rocks as limestone, dolomitic limestone and dolomite, with the insertions of sandy and muddy layers. Six members are classified of this group in the surveyed area. In the southern part all the members and in the northern part upper three members (IV, V and VI member) are thought to be distributed. The lowermost member (I member) of the Pucara Group is correlated to the Aramachay Formation at the type locality, but the other members are not correlated well.

(7) Five main horizons of dolomite are found in the I, III, IV and V member. The dolomite contained in the III member distributed from the south of Oxapampa to Tambo Maria and around San Vicente is most extensive as is seen around Oxapampa where its thickness reaches 300 to 400 meters and the extension is over 15 km.

(8) The dolomite has what is called zebra-structure --- the banded structure composed of the bands of coarse grained white dolomite and fine grained dark dolomite --- and the mineral indications mainly of sphalerite at San Vicente and at Tambo Maria are recognized in such dolomite showing this structure.

(9) In the surveyed area, anticlinal and synclinal structures with the axes of NNW-SSE develop well, which compose the fundamental frame of the geological structure in this area. Normal and reverse faults of the same trend, NNW-SSE (partly N-S) as that of the folding axes develop as well as the fissures of the trends of E-W, NWW-SEE and NNE-SSE related to the lateral pressure of E-W or NEE-SSE, which is thought to have formed the above main geological structure represented by NNW-SSE direction.

2-2. Results of the Geochemical Survey

In the surveyed area, the geochemical survey has been carried out in association with the geological survey, to obtain informations on the mineralization. The synthetic elucidation of the survey results, including the results of the past year's surveys of this series in addition to those of the present year's survey, are given below.

(1) The geochemical survey by soil samples has been carried out in the reconnaissance areas, in the semi-detailed survey areas and in the detailed survey areas. Cu anomalies are detected in the areas where vein type mineralizations are recognized in the Pucara Group or in the granites,

and where Cu indications have been found in Jurassic diorites and Tertiary monzonites. Pb-Zn anomalies are not only limited to the area where the Pucara Group is distributed, but they are recognized to coincide with the area occupied by the dolomitic limestone and the dolomite. On the other hand, Ni anomalies are found in the area where gneisses and Jurassic diorites are distributed.

Consequently, it has been clarified that the surveys for the exploration of lead and zinc mineralization should be carried out in the area where the Pucara Group is distributed.

(2) In the detailed survey areas, the geochemical survey by rock samples has been carried out for Cu, Pb and Zn contents of the carbonate rocks, in addition to that by soil samples. By the results of the analytical research, it has become evident that the population is composed of the following three groups of different character as for the elements of Pb and Zn:

- group showing the high frequency in the average values of the whole samples
- group showing the high frequency in the average value and higher value than the average value of the whole samples
- group showing the high frequency in lower value than the average value of the whole samples

(3) The group whose average values (Cu 8 ppm, Pb 88 ppm, Zn 217 ppm) are higher than the average values of the whole samples (Cu 9 ppm, Pb 50 ppm, Zn 60 ppm) are located mainly in the western part of the surveyed area --- along the igneous rocks intruded in the Pucara Group. On the other hand, group whose average values (Cu 6 ppm, Pb 31 ppm, Zn 23 ppm) are lower than the average values of the whole samples are located mainly in the eastern part of the surveyed area.

(4) The threshold values for the anomaly of the group with lower average values have been statistically defined as Cu 22 ppm, Pb 194 ppm and Zn 412 ppm. The Pb and Zn anomalies extracted according to those threshold values are found in the neighbouring area of the igneous rocks, without any relation to the species of the rocks. The zonal distribution in the general sense is not recognized, but rather the reverse case has been found. The above mentioned is thought to indicate that the essential lead and zinc contained in the limestone or in the dolomite would have been rearranged to form the concentration under the influence of the intrusion of the igneous rocks. (Anomaly of San Roque type)

(5) The threshold value for the anomaly of the group with lower average value has been statistically defined as Zn 27 ppm. The main anomaly (Tambo Maria type) extracted according to this threshold value is found along the dolomite in Tambo Maria area --- especially coinciding with the area where the dolomite showing zebra-structure is distributed, extending about 10 km. The remobilization of zinc related to the structural movement has been suggested by the facts that the content of Zn is lower than that of Pb and that the mineral indication at Tambo Maria has been found in this anomaly.

(6) As above, although the geochemical survey by soil show remarkable dispersion of each element after leached out from rocks, the geochemical survey by rock is thought to be quite effective for the exploration of this sort of mineralization as it can supply informations on the remobilization of the metal elements in addition to the performances to extract anomalies of the high values as well as the special low value anomalies.

2-3. Results of the Geophysical Survey

The results of gravity survey and electrical survey in this surveyed area can be summarized as follows:

2-3-1. Results of the Gravity Survey

Gravity observations and levelings were carried out in this surveyed area and the results are represented as Bouguer anomaly maps.

Based on the Bouguer anomaly map by correction density $\rho = 2.67$, density structure of the area is analize by gravity trend analysis, wave length analysis, two dimensional analysis, three dimensional analysis, etc., which are represented as residual gravity map of third order, normal structure map, underground structure profiles, and underground structure map.

(i) From the Bouguer anomaly map ($\rho = 2.67$) a large-scale trend which dips to SWW direction controlling the whole surveyed area was detected. Because this trend inclines SWW-ward, the density anomaly with the same tendency deep in the ground and the existance of isostasy could be presumed.

(ii) In the residual gravity map of third order a gravity anomaly distribution in the relatively shallow underground was extracted, and relations between gravity anomalies and main layers were roughly classified as follows:

High gravity anomaly ..... Mitu Group, Pucara Group

Low gravity anomaly ...... Oriente Group, Pusagno granites

(iii) While the density anomaly relating to the variation of rock facies in the same layer was found and it is clearly shown in the normal structure map as gravity anomaly. For typical example of this an area predominated by dolomite in Pucara Group corresponds to high gravity anomaly, while that of sandstone to low gravity anomaly.

(iv) As discontinuity planes of density in the underground structure many fault-like step structures mainly extending to the N-S or the NNW-SSW direction were presumed. These fault-like step structures agree fully with locations and directions of faults recognized by the geological survey. Adaptability of the gravity survey to analized geological structure is proved.

(v) At the center of the surveyed area a high density zone having about 2 Km ~ 5 Km width and continuing approximately N-S-ward was detected. This zone coincides with an area predominated, especially, by dolomite layer in Pucara Group. Moreover, existence of zebra-structure in this dolomite bed could be expected and this area was chosen as a possible ore bearing area of strata-bound lead and zinc deposits in Pucara Group.

(vi) At the both ends of this high density zone underground structure is divided into sections by fault-like step structures. Especially, a fault-like step structure in the eastern side controls distribution of Pucara Group and forms a boundary between post Cretaceous sediments distributed in the east.

(vii) From the east to the north of the surveyed area large-scale low density zones line up at intervals approximately to the NNW-SSE direction. They are considered to form a graben zone including a tectonic line connecting Tingo Maria to La Marced and the graben zone has a maximum width of 6 Km and a depth of more than 2,000 m. In this graben zone relatively fresh complex belonging to Oriente Group, Chonta Group and La Merced Formation are thickly sedimented.

(viii) In this vicinity of Maria Tereza, the southwest of the surveyed area, a low density zone reflecting distribution of Pusagno granite is extending to the N-S and indicates an intrusion controlled by fault-like step structure in the underground. This Pusagno granite, as clearly shown in the underground structure profile, is bigger in the shallow underground covered with Pucara Group in its estern part than its distribution on the surface of the ground.

(ix) The basement is generally shallow in the area with San Roque at its center in the north of the surveyed area. In the vicinity of San Roque, the arrangement of gravity anomaly having NNW-SSE direction which can be traced continuously from the south of the surveyed area is interrupted. This fact suggests a tectonic activity might occur in the vicinity of San Roque.

Outlines of underground structure assumed from the results of gravity survey are discribed above. It is believed that further informations can be obtained by adding more precise knowledges and reviewing the results of the gravity survey in future.

2-3-2. Results of the Electrical Survey

Results and analysis of the electrical survey by short electrode intervals are summarized as follows:

(i) Average values of FE and resistivity of zebra dolomite with lead and zinc are 0.68% and 3,088 Ω m. By comparing with 1.36% and 2,182 Ω m of zebra dolomite layer of country rock, the difference of electrical properties between mineralized zebra dolomite and barren zebra dolomite is not significant.

(ii) Average values of FE and resistivity of limestone mineralized by galena near San Roque are 2.10% and 2,952 Ω m. By comparing with 1.44% and 1,848 Ω m of barren limestone, a difference between them is not significant.

(iii) Average values of FE and resistivity of dolomite are 1.23% and 3,050 Ω m. Dolomite without zebra structure can barely be separated by resistivity from zebra dolomite which can be a host rock of strata-bound lead and zinc deposit, but cannot be separated by FE. However, resistivity difference of them is also hard to show significant.

(iv) Resistivity value of argillized granite porphyry near San Roque is 182 Ω m and it is very small compared with that of other rocks. If there is any relation between argillization of granite porphyry and impregnated ore deposit in sedimentary rocks, a resistivity value of granite porphyry can be used for prospective indication.

(v) Resistivity value of Pusagno granite is 14,246 Ω m and compared with that of other rocks, it is especially high. While resistivity value of argillized Pusagno granite is 1,497 Ω m and it shows rather low.

(vi) FE values and resistivity values of sandstone, soil and talus sediments are not special as background values and they are nothing disturbing of employing IP method in the area.

(vii) From the results of model calculations carried out by using informations of electrical properties mentioned above, adaptability of IP electrical prospecting method in this area is summarized as follows: Strata-bound lead and zinc deposits represented by Pucara Group and zebra dolomite near Tambo Maria are hardly detected by apparent resistivity and FE from model calculations. It is difficult to apply IP method for exploring this type of lead and zinc deposits.

(viii) Regarding an dissemination type of ore deposit in sedimentary rocks near San Roque, if a width of impregnated zone is more than 20 m and FE value is over 0.3%, the application of IP method is considered to be useful. However, FE value of impregnated zone in this surveyed area is only 2.1% and such FE value is too small to apply IP method.

(ix) Regarding a porphyry copper type deposit in monzonite distributed in the east of Tambo Maria, if FE value of deposit is more than 5% application of IP method is possible. However, a measurement on an outcrop of mineralized monzonite in the surveyed area was not carried out in this survey, therefore the application of IP method to this type of ore deposit must be studied and judged comprehensively from the results of the geological survey.

2-4. Results of the Diamond Drilling

(1) Three of the four diamond drill holes performed in the present year, except for the hole No. 52-2 which has been drilled through the Mitu Group, have caught the carbonate rocks of the Pucara Group. By the lithological and stratigraphical correlation, it has been clarified that they belong to the V member of the Pucara Group, defined by the results of the geological survey.

(2) The V member of the Pucara Group in this place is divided into three major horizons, from lithofacies, that is upper, middle and lower horizons. The characteristic feature of the upper horizon is that the dolomite is recognized remarkably in the hole No. 52-1 with little amount of dolomite found in the other holes.

(3) The middle horizon is composed of the rocks of muddy facies with occasional insertions of limestones. In the top part of this horizon, thin layers of sandstone and sandy dolomite, which are regarded as the key bed for the classification of this horizon are found.

(4) The lower horizon is constituted mainly by limestones, but in the northern area where the drill hole No. 52-1 is located, sandy and muddy rocks are more abundantly recognized than in the drill hole No. 52-3 and No. 52-4.

(5) In all three drill-holes, fossils mainly of marine invertebrate are recognized abundantly. They are Crinoids, Bryozoan, Bivalves, Brachiopods, Gastropods, Echnoides, and Foraminifera. It is thought that the more precise stratigraphical correlation would be possible by the detailed examination of these fossils. This is one of the problems left for future study.

(6) The Mitu Group, caught by the hole No. 52-2, is recognized to be sited as small mass between two faults of NNW-SSE, in the area occupied

by the Pucara Group. These faults of the above trend are one of the major geological structure in this surveyed area, and it is thought that the Mitu Group has been brought upward from under the Pucara Group to the surface by the block movement.

(7) The galena and sphalerite mineralization found in the middle horizon in the hole No. 52-1 and the galena dissemination in the upper horizon caught by the hole No. 52-3 are the main mineralizations found in the drill holes. There are other beds showing high metal contents of Pb and Zn.

2-5. Ore Deposits

The synthetical elucidation of the survey results, including the results of the past surveys belonging to this series of the survey in addition to those of the present year's surveys, are given below.

(1) In the surveyed area, there are known mineralization as strata-bound lead and zinc deposits and disseminated lead and zinc deposits in the Pucara Group, copper-lead-zinc deposits of contact metasomatic type and of vein type, and porphyry type copper deposit in monzonite. The most important mineralization among the above-mentioned in this area is the strata-bound lead and zinc deposits in the Pucara Group.

(2) The strata-bound lead and zinc deposits are represented by San Vicente deposit worked at present, Pichita Caluga deposit now out of operation and Tambo Maria mineral indication. It has been clarified that all of them are emplaced in the dolomites belonging to the III member.

(3) As for Tambo Maria mineral indication, thought it is as small as only 30 cm in thickness and about 3 m in length at the outcrop so far recognized, the following important informations as for the mineralization in this survey area have been obtained.

- The mineralized bodies are emplaced in the zebra-structure, especially in the thick zebra-structure.
- It is recognized that the mineralized bodies are localized in special spots in the geological structure, where structural disturbances as folds and fissures are accompanied.
- The ore composed mainly of sphalerite is dense in the white dolomite bands of the zebra-structure and less in amount in the dark dolomite bands. The crystal grains are coarser in the white dolomite bands.
- By the results of the geochemical survey by rock samples, it has become evident that, though there are sphalerites recognized megascopically in the dolomites, the dolomites around the Tambo Maria mineral indication contains less amount of zinc than lead, in spite of the fact that the ordinary carbonate rocks in the surveyed area contain more zinc than lead.

(4) San Vicente deposit is thought to have almost the same character of the emplacement of the mineralization as the Tambo Maria mineral indication.

(5) The development of the zebra-structure is thought to be due to the recrystallization of dolomites around the space caused by the lateral pressure at the time of the regional structural movement, from the points that the grains of the white dolomites are coarser than those of the dark dolomites, that the white dolomites contain almost no impurities and that the space is left occasionally in the middle of the white dolomite band, in addition to the fact that the distribution of the zebra-structure coincides with the direction of the regional geological structure, namely, NNW-SSE.

(6) From the above, it is thought that the mineralization of this type

would have been caused by the concentration of ore minerals, as is observed in the case of the enrichment of ore minerals at San Vicente, through the mobilization of the metal elements of lead and zinc originally contained in the carbonate rocks, in the process of formation of the zebra-structure related to the structural movement. Where thick zebra-structures are well-developed, the dolomite would have been spaceous due to folds and faults, and the recrystallization would have been continued in quite a long period to afford favorable condition for the remobilization and the enrichment of the ingredients to form the ore minerals.

(7) The mineralization of the disseminated type has been found around San Roque, and also has been caught by the diamond drilling carried out in this year. All the mineralizations of this type recognized on the surface are lead-dissemination in limestone, and are located along the igneous rocks in the western part of the surveyed area, associated with calcite veinlets or standing by themselves in limestones.

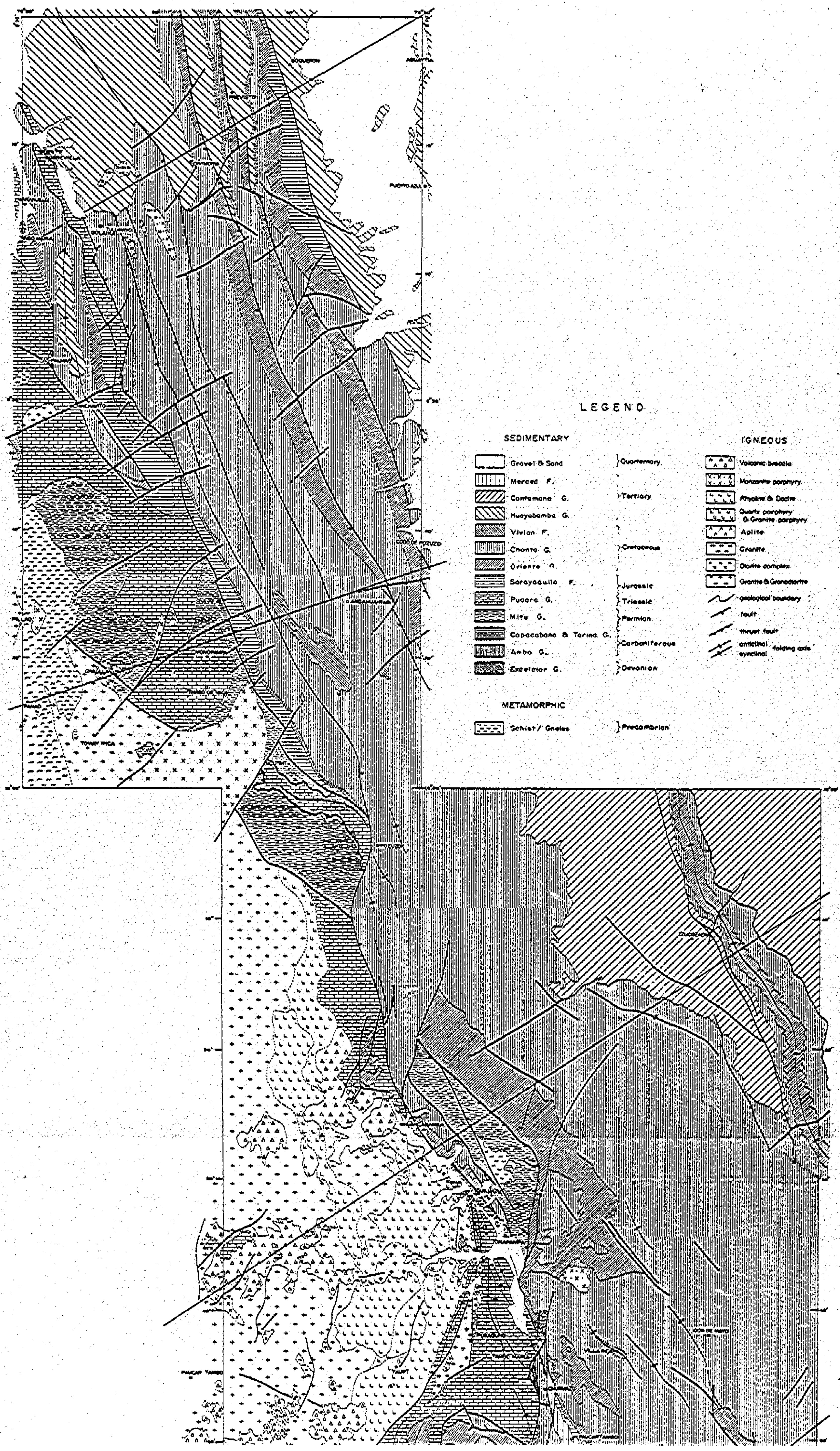
Also, in the drill cores, megascopic sphalerites are recognized only in the dolomite caught by the drill hole No. 52-1. No sphalerite has been observed with naked eyes in the cores of the other drill holes. However, there are several beds to show the Zn content of about 1,000 ppm. Galena has been found in the cores of the drill holes No. 52-1 and No. 52-3.

(8) In San Roque area, the sphalerite and the galena megascopically recognized are mostly euhedral and under microscope most of them are found as granular anhedral grains of about 40 microns in size.

(9) The most characteristic aspect of the distribution of zinc, regardless of the beds of limestone or dolomite, is that the beds of high Zn content is related to muddy rocks, as for their stratigraphical position that these beds are overlying directly the muddy rocks or situated lying

in the muddy rocks. This is especially remarkable with the muddy dolomites and the limestones belonging to the middle horizon, which is quite important as the mineralized horizon in this San Roque area.

(10) From the above facts, it is considered about the mineralization of the disseminated type at San Roque area that the elements of lead and zinc essentially deposited at the period of the sedimentation of the limestones would have been remobilized by the diagenesis and the igneous activities after the deposition.


LEGEND
SEDIMENTARY
Gravel & Sand
Merced F.
Contamana G.
Huayabamba G.
Vivian F.
Chonta G.
Oriente F.
Sarayaquillo F.
Pucara G.
Mitu G.
Copacabana & Tarma G.
Ambo G.
Excelsior G.
Quaternary
Tertiary
Cretaceous
Jurassic
Triassic
Permian
Carboniferous
Devonian
METAMORPHIC
Schist / Gneiss
Precambrian
IGNEOUS
Volcanic breccia
Monzonite porphyry
Rhyolite & Dacite
Quartz porphyry & Granite porphyry
Aplite
Granite
Diorite complex
Granite & Granodiorite
geological boundary
fault
thrust fault
anticlinal synclinal folding axis
PUERTO AZUL
CODO DE POZUZO
PAUCAR TAMBO

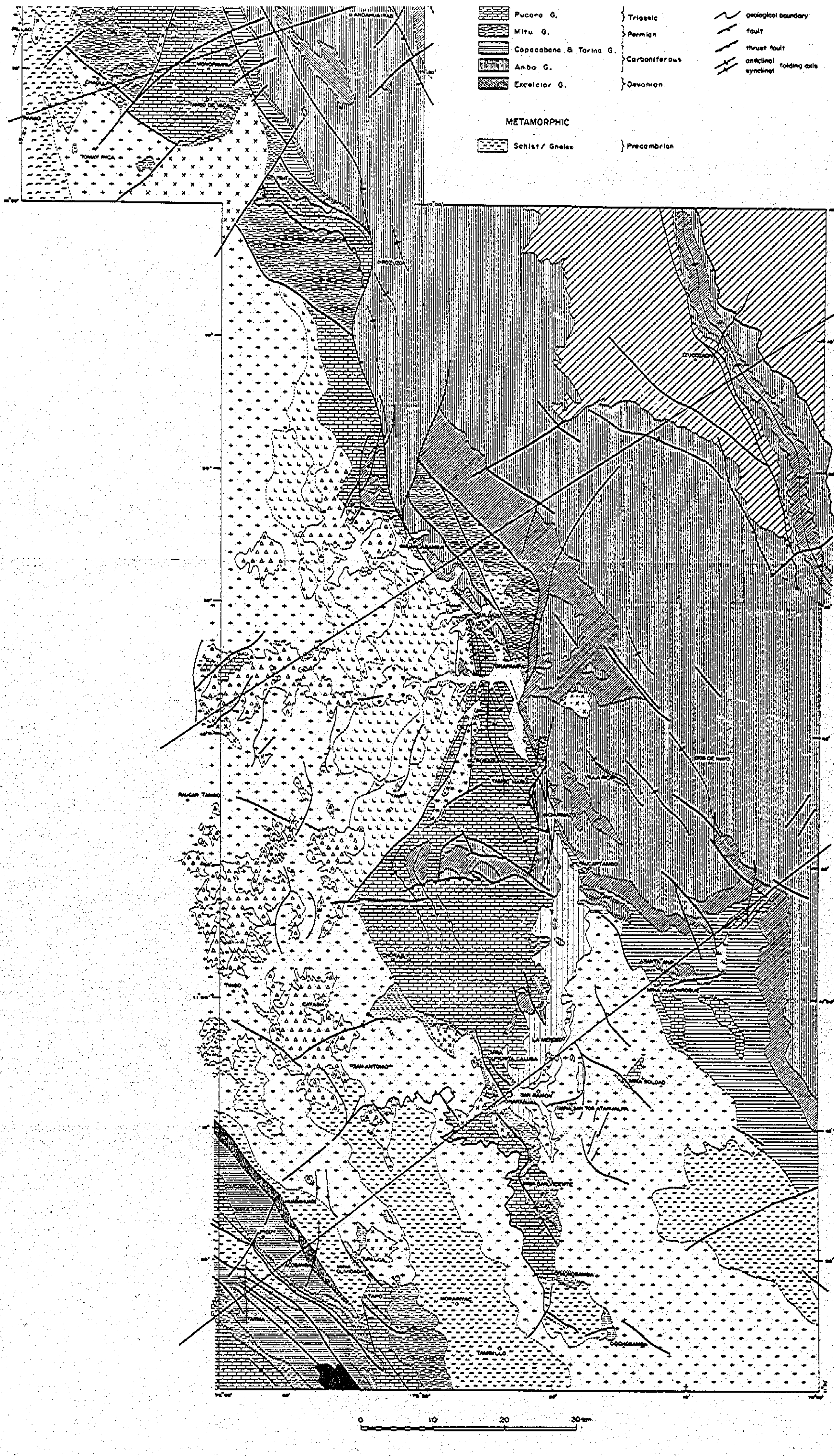
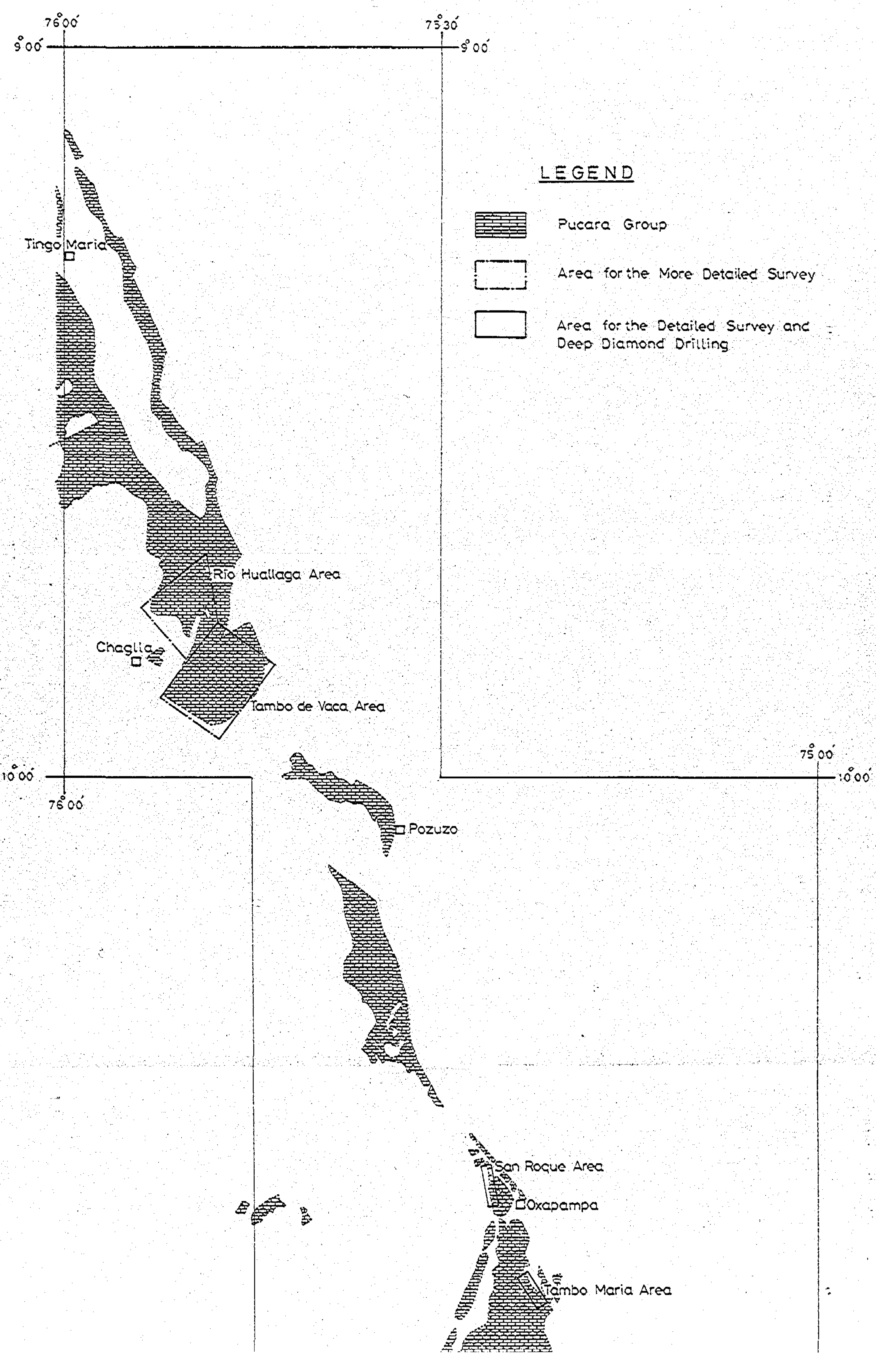


Fig. 4. Generalized Geological Map of the Surveyed Area



76°00′
75°30′
9°00′
9°00′
LEGEND
Pucara Group
Area for the More Detailed Survey
Area for the Detailed Survey and Deep Diamond Drilling
Tingo Maria
Río Huallaga Area
Chaglla
Tambo de Vaca Area
75°00′
10°00′
10°00′
76°00′
Pozuzo
San Roque Area
Oxapampa
Tambo Maria Area

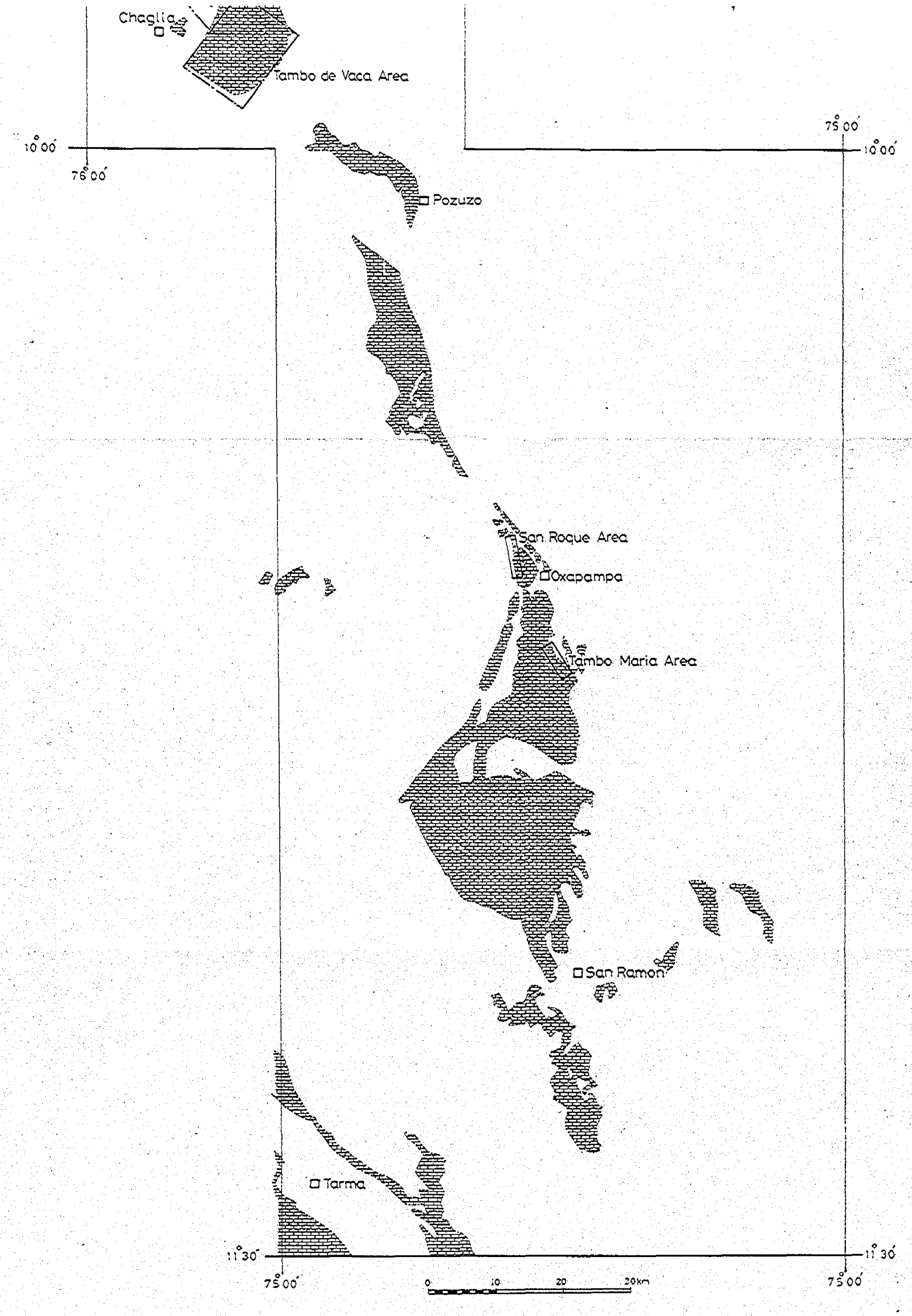


Fig. 5. Recommendation Map

Chapter 3 Conclusion and Future Aspects

Through the various surveys which have been carried out since the beginning of the present survey, the important points as the indicators for the future programs have been floted out as follows.

(1) The strata-bound lead and zinc deposits are emplaced in the dolomite bed associated with zebra structure.

(2) Ore minarals of that are localized in such places where the structural disturbaces as folds and faults are accompanied.

(3) The concentration of the sphalerite in the strata-bound lead and zinc deposits is thought to be taken place at the formation of recystallized zebra structure caused by the regionally structural movement.

(4) The stratigraphycal localization for disseminated lead and zinc deposits are quite important not only in the dolomite beds but also in the muddy beds.

(5) The ore minerals of that are presumed to be concentrated by the remobilization of lead and zinc elements, which essencially have been precipitated in sedimentary rocks, caused by the igneous activity and others.

(6) Before the surveys of present year, it have been presumed that the igneous rocks carrying high density would exist under the Pucara Group. After that, it is become to be clarified the distribution and the shape of dolomite beds in the subsurface where would be expected the high possibility of mineral depositions, as the igneous rocks carry lower density than the dolomite.

From the above-mentioned, further surveys are recommended to be carried out, in the way as writen below, in the Oxapampa area including San Roque and Tambo Maria, where the potentiality of subsurface mineral deposits would be considered to be fairly high, in addition to the areas of Rio

Huallaga and Tambo do Vaca, whore the possibility of tho emplacement of ore deposits would be clarified to be high by the further survey.

(1) It is necessary to comprehend tho favorable geological situation where high contents of lead and zinc would be expected, from the examination of the stratigraphy and geological structure of dolomite and muddy rocks, and from the consideration of paleo-environment of the sedimentation. Geological survey through the corrolation of lithofacies and fossils, geochemical survey by rocks and deep diamond drilling are effective.

(2) There are the high-grade concentration of lead and zinc in the dolomite where the zebra structure develops and especially the structural disturbance observes. From that, it is necessary to detect the location of ore concentration by the more detailed works. Geological survey combined with trenching survey, geochemical survey by rocks and deep diamond drilling, introducing into the results of gravity survey, will be effective.

(3) By clarifying in detail the mechanism of the concentration of ore minerals, it is necessary to aid the survey works of above-mentioned method. Mineralogical study of ore minerals will be effective.

As the concrete program, the following surveys are recommended to be carried out in the next year:

(1) Oxapampa area (San Roque, Tambo Maria)

- Geological survey
- Geochemical survey (by rock samples)
- Trenching survey
- Deep diamond drilling

(2) Northern area (Rio Huallaga, Tambo de Vaca)

- Geological survey
- Geochemical survey (by rock samples)

REFERENCES

Bellido, E. B. (1969)

Sinopsis de la Geología del Perú
Servicio de Geología y Minería Boletín, No. 22 (in Spanish)

Bellido, E. B. et al, (1972)

Aspectos Generales de la Metalogenia del Peru
Servicio de Geología y Minería, Perú (in Spanish)

Capdevila et al. (preliminar)

L'age Permien du Granite de La Merced Peru Central: Observations de Terrain et Isochrone Rb/Sr. (handwriting unpublished) (in French)

Dalmayrac, B. (preliminar)

Estudio Geologico Preliminar de la Cordillera Oriental Servicio de Geologia y Mineria (in Spanish)

Dunin, E. B. (1975)

Control Litológico y Estratigráfico en la Ubicación de los Mantos con sulfuros de Metales no Ferrosos en las Capas calcareas del Perú Central.
Boletín de la Sociedad Geológica del Perú, No. 50. (in Spanish)

Heyl, A.V. et al. (1974)

Isotopic Evidence for the Origin of Mississippi Valley-Type Mineral Deposits: A Review. Economic Geology, Vol. 69

Kobe, H. M. (1977)

El Grupo Pucara y su Mineralización en el Perú Central.
Boletín de la Sociedad Geológica del Perú, No. 55-56. (in Spanish)

Levin, P. M. (1973)

Nota Preliminar Acerca del Granito de San Ramón
Boletín de la Sociedad Geológica del Perú, No. 43 (in Spanish)

Levin, P.D. & Samaniego, A. A. (1975)

Los Sedimentos del Grupo Pucará en el Area de Chanchamayo, Perú Centro-Oriental. Boletín de la Sociedad Geologíca del Perú, No. 45 (in Spanish)

Lepeltier, C. (1969)

A Simplified Statistical Treatment of Geochemical Data by Graphical Representation. Economic Geology, Vol. 64.

Mégard, F. (1968)

Geología del Cuadrangulo de Huancayo
Servicio de Geología & Minería Boletin, No. 18. (in Spanish)

Megard, F. (1973)

Etude Geologique D'une Transversale des Andes au Niveau du Perou Central
Universite des Sciences et Techniques du Languedoc pour obtenir le grade de Docteur es Sciences Naturelle (in French)

Morales, B. A. (1977)

Sinopsis Explicativa del Mapa Geológico del Perú
Instituto de Geología y Minería, Boletín No. 28 (in Spanish)

Pardo, A.A. etc. (1973)

Estratigrafía Evolución Tectónica del Mesozoico y Cenozoico de la Región de la Selva del Perú
II Congreso Lationoamerica de Geología Caracas, Venezuela (in Spanish)

Pardo, A. A. etc. (1973)

Estratigrafía y Evolución Tectónica del Mesozoico de la Región de la Selva del Perú
II Congreso Latinoamericano de Geolagía Caracas, Venezuela (in Spanish)

Schneider, H. J. (1964)

Facies Differentiation and Controlling Factor for the Depositional Lead-Zinc Concentration in the Ladiman Geosyncline of the Eastern Alps.
Developments in Sedimentology, Vol 2.

Skall, H. (1975)

The Paleoenvironment of the Pine Point Lead-Zinc District
Economic Geology, Vol. 70.

Szekely, T. S. & Grose, L. T. (1972)

Stratigraphy of the Carbonate, Black Shale and Phosphate of the Pucara Group. (Upper Triassic-Lover Jurassic). Central Andes Peru.
Geol. Soc. Amer. Bull., No. 18

PARTICULARS

PART I

Geological Survey

PART I Geological Survey

LIST OF ILLUSTRATIONS

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LIST OF PLATES (in the associated case)

Chapter 1 Outline of the Survey

1-1. Purpose of the Survey

Through the geological survey carried out by 1976, the distribution and the structure of the Pucara Group were well ascertained and several new findings of so-called "Strata-bound lead and zinc ore deposits" as well as the disseminated lead-zinc mineral indications in the Pucara Group were brought about. Furthermore, it was definitely shown that it would be effective for the prospect of mineralized zones to trace such elements as lead and zinc etc. contained as impurities in the rocks.

Considering the above, the purpose of the geological survey of the present year has been prescribed as follows.

- The detailed geological survey is to confirm the distribution and the form of the mineralizations as well as to comprehend their relation to the geological structure, in addition to the endeavour to discover new indications of ore mineralization.
- The geochemical survey, mainly by rock samples, and programmed to be performed with the geological survey, is to obtain details of the aspect of the distribution of the impurity elements in the rocks.
- The semi-detailed geological survey and the reconnaissance, in the areas where available information is still insufficient in spite of the past surveys, are to add more informations about the behaviors of metal elements and the structure of the Pucara Group for the examination of the possibility of the emplacement of ore deposits.

1-2. Field Works

To accomplish the works for the purpose as mentioned above, the detailed survey have been carried out along the routes established with the interval of about 1 km in the direction crosscutting the main geostructure in the programmed area, utilizing the topographical maps published or specially prepared for the present survey. (Scale, 1/10,000 and 1/25,000) Most of such routes required bush cutting.

Land-surveying with pocket compass was carried out in a scale of 1 to 2,500 at the same time as the geological survey in San Roque area and in Tambo Maria area, where it was thought to be necessary to conduct more detailed examination because, and where the most distinct features of the indications of mineralization had been found among the detailed survey areas examined before. Two trenches were excavated in Tambo Maria area.

For the semi-detailed geological survey, topographical maps of 1 to 25,000 have been used, while geological reconnaissance was carried out with 1 to 100,000 SLAR mosaic maps in addition to the topographical maps of 1 to 25,000. In these survey works, more informations were obtained by the reconnaissance along selected roads and mountain paths, apart from those along which surveys were performed before.

For the geochemical survey, samples were collected at the same time as geological survey along the survey routes. The density of the sampling points is every 100 meters in the detailed survey area, every 500 meters in the semi-detailed survey area and every 1,000 meters in the reconnaissance area, along each route.

These works were carried out by six combinations of the engineers of a Japanese and a Peruvian, while in these areas of Tambo Maria and San Roque where specially detailed survey were contracted two Peruvian and two Japanese performed the works.

1-3. Laboratory Works

Following the field works the analytical works including the results of diamond drillings were carried out. Main laboratory works are as shown below.

		Geological Survey (samples)	Diamond Drillings (samples)	Total (samples)
(1)	Microscopy of thin sections of rocks	82	13	95
(2)	Microscopy of polished sections of ores	26	13	39
(3)	Chemical analysis of ores (Pb Zn Cu)	19	69	88
(4)	Analysis by X-ray diffraction	52	4	56
(5)	Determination of fossils	20	4	24
(6)	Isotopic age determination	3	-	3
(7)	Whole rock analysis of igneous rocks	5	-	5
(8)	Chemical analysis of the samples collected for geochemical survey	1,762	-	1,762
	Reconnaissance area (262)			
	Semi-detailed survey area (315)			
	Detailed survey area (rocks) (931)			
	Detailed survey area (soil) (254)			
(9)	Chemical analysis of minor elements contained in carbonate rocks (Mg, S)	124	69	193
(10)	X-ray microprobe analysis	3	-	3
(11)	General analytical work of geology and ore deposits			

Chapter 2 Geology and Geological Strucutre

The geology of the subject area has been examined in detail through the survey works carried out up to last year. Especially, the stratigraphy and the geo-structure of the Pucara Group have been ascertained well in detail as the group was one of the main subject of the geological survey. The results of such surveys are summarized in the Volume 5 of the report.

In the present year, more detailed geological and geochemical surveys have been carried out in the areas regarded as carrying great prestige by the ore mineralization and the geochemical features, based on the results of the past surveys.

Individual description of the geology has been given already. Avoiding the duplication of such descriptions, chiefly the matters cleared up by the present surveys are shown in this report.

2-1. Outline of Geology

The distribution of sedimentary, igneous and metamorphic rocks exposed in the subject area, where geological surveys have been carried out since 1975, can be said roughly to be controled by the NNW-SSE direction according to the general topographical features and to the geo-structure in the region. To mention more in detail, the Eastern Andes, which corresponds the western part of the surveyed area, is occupied by upper Paleozoic sedimentary rocks on the base of gneisses, while the Sub-Andes Belt, defined geologically in Peruvian geo-structure from the eastern margin of the Eastern Andes to the Amazon Plain through the Inter Basin*, is constituted by the sedimentary

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* In this report, the lowland constituted by the following areas is called "Inter-Basin";
Along Huallaga River around Tingo Maria, Along Huancabamba River around Oxapampa and along Chanchamayo River around San Ramon.

rocks of Mesozoic age or later. Bounded by the fault along the eastern margin of the Inter-Basin, which is called Tingo Maria--La Merced tectonic line, as it runs in NNW-SSE direction from the east of Tingo Maria to the east of La Merced through Pozuzo and Oxapampa, the west of the fault is occupied by the beds up to middle Mesozoic age composed mainly of Pucara Group of Triassic to Jurassic system, while the east of it is underlain by the sedimentary rocks mainly of middle Mesozoic to Tertiary age.

The igneous activities are recognized to have been intermittently in the late Paleozoic to early Cenozoic Era, along the geoanticlinal belt in the area around the boundary of the east Andes to the Sub-Andes Belt. In the Sub-Andes Belt, a little evidence has been recognized of the igneous activities of the early Cenozoic Era along the Tingo Maria--La Merced tectonic line.

The sedimentary rocks are grouped into the followings as described from the lowest upwards stratigraphically;

Paleozoic: Excelsior Group, Ambo Group,
Copacabana -- Tarma Group, Mitu Group

Mesozoic : Pucara Group, Sarayaquillo Formation,
Oriente Group, Chonta Group,
Vivian Formation.

Cenozoic : Contamana Group, Huayabamba Group,
La Merced Formation, Quaternary sediments

The stratigraphical names as mentioned above are mainly after Bellido, E.B.(1969), who defined the sedimentary rocks distributed in the area including the departament of Junin, Pasco and Huanuco. But the names after some published reports or given in this present survey are employed partly.

The stratigraphical succession in the southern and the northern parts of the surveyed area is shown in Fig. I-1.

2-2. Geology of Individual Surveyed Area.

2-2-1. Oxapampa Area (PL. I-5, I-6, I-9)

The Pucara Group is distributed in the central part of the Oxapampa area and the younger sedimentary rocks than the Pucara Group develop in its east. The western part is occupied by the igneous rocks.

The distribution of the Pucara Group is mainly in the west of Huancabamba River and Churumazu River flowing in NNW-SSE direction. In the north of Oxapampa, the group develops in fairly narrow zone of the width of about 3 km, with the trend of NNW-SSE, while it expands to occupy 10 km in width in the southern part of the area, with the trends of NNW-SSE in eastern part, N-S in central part and NNE-SSW in western part where the group interlies between igneous bodies. The Pucara Group is composed of such rocks as limestone, dolomite, sandstone and muddy sandstone and the total maximum thickness around Oxapampa is thought to be 2,300 meters. There is a dolomite bed quite extensively distributed as 300 to 400 m in thickness and about 15 km in extension, seen in the eastern part of the area. But most of the dolomite beds other than the above are as thin as under 100m. The dolomite bed is observed what is called zebra-structure everywhere, which consists of banded structure of white crystalline dolomite and black microcrystalline dolomite. (It is called zebra-dolomite.) Details of the structure are given in the next Chapter and in the Chapter 5.

The younger sidementary rocks distributed in the east side of the Pucara Group are Oriente Group, Chonta Group etc., and bounded to the Pucara Group by the Tingo Maria---La Merced tectonic line.

In the western part, Mitu Group develops in a small scale along the margin of the igneous body. Distribution is limited in a narrow zone bounded by the faults of N-S and NNW-SSE in direction. Through the past surveys the rocks were thought to be a part of the Pucara Group or to be volcanic breccia of Cretaceous to Tertiary period. However, it has become evident by the prosent survey that the rocks is volcanic conglomerate, composed of the pebbles mainly of acidic volcanic rocks and granite with the matrix of red sandy or tuffaceous rock, as is observed along the road-cutting for the drill site and in the drill-core of the hole No.52-2. And, by the above evidence of the lithological features, the bed has been confirmed to be correlated to Mitu Group by Bellido, E.B. (1969).

As for igneous rocks, granite, porphyritic rocks as granite-porphyry and quartz-porphyry and volcanic rocks like dacite and rhyolite are distributed in the western part of the area, and the intrusion of monzonite is seen in the eastern part.

The granite is observed to have intruded the Pucara Group, between the East Pusagno and the West Pusagno area, in the elongated form in NNW-SSE direction, and also as a small stock at the west of Oxapampa, corresponding to the north-extension of the above-mentioned body. The granite is coarse grained and contains abundant pink potash feldspar, associated with quartz, plagioclase and biotite. Absolute age determination has shown the intrusion of the granite to be of late Jurassic to early Cretaceous period. (Refer to the Volume 5.)

The porphyritic rocks as granite-porphyry and quartz-porphyry are seen intruding the Pucara Group along its western margin. The rocks are medium to fine-grained and has remarkable porphyritic texture, with the constituent minerals of quartz, potash feldspar and small amount of plagioclase. The result of the absolute age determination by K-Ar method has given 153 m.y. (sample No. C-411) and 288 m.y. (sample No. P-555). But, as it is considered to be likely field-geologically that the porphyritic rocks are in transitional relation to the granite of late Jurassic to early Cretaceous period, it is necessary to examine furthermore about the period of the intrusion of these porphyritic rocks, including the investigation of the relation to the acidic effusive rocks of dacitic lava and pyroclastic rocks distributed in the west side of the West Pusagno area.

The Pucara Group in the area is dominated by the synclinorium structuto, though it bears anticlinal structures locally. The direction of the fold-axes are mostly NNW-SSE in the east of Pusagno, and is N-S in the area from Oxapampa to Pusagno, while, in the west of Pusagno, it occasionally shows NNE-SSW in harmony with the trend of igneous rocks. Such fundamental geo-structure as the above continues to the north beyond the limit of the area. The plunge of the fold-axes are mostly horizontal or slightly to the north. Therefore, in the northern part of the area, upper part of the Pucara Group appears.

The fault structure is in good harmony with fold-axes. The most remarkable fault is Tingo Maria---Merced tectonic line running along the eastern margin of this area. The movement of subsidence in the east of the teotonic line and that of upheaval in the west of it is shown well.

There are other faults of N-S or NNE-SSW roughly parallel to the fold-axes. As afore-mentioned, some faults are seen among them to have caught and brought upwards to expose on the surface the Mitu Group which is situated stratigraphically lower than Pucara Group, in the western part of the area. Such movement is thought to be one of the characteristics of the tectonic movement of late Cretaceous period to early Cenozoic Era in the area.

Furthermore, faults of E-W or ENE-WSW, cutting the above main structure of roughly N-S direction, develop well as seen around Tambo Maria or Pusagno.

2-2-2. Huancabamba Area (PL. I-5.(7))

The area is located at about 30 km north-north-west of the city of Oxapampa. The present survey carried out in this area includes the detailed geological survey of an area of 4 km^2 and the semi-detailed survey of an area of 42 km^2 around the detailed survey area.

By the survey results, it has been ascertained that sedimentary rocks are distributed in the central, northern and eastern part of the area and that volcanic pyroclastic rocks of Cenozoic Tertiary age develop in the southern and western part of the area.

The Pucara Group is composed mainly of dark to grey colored limestone with a few inserted beds of dolomite. In the central part of the area, there are recognized insertions of fine-grained grey sandstone, which are found to contain ammonite correlated to Sinemurian to Pliensbachian epoch. (Refer to A.I-8)

Oriente Group, composed mainly of grey sandstone, covers the Pucara Group with unconformaty, and lies in topographical high lands. Sarayaquillo Formation, which usually overlies the Pucara Group unconformably, is missing in the area.

The volcanic pyroclastics in the southwestern part comprise andesitic and dacitic pyroclastic rocks and tuffaceous rocks. They are bounded to the Pucara Group by faults, but as they are seen to overlie La Merced Formation of Cenozoic Tertiary age (Refer to Volume 5), the formation of these rocks is thought to be in the Neogene peirod.

Small intrusive body of quartz-porphyry is recognized in the southern part of the area.

2-2-3. Tingo Maria Area (PL. I-7)

The area is underlain by the Pucara Group and the sedimentary rocks younger than that. No igneous rock has been recognized.

The Pucara Group is composed of dark-colored limestone and limestone-dolomite beds with the thickness up to 2,000 meters. The group is distributed in the central part of the area along Turumayo River, with the trend of NNW-SSE dipping 40° to 60° to the east. Two dolomite beds with the thickness of several 10 meters are recognized, showing zebra-structure only partly. No fossil has been found in these beds throughout the past and present surveys.

The younger sedimentary rocks are Oriente Group, Chonta Group and Tertiary Complex, distributed in both sides of the Pucara Group. The Oriente Group, composed mainly of white fine to medium-grained sandstone with insertions of thin layers of shale and siltstone, develops in small areas in both sides of the Pucara Group. Along the outer side of the Oriente Group, there is distributed Chonta Group, composed mainly of red sandstone and shale with grey compact limestone. The younger sedimentary rocks than the Pucara Group show the trend of NNW with the dip of 40° to 60° to the east, which is roughly parallel to the strike and the dip of the Pucara Group. In the westside of the area occupied by the Pucara Group, inversion of the beds is observed between Chonta Group and Oriente Group. In the north of the city of Tingo Maria, though beyond the limit of the area, conformable accumulation is evidently recognized from Sarayaquillo Formation to Oriente Group and Chonta Group. Therefore, it is though to exist the isoclinal syncline structure with the axis planes dipping east in the westside of the area. On the other side, in the Pucara Group there seems to be the isoclinal anticlinal structure that is contrasted with the isoclinal syncline of the west side. The Pucara Group is bounded to the Oriente and the Chonta Group in its eastern margin by a remarkable normal fault, which is called Tingo Maria--La Merced tectonic line, representing the eastern limit of the distribution of the Pucara Group.

2-2-4. Rio Huallaga Area (PL. I-8, I-10)

Supplementarily geological reconnaissance has been carried out about the Pucara Group distributed in the area around the valley of Rio Huallaga, from Tingo Maria to near Chaglla in the northern part of the surveyed area.

The Pucara Group in this area comprises beds of black to dark grey colored muddy limestone, pale grey limestone and dolomite. There is no need to revise the distribution and the geo-structure of the Group ascertained by the past surveys. The trend is mostly NNW-SSE and synclinal structure is seen plunging to the north. In the present survey, it has become evident that dolomite beds are distributed in the whole area, and that they are roughly of the same horizon viewing from the stratigraphical relation to upper and lower horizons. It is thought that they are in a position to appear on the surface in repetition by the block movement uplifting north side of faults trending NNE-SSW, which cut the Pucara Group. (Refer to PL. I-10) This dolomite shows zebra-structure in places. It is notable that, around Tambo de Vaca in the southernmost part of the area, zebra-structure is recognized to extend over 3 km along the strike of the beds, which is the most remarkable of the zebra-structures found in this area.

The Pucara Group overlies unconformably the Mitu Group composed mainly of andesitic lava and tuff. Around Chinchavito in the central part of the area, the Mitu Group is missing and it has been confirmed that the Pucara Group overlies unconformably the schistose granite as the basement of the Mitu Group. Consequently, with the remarkable block movement represented by the faults of NNE-SSW trend, it is thought that the basement is quite uneven, having very complicated features.

2-2-5. Pozuzo Area (PL. I-8, I-10)

In the vicinity of Pozuzo, geological reconnaissance has been carried out supplementarily around the area where the Pucara Group is distributed along the Santa Cruz River branched from the Huancabamba River. In this area, the Pucara Group is distributed in the lowland along the Santa Cruz River, while the Mitu Group lies on the highland bounded by the overthrust to the Pucara Group. The Pucara Group extends in E-W or in NWW-SEE and is composed mainly of grey to dark-colored limestone with less amount of marl layers. The following fossils have been found in the exposures of this dark limestone on the left-bank of the Santa Cruz River. (Determination of the fossils by Prof. Masafumi Murata of Kumamoto Univ.)

Arietitidae, Gen et sp.

Euasteroceras ? sp.

Epammonites sp.

Gleviceras sp.

The dark limestone is correlated to Sinemurian to Pliensbachian epoch of the Jurassic period, on the basis of these fossils. (Refer to A. I-8, I-9)
The distribution of dolomite has not been confirmed.
The Mitu Group is constituted by rhyolitic or dacitic lava and tuffs.

2-2-6. Rio Santa Cruz area and Raymondi area. (PL. I-8, I-10)

Semi-detailed survey has been carried out in the Rio Santa Cruz area and in the Raymondi area, situated approximately in the middle of Oxapampa and San Ramon. The area between these two areas is occupied by the younger sediments than the Pucara Group, that is, Sarayaquillo Formation, Oriente Group and Chonta Group. The Pucara Group is distributed in both north and south sides of the younger formations overthrustingly. The Pucara Group in the Raymondi area, in the south side, comprises mainly grey limestone and no dolomite has been ascertained in the Group. The trend of the Group shows NE-SW with the dip of 20^{o} to 40^{o} to the southeast, which seems to have been affected by the structural pressure concerning the overthrust movement. Also, in the Rio Santa Cruz area in the north side, the same features of lithofacies and geo-structures are recognized as found in the south, in addition to the existence of thin dolomite beds. No zebra-structure has been recognized in these dolomite beds. The distribution of igneous rock has not been ascertained in these areas.

2-2-7. Rio Oxabamba Area (PL. I-8, I-10)

Supplementary geological reconnaissance has been carried out, too, in the valley of Oxabamba River about 10 km west of San Ramon. The southern part of the area is underlain by the granites which are thought to have intruded in the Paleozoic age, while sedimentary rocks of the Mitu Group and the Pucara Group are distributed in the northern part.

The granites in this area include medium to fine-grained granodiorite as the main member with medium to fine-grained diorite and small stocks of gabbroic diorite in the northern and western parts of the area. The isotopic age determination by K-Ar method has shown 306±11 m.y.

The granites are unconformably overlain, along the northern and the eastern margin, by the Mitu Group, which is composed mainly of reddish brown to greyish brown sandstone and shale with insertions of rhyolitic and dacitic lavas. The Pucara Group is distributed overlying the Mitu Group with unconformity and is composed, from the lowest upwards, of limestone with thin layers of dolomite, dark muddy limestone and limestone-dolomite beds. No fossil has been found in these beds, but the Pucara Group in this area can be correlated to the Pucara Group in San Vicente, as the lithofacies of the Group in this area are similar to those distributed in the south of San Ramon, especially to those observed at San Vicente. However, zebra-structure has not been recognized in these dolomite beds. As synclinorium with the axes of NNW-SSE is recognized in the Pucara Group in this area but details are not known.

2-3. Summary of the Pucara Group

The present survey has been carried out for various purposes, one of which is to clarify the stratigraphy and the geo-structure of the Pucara

Group, as the Pucara Group is thought to be important as country rock for strata-bound lead-zinc ore deposits. The outline of the present year's survey has been described. The geological features of the Pucara Group has been fairly well grasped especially those of Oxapampa area are elucidated in detail. They are summarized and described in this paragraph.

2-3-1. Stratigraphy

Outline of the stratigraphical succession is given in Fig. I-1 and I-2, and main fossils collected in the area are shown in Table I-2. They indicate that lower part of the Pucara Group is missing in the area around Tingo Maria, rendering the middle to upper part to the examination, while, in the area of Oxapampa to San Ramón, whole succession from the lowest to the uppermost is observed. The Pucara Group is classified into six members. They are described from the lowest to upwards followings.

(1) I member (Lower dolomite and limestone beds)

The I member is distributed particularly around San Ramon and San Vicente in the southern part of the surveyed area. Around San Vicente, the I member overlies the Mitu Group with slight oblique unconformity but locally with parallel unconformity. The I member is composed of grey siliceous limestone, well-bedded dark-colored limestone, alternation of bituminous shale and fine-grained sandstone, and dolomite. Dolomite has zebra-structure locally. Along the boundary with the II member, there is calcareous breccia. This member is correlated by Levin et al. (1975) to Ladinian or Carnic epoch of Trias based on the fossils contained in it. It is thought to be correlated to Chambara formation in the type locality, defined by Megard, F. (1968).

(2) II member (Dark-colored limestone beds)

The member II is distributed in the south of Oxapampa; that is, from the city of Oxapampa extending in SSE direction to around Churumazu, and from the catchment area of Santa Cruz River to around Pusagno in the western part of the surveyed area, rocks of the II member are distributed mostly surrounding topographcal low lands. They are not found in the north of Oxapampa.

The II member is composed of dark to grey well-bedded limestone with insertion of muddy layers, and around San Vicente with insertion of grey medium to fine-grained sandstone. The total thickness is thought to be more than 300 meters. The fossil of ammonite indicating Hettangian epoch of Jurassic period has been found in the II member around San Vicente. (Refer to Volume 1).

The same sort of fossil is found in Tambo Maria area through the present survey. (Refer to A. I-8, I-9). Consequently, the II member is correlated to the lowermost of the Aramachay Formation defined by Megard, F. (1968). However, as another fossil indicating Sinemurian epoch has also been found in this member near Tambo Maria, further examination is required for the age correlation of the member.

(3) III member (Limestone and dolomite beds)

The III member is composed of grey to purplish grey crystalline dolomite and dark grey criptocrystalline limestone. It is distributed in the south of Oxapampa, overlying dark-colored limestone. Limestone and dolomite distributed in Rio Santa Cruz and in Raymondi are parts of this member. The thickness is 100 to 650 meters.

In the eastern part of the south of Oxapampa, dolomite is predominant forming thick beds, and limestone is seen less in amount. Dolomite here has several beds of banded dolomite(zebra-dolomite), among which the most remarkable bed is that found in the central zone, extending over 2.5 km with the maximum thickness ever observed of 150 meters. At Tambo Maria, sphalerite ore deposits are associated with the dolomite accompanying zebra-structure. This type of mineralization in dolomites is also quite remarkably seen in San Vicente.

In the area other than Tambo Maria, cryptocrystalline limestone is predominant and dolomites are seen forming quite thin beds or locally missing completely. Although some zebra-dolomites are observed locally, their scale is small and their extension is limited.

(4) IV member (Sandstone)

The IV member is distributed around Oxapampa and Pusagno. It is constituted by well-bedded dark brown (pale brown to yellowish grey when weathered) fine to medium-grained sandstone locally with insertions of dark muddy limestone. It is observed to change transitionally to the upper dark limestone beds in the East Pusagno area. The thickness is variable from 0 to 350 meters. In Oxapampa area, the bed is quite well continued and has been treated as key bed in the present survey. It is partly fossiliferous but poor in index fossils.

(5) V member (Limestone and dolomite beds)

The V member is distributed in the topographical high land from near Oxapampa to the east of Pusagno, in the southern part of the surveyed area. The member is composed of dark grey cryptocrystalline limestone and sparitic limestone with a few dolomite beds. In the lowermost part of the member, dark-colored or dark grey muddy limestone develops locally. The muddy limestone which transitionally changes to the sandstone in the East Pusagno, contains of the fossil of ammonite indicating Hettangian epoch of the lower Jurasic. (Refer to Volume 5) But, as the same kind of fossil has also been collected from the dark-colored limestone bed of the II member as aforementioned, further examination is required for the solution of the problem of mineralized horizons stratigraphically. The thickness of the member is about 350 meters.

Most of dolomite layers contained in the limestone beds are less than

100 meters in thickness, and locally contain remarkable zebra-structure with pale brown or pale grey color. But there is a dolomite bed over 100 meters in thickness, near San Roque in the northwest of Oxapampa, but the zebra structure is not developed in this dolomite.

The V member is mostly fossiliferous. Especially, limestone and dolomite around San Roque contain such fossils as Bivalves and Braquiopoda. But, it is impossible to determine the age of the beds from them though they are thought to be of Jurassic period.

Dark muddy limestone and grey limestone distributed from near Chinchavito to Tambo de Vaca through Chaglla in the valley of Rio Huallaga, in the northern part of the surveyed area, are correlated to the V member of the southern part, on the basis of lithofacies and collected fossils. (Sample No. I 347) Also, dark grey limestone, containing calcareous sandstone and muddy limestone distributed around Pozuzo, is correlated to the V member, based on the fossils. (Sample No. M 451)

(6) VI member (Dolomite and limestone beds)

In the southern half of the surveyed area, the VI member is found in small outcrops on the right-bank of Huancabamba River in the north of Oxapampa, while the distribution of this member is seen in the whole Rio Huallaga area in the northern half. It comprises dolomite and limestone with inserted layers of shale or muddy limestone. Near Huancabamba, it is recognized to insert the bed of sandstone. The dolomite is coarse-grained and crystalline with pale purple to pale grey color, carrying zebra-structure everywhere. Dolomite is found to be most remarkable around Tambo de Vaca, and its thickness reaches about 300 meters. The limestone is pale grey to grey in color, and cryptocrystalline, with inserted layers of dark-colored or dark grey well-bedded sandstone or muddy limestone. It is considered that the limestone is correlated to Sinemurian epoch of Jurassic period, based on the fossils collected from the above inserted muddy limestone (Sample No. B013, B030) through the survey carried out last year. The thickness of this member is about 700 meters.

2-3-2. Correlation of the Pucara Group

The members of the Pucara Group in the north and in the south are correlated on the basis of the collected fossils and by the key bed, which is represented by the sandstone bed of the IV member. The result is shown in Fig. I-2.

The Pucara Group in the departament of Pasco and Junin, etc., has been studied well in detail by Megard, F. (1968), by Sketzely et al. (1972) and by others. Also, there is a report of the study of this Group around San Vicente mine by Levin, P. By these studies and reports, the Pucara Group in the type localities is divided into three formations of Chambara, Aramachay and Condrosinga in the order from the lowest. In the surveyed area, it can be said through the results of this series of surveys that the I member is correlated to the Chambara Formation of Triassic period (Ladinian to Carnic epoch), while the II member is correlated to the lower part of the Aramachay Formation, based on the index fossils found in the area, which indicate the lowermost of Jurassic period. But the upper limit of the II member has not been confirmed yet. To mention more in detail, although the Aramachay Formation has been regarded to correspond the II member and III in the 1975 report (Volume 5), viewed from the particulars of their litho-facies, re-consideration is now required on the correlation of them as the fossils respectively indicating Hettangian epoch and Sinemurian epoch have been found almost in the same place in the II member in Tambo María area and also a fossil indicating Hettangian has been collected from the V member in the East Pusagno area. Accordingly, no correlation has been done in this report, leaving the problem to further examination.

2-3-3. Distribution and Genesis of the Dolomite

In the surveyed area, five beds of dolomite are found in the southern part and two beds are confirmed in the northern part, in addition to thin layers and lenticular beds of dolomite found in places. Although exceptionally thick lens of dolomite is seen in an area around San Roque, usually dolomite forms layers of the extension of over 10 km as seen Oxapampa and of several ten km as distributed in the valley of Rio Huallaga. Most dolomite is crystalline and occasionally accompanies zebra-structure. Some dolomites contain abundant marine fossils such as fragments of shell, foraminifera, radioralia or algae, as seen in the dolomite distributed near San Roque.

For the information of magnesium content in relation to sulphur and zinc in the dolomites, selected 124 samples of carbonate rocks collected for the geochemical survey were analysed for Mg and S contents. The results of analysis are shown in Table I-2 and in Fig. I-5, and the relation of Mg, S and Zn is shown in Fig. I-6.

The following information has been obtained from the above results.

(1) The samples for analysis were selected almost at random from the detailed survey area near Oxapampa. The samples determined as dolomite in the field survey contain more than 9% of Mg, while other samples contain less than 2% of Mg. Only a few samples contain intermediate 2 to 9% of Mg.

(2) The dolomite samples showing zebra-structure contain over 10% of Mg, though it is shown by only four examples. (Sample No. M401, M416, M466, L410) It was confirmed by the results of the examination last year that the dolomite sample collected from the exposure including the mineral indication at Tambo Maria shows more than 11% of Mg. (Refer to Volume 5)

(3) Sulphur content in the carbonate rocks is mostly under 3% and no noteworthy relation of the sulphur content to the contents of zinc and magnesium has been found from the analysis results.

From the above-mentioned informations, it can be said that the dolomites are comparatively homogeneous as far as magnesium content concerns. Abundant fossils have been found in the dolomite. It is well-known that marine invertorbrate and algae contain much magnesium ingredient. Accordingly, it is thought that the major element of the formation of the dolomite in the survey area might have been the exchange of Ca ingredient contained in limestone beds with Mg contained in sea-water in the process of diagenesis until the consolidation of the beds originally sedimented as limestone, although there must be some dolomite which originally deposited as biogenetic rocks.

2-4. Geological Structure and Geological History

In everywhere in the surveyed area, geological structures such as folds, faults or fissures develop well, the direction of which is mostly NNW-SSE. These regional geological strucutures are thought to have been formed through the tectonic movements of several periods from Paleozoic to Cenozoic Era, accompanying lateral pressures of the direction of E-W or NEE-SWW.

Development of the synclines and the anticlines bearing the axes of the direction of NNW-SSE is recognized in the post-Triassic sedimentary rocks deposited after Trias of Mesozoic Era, distributed in the central to eastern part of the surveyed area. Among them, the syncline in the Pucara Group is most remarkable, and it continues from the southern part to the northern part.

There are three major orogenic movements recognized in this surveyed area, at the periods of Paleozoic, middle Mesozoic and latest Mesozoic Era. (Refer to Fig. I-4). For the examination of the geological structure in the surveyed area, it is necessary to throw light on the geohistorical consideration.

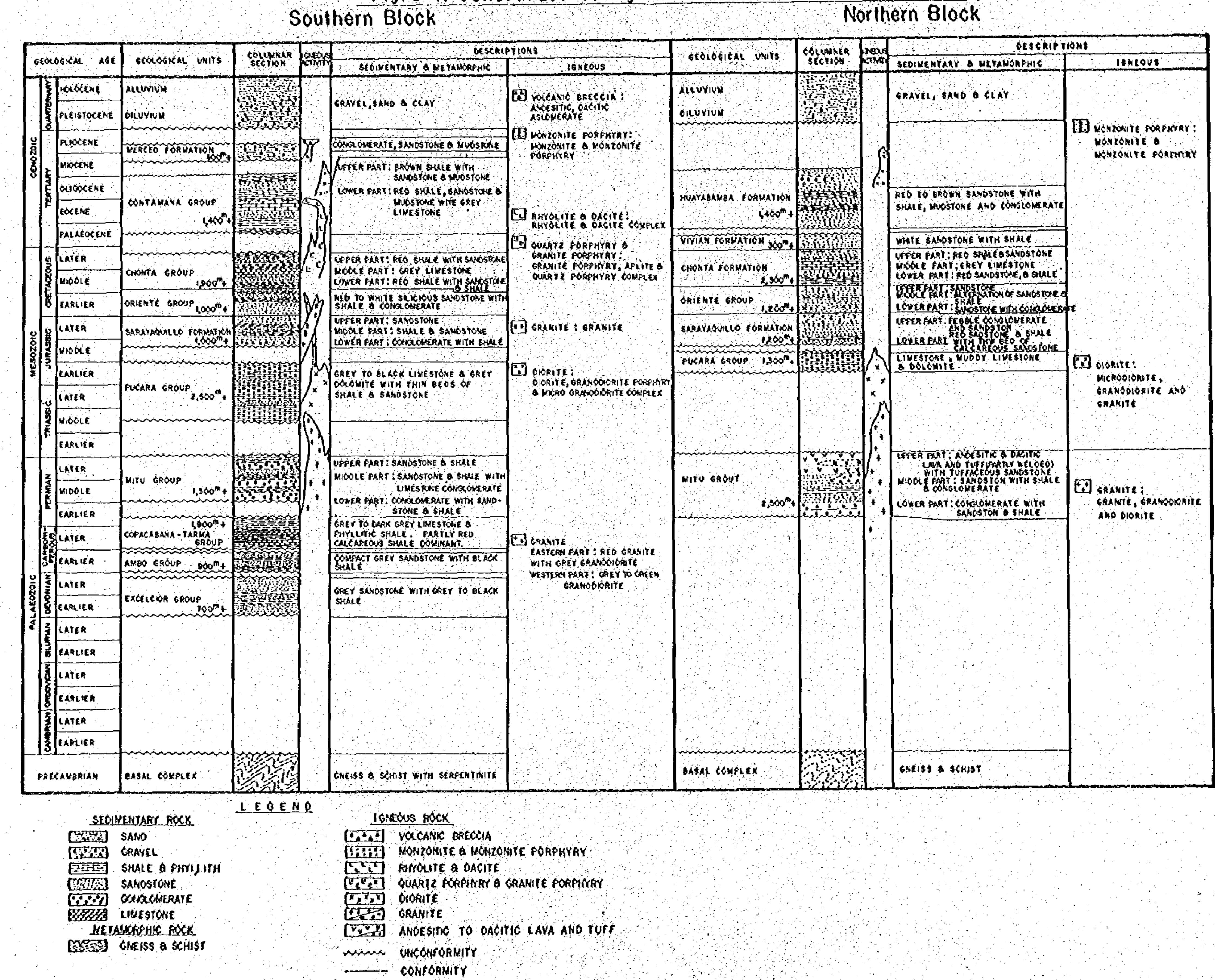
In Paleozoic Era, it is recognized that Hercynian orogenic movement were there in the belt including the surveyed area, characterized by the formation of the folding structure after the accumulation of the Excelsior Group. The tectonic activity at the end of Devonian period and the block upheaval, the fault movement and the intrusion of igneous rocks along the East Andes are recognized to have been active. It can be said that the primary patterns of the major geological structures of the direction of NNW-SSE in the surveyed area were formed at the period of the Hercynian orogenic movement.

After the accumulation of the beds of the Mitu Group, a geosyncline was formed to receive the marine sediments of the Pucara Group, which is thought to have deposited in the variable environments such as subsidence or upheaval in the sedimentary basin, as it is characteristic with the variation of lithofacies.

The Nevadan orogenic movement accompanying the intrusion of diorites were active around the East Andes, after the sedimentation of the Pucara Group. Following the accumulation of the Mesozoic Sarayaquillo Formation, there is a period of Andean orogenic movement, which has been in long continuance up to the present age since the end of Mesozoic Era. The Andean orogenic movement is quite extensive and is composed of several stages of the activities accompanying folds, faults and the intrusions of igneous rocks. Thus, the structural constituents such as folds and faults have been attained to the completion through the Andean orogenic movement, based on the formation of primary structural patterns in the Hercynian orogenic movement.

The present geological structures as folds or faults have been described in Chapter 2 of the Volume 5, and none will be stated here, to avoid the duplication.

Fig. I-1. Generalized Geological Columns of the Entire Surveyed Area



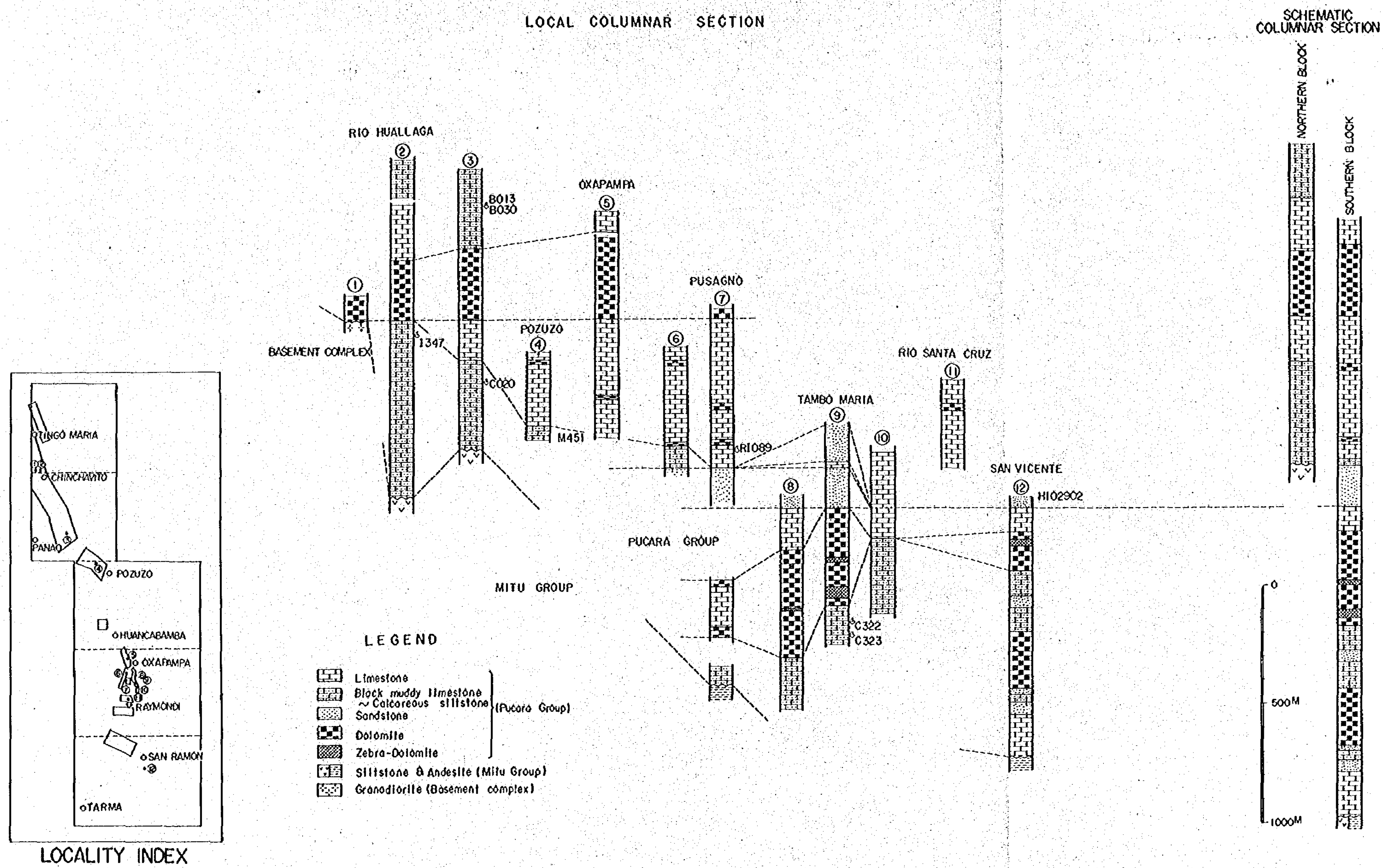
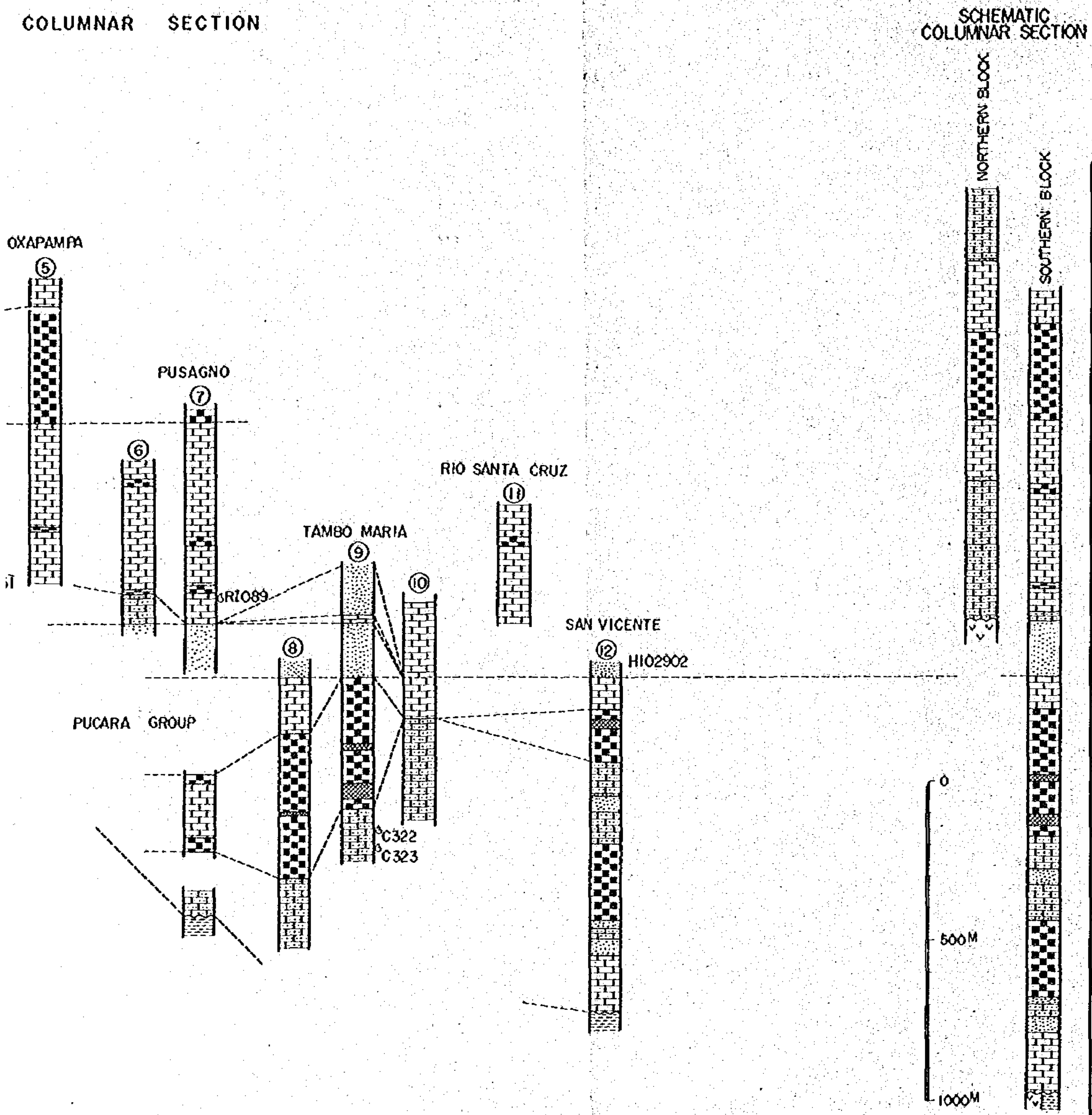


Fig. I-2. Generalized lithological distribution and correlation of the Pucara group



		LITHOLOGY & OTHERS — NORTHERN BLOCK	LITHOLOGY & OTHERS — SOUTHERN BLOCK	NUMBER OF MEMBERS
Lower - Jurassic	Pucara Group	Bedded, black colored, muddy limestone Light grey crystalline limestone Grey, compact to crystalline dolomite, frequently showing zebra structure.	Black colored, aphanitic limestone Grey to brownish grey crystalline dolomite, in some part, showing zebra structure.	VI
		Grey colored limestone. Bedded, black colored, muddy limestone, in some area, it is lacking.	This member is composed of dark grey colored, aphanitic limestone & light grey crystalline limestone, intercalated by two or three beds of crystalline dolomite. Ammonite fossils come from lower part of this member.	V
			Dark brown colored (light brown colored in weathered part), fine grained sandstone, partly with limestone	IV
			Grey colored, micritic limestone. In some part, it is lacking. This member is predominantly composed of fine to coarse crystalline dolomite, in which two or three beds showing zebra structure are seen. At Tambo Maria & Son Vicente (bedded type), ore bodies are emplaced in one of these beds. In some area, this member is lacking	III
			This member is composed of black, muddy limestone & calcareous, well bedded fine grained sandstone. In Tambo Maria, ammonite fossils come from this sandstone.	II
Upper Triassic			Crystalline dolomite, partly showing zebra structure Black shale & fine grained sandstone with black limestone Black to dark grey limestone, abundant in calcite networks.	I
Perm.	Mitu G.	Reddish brown colored siltstone, conglomerate, andesitic lava & tuff, dacitic lava & tuff (Mitu group)		

Fig. 1-2. Generalized lithological distribution and correlation of the Pucara group

SAMPLES OF SEPTEMBER 1975 SURVEY

SAMPLE NO.	ROCK NAME
5	META ANDESITE
8	MICRODIORITE
18	DAOITE
93	WHITE GRANITE
208	MICROGRANODIORITE
218	RED GRANITE

SAMPLES OF AUGUST 1976 SURVEY

229	DIORITE PORPHYRY
271	MICRODIORITE
287	SHISTOSE DIORITE
301	DIORITE
320	GRANITIC ROCK
324	PORPHYRITIC DIORITE

SAMPLES OF MAY 1976 SURVEY

Field NO. OF MAY 1976 SURVEY	ROCK NAME
A - 011	RED GRANITE
H - 011	DIORITE
H - 013	MICROGRANODIORITE
H - 014	PINK GRANITE
K - 264	MONZONITE
K - 265	"
S - 062	MICROGRANITE
T - 013	GRANODIORITE
T - 044	DACITIC TUFF
T - 054	PINK GRANITE

SAMPLES OF JUNE 1977 SURVEY

A - 346	DIORITE
C - 411	QUARTZ PORPHYRY
L - 512	MONZONITE
L - 514	GRANODIORITE
P - 555	QUARTZ PORPHYRY

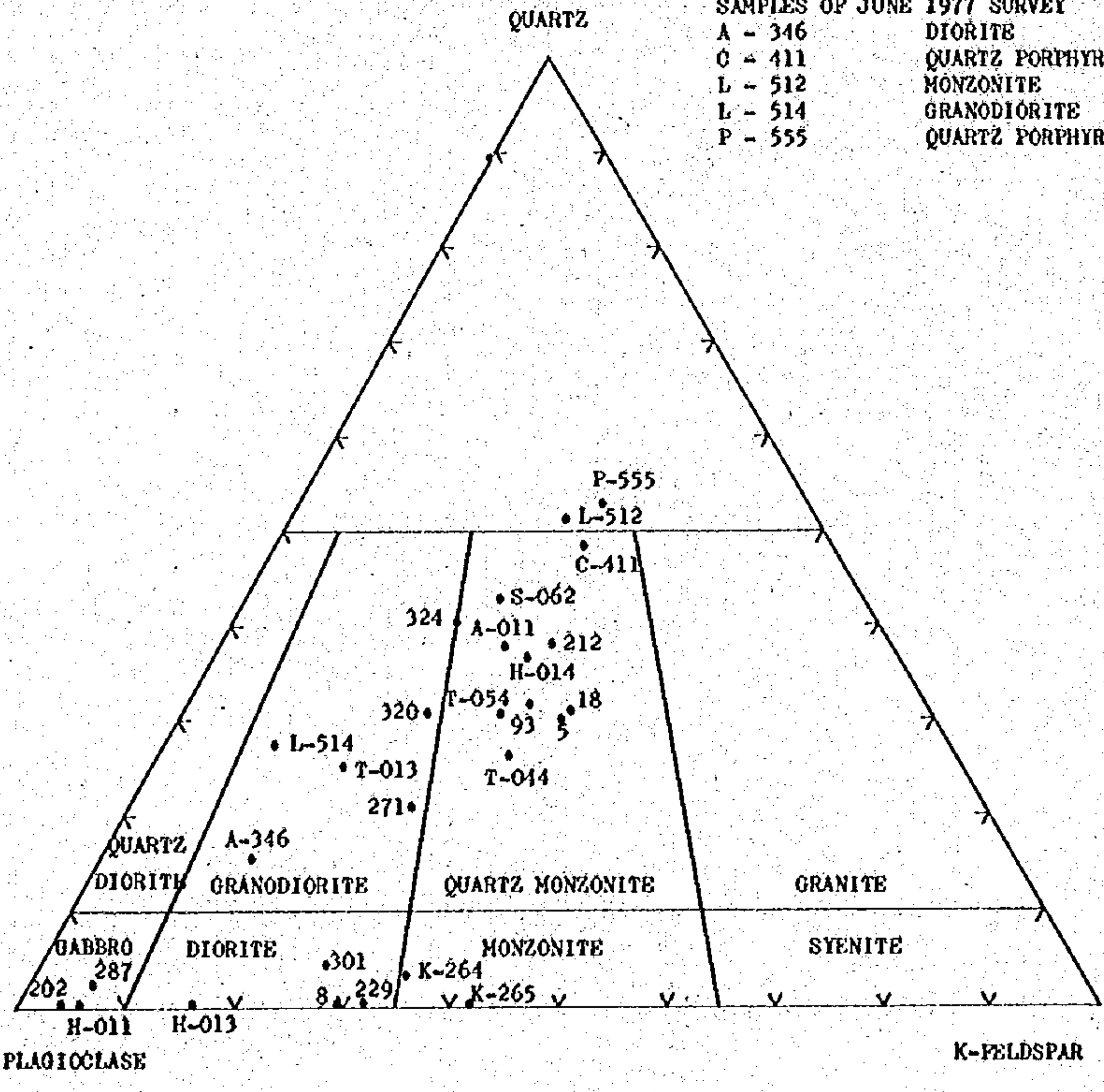
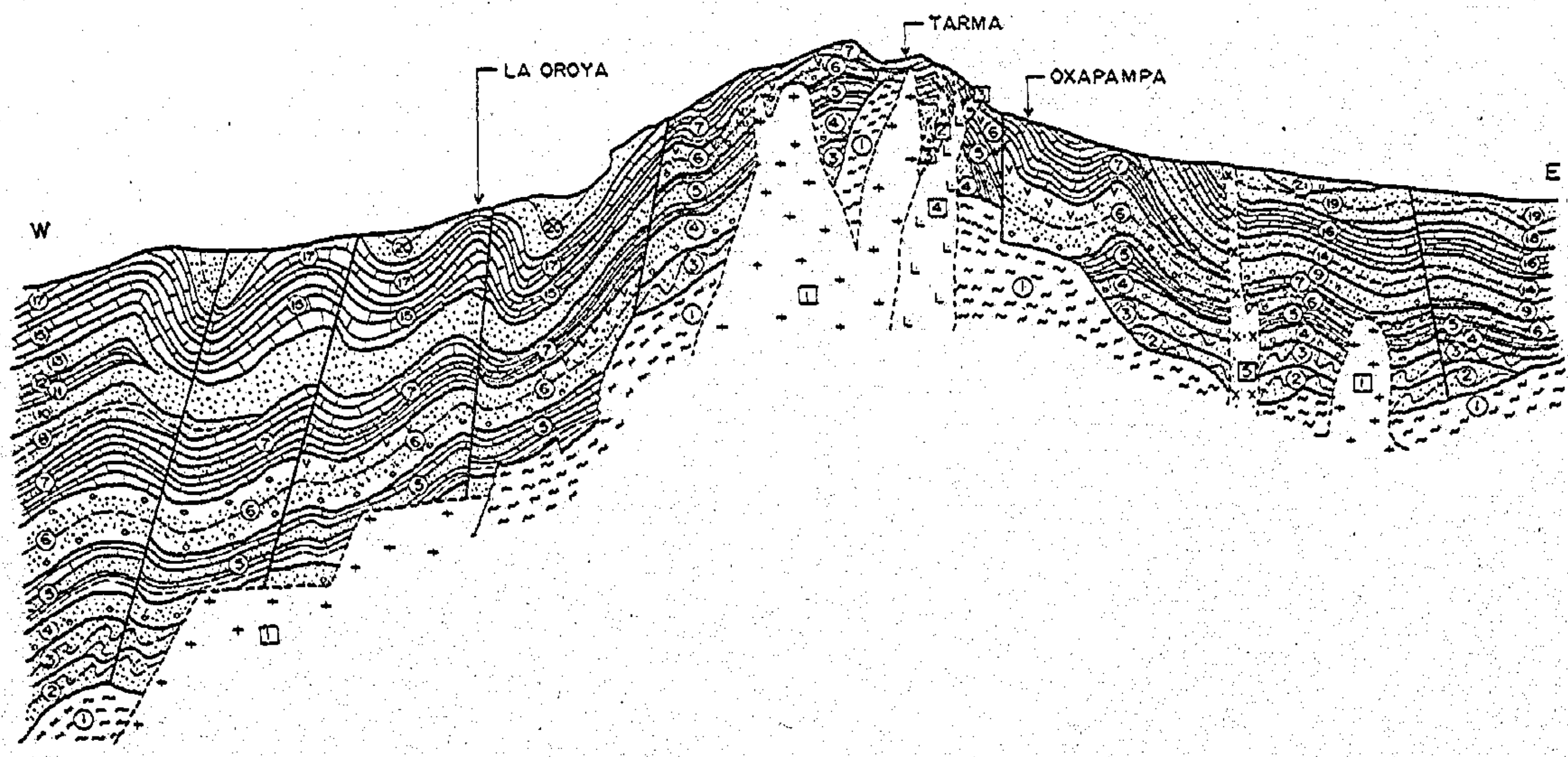
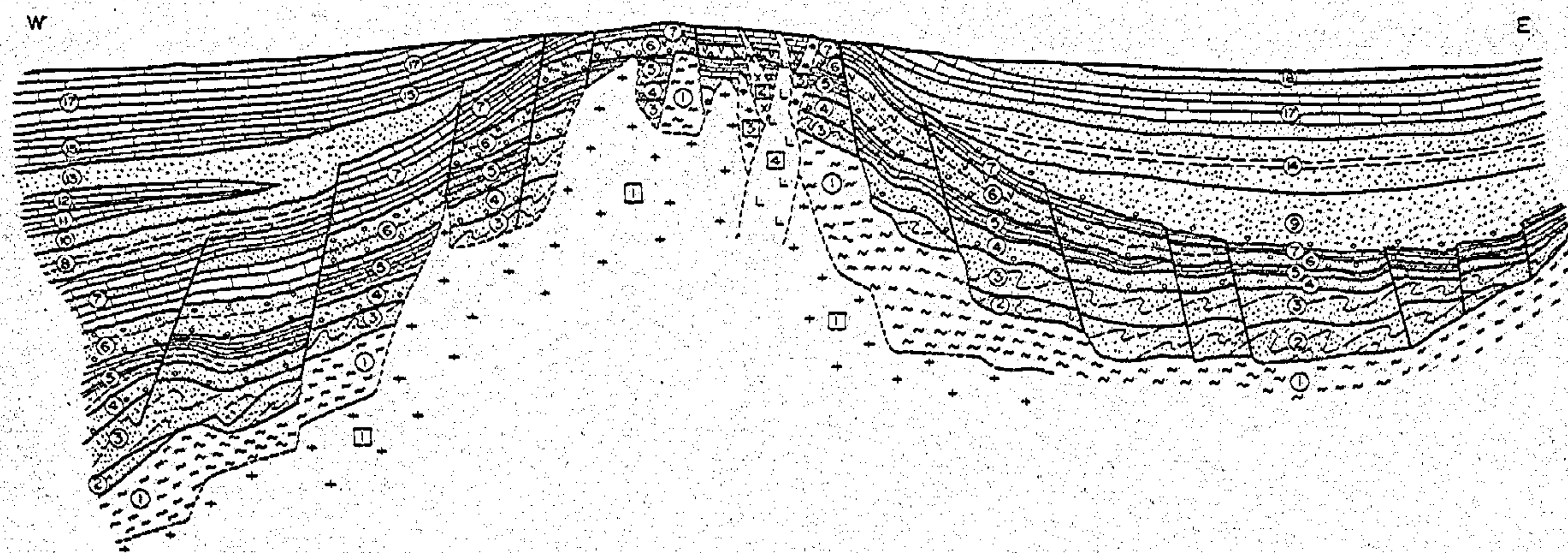


Fig. I・3. Ternary diagram of normative quartz-plagioclase-kalium feldspar

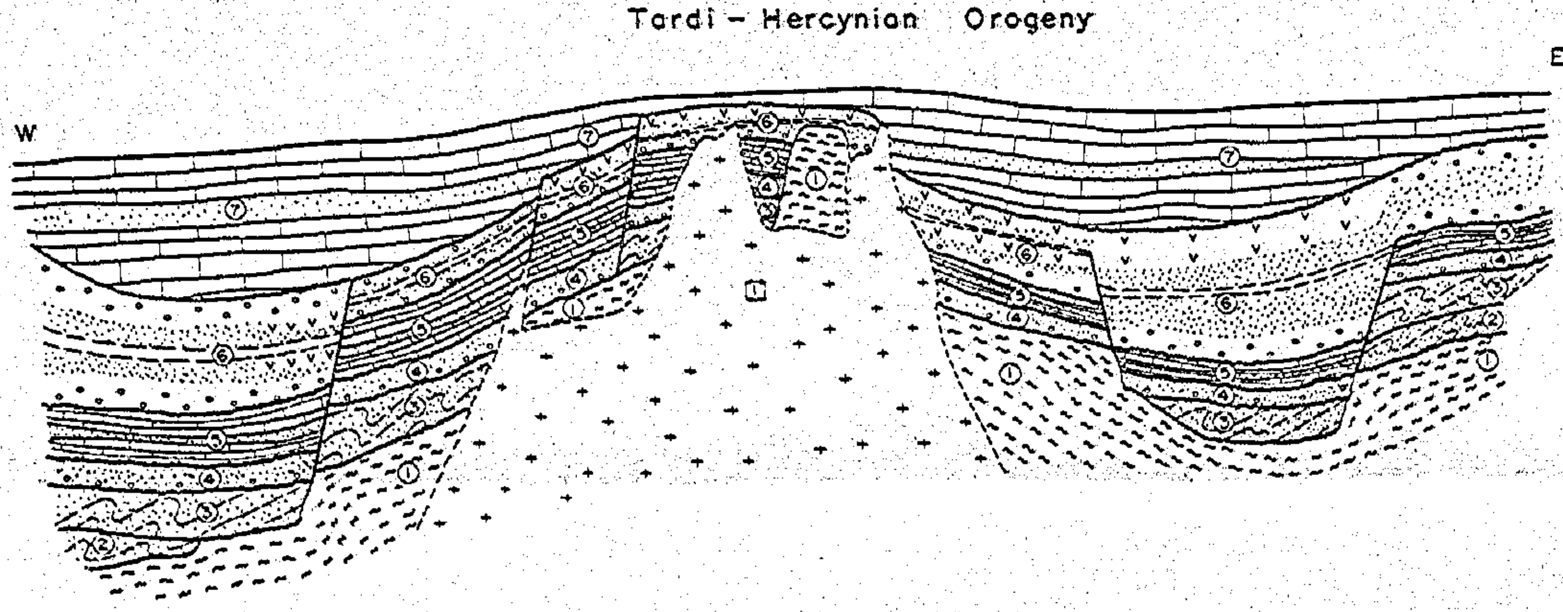
Andean Orogeny



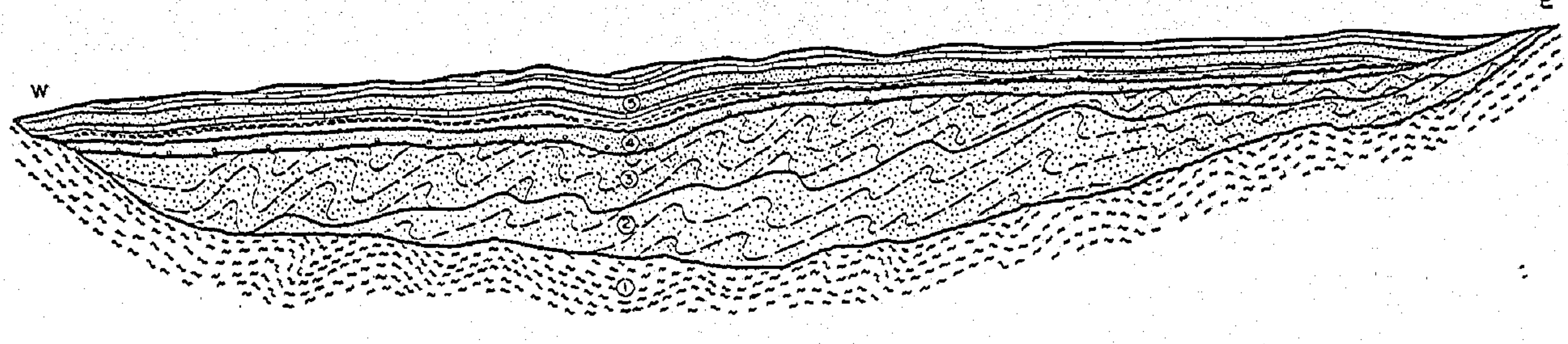
Nevadan Orogeny



Tardi – Hercynian Orogeny



Eo – Hercynian Orogeny



SEDIMENTARY ROCKS

IGNEOUS ROCKS

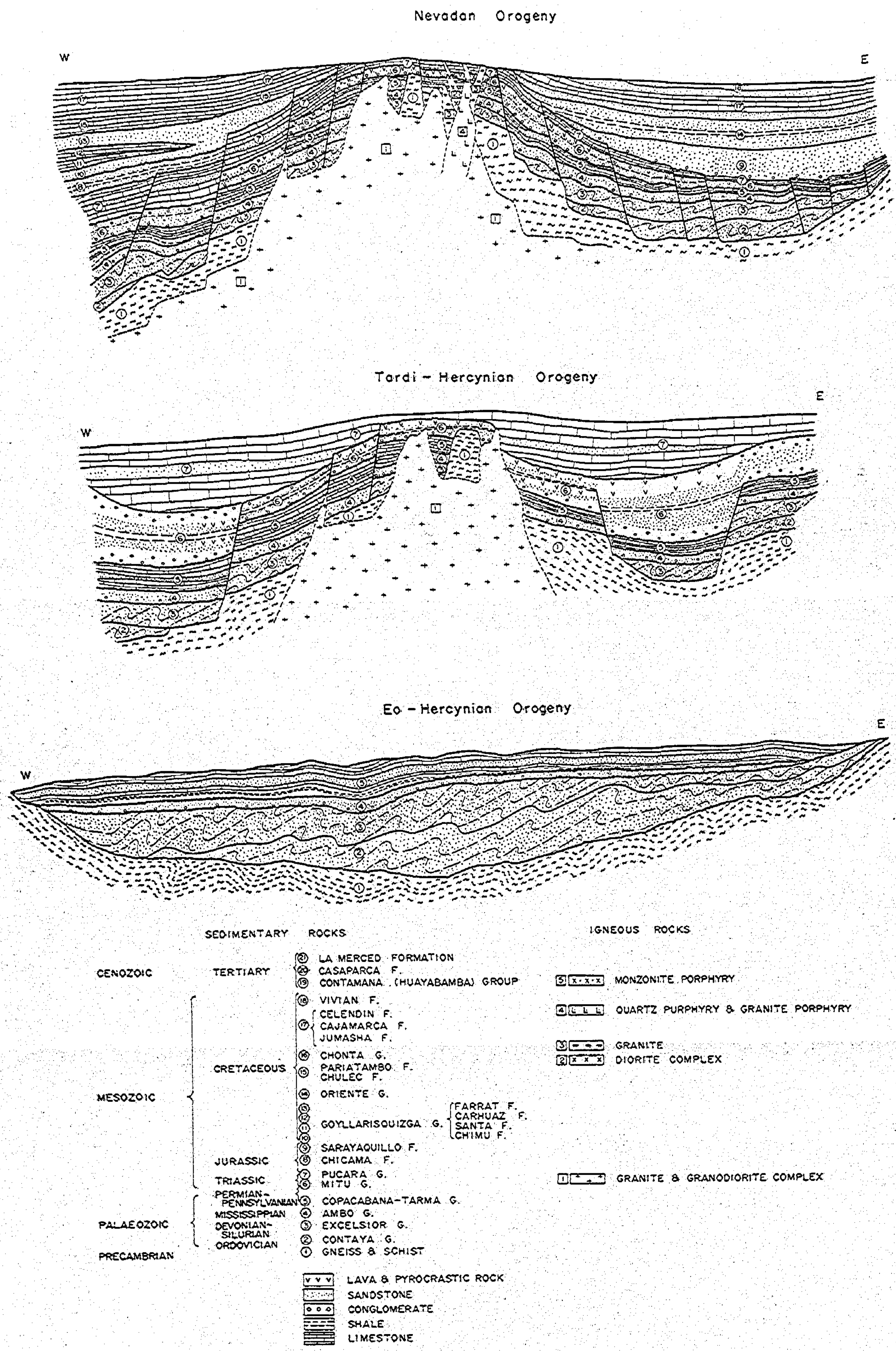


Fig. 1-4. Scheme of Orogenic Cycle in the Surveyed Area

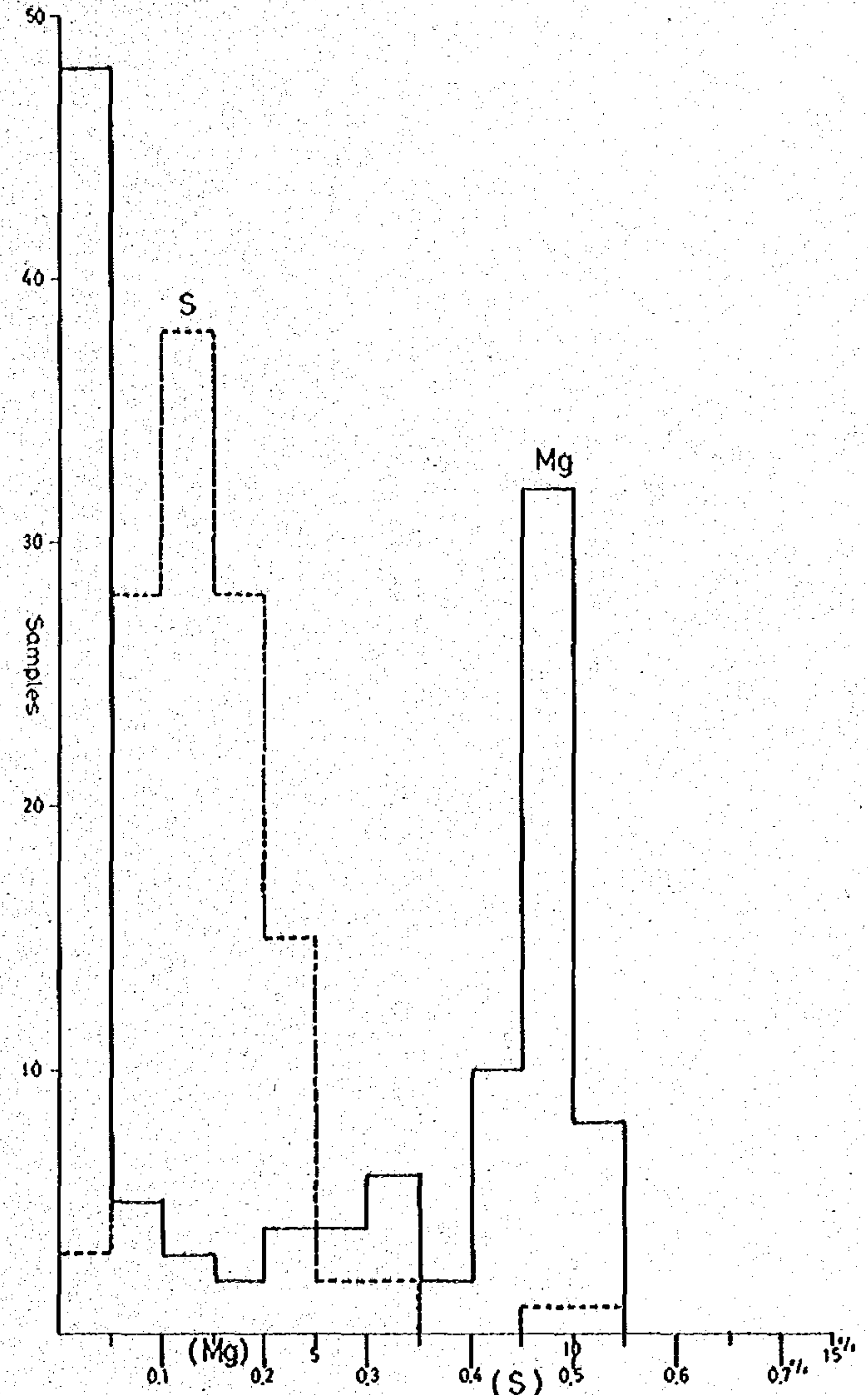


Fig. I-5. Histogram of Mg and S contents on carbonate rocks.

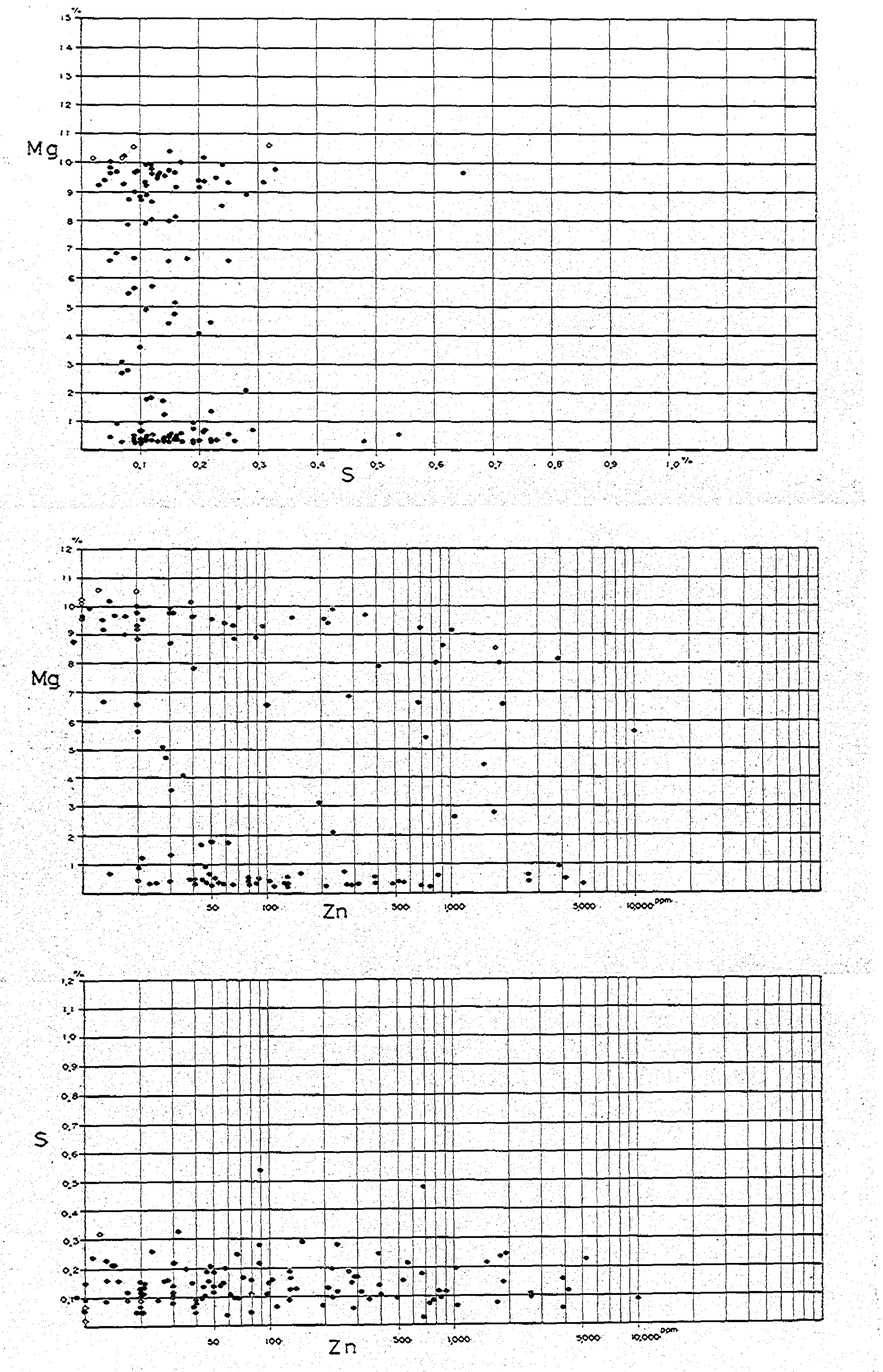


Fig.I-6. Relation of Geochemical Values between Zn, Mg and S contents on Carbonate Rocks.

Table I - 1. Fossils from Pucara Group in the San Ramon - Oxapampa - Tingo Maria area

	Rock facies	Thickness	Fossils	Triassic: Scythian	Triassic: Anisian	Triassic: Ladinian	Triassic: Carnian	Triassic: Norian	Triassic: Rhaetian	Jurassic: Hettangian	Jurassic: Sinemurian	Jurassic: Pliensbachian	Jurassic: Toarcian
VI	Upper part: Well bedded muddy limestone Lower part:Crystalline dolomite and micritic limestone	700 m ±	Euasteroceras ? sp.								—		
V	Grey to dark grey limestone, crystalline dolomite and black muddy limestone	600 m ±	Arietitidae, Gen.et sp.								—	—	
			Epammonites sp.								—		
			Gleviceras ? sp.								—		
			Cheltonia ? sp.								—		
			Psiloceras planorbis (Soverby)							—			
IV	Well bedded sandstone	0 - 350m	Metophiceras sp.								—		
			Ariniocerass sp.								—		
III	Crystalline dolomite and micritic limestone	200~650m	Epammonites of latisulcatus								—		
II	Well bedded, calcareous shale - siltstone and muddy limestone	300 m +	Epammonites sp.								—		
			Psiloceras (Franziceras) sp.							—			
			Psiloceratinar Gen. et sp.							—			
			Psiloceras sp.							—			
I	Upper part: Crystalline dolomite and grey limestone Middle part: Well bedded black limestone & fine sandstone Lower part: Well bedded partly siliceous grey limestone	500 m +	Avicula contorta porti *						—				
			Terebratula gregaria Suess *						—				
			Aulacoceras induseus Münst				—						
			Protrachyceras reitzi *			—							

* According to Levin M. Peter Samaniego A Alberto Boletin de la Sociedad Geologica del Perú Tomo 45 1975.

Table I - 2. Magnesium and sulpher contents of carbonate rocks in the detailed survey area

<u>Geological Index</u>

Pucara Group	PDO	Dolomite
	PLS	Limestone
	PSS	Sandstone

Sample No.	Location	Rock No.	Geological Index	Zn Content (ppm)	Mg Content (%)	S Content (%)
688	8	A306	PDO	1,022	9.17	0.20
689	8	A308	PLS	3,993	0.95	0.06
690	8	A309	PDO	3,975	8.11	0.16
691	10	A315	PLS	45	0.49	0.11
694	10	A321	PLS	287	6.87	0.06
695	6	A323	PLS	21	1.25	0.14
696	6	A325	PLS	65	0.31	0.10
697	6	A326	PDO	351	9.68	0.09
698	6	A327	PDO	833	8.03	0.12
699	6	A328	PLS	103	0.42	0.16
702	20	A340	PLS	43	0.32	0.10
703	23	A403	PLS	62	1.78	0.11
704	23	A406	PDO	31	9.78	0.33
705	23	A414	PDO	67	9.32	0.25
706	23	A420	PLS	46	0.94	0.19
707	23	A428	PLS	14	0.69	0.21
708	23	A429	PLS	38	0.50	0.15
712	4	C308	PLS	4,220	0.51	0.12
713	4	C310	PLS	666	6.64	0.18
714	7	C311	PLS	55	0.37	0.14
715	7	C315	PDO	97	9.31	0.11
716	7	C318	PLS	47	0.39	0.16
719	11	C329	PLS	44	1.70	0.14
720	11	C340	PLS	197	3.09	0.07
722	11	C354	PDO	39	10.15	0.07
724	9	C401	PLS	28	4.72	0.16
725	4	C404	PLS	406	7.92	0.11
726	4	C409	PDO	68	8.81	0.10
727	4	C410	PLS	232	2.08	0.28
732	23	C503	PDO	21	9.56	0.13
733	23	C510	PLS	25	0.32	0.09
736	23	C538	PDO	9	8.76	0.10
737	23	C541	PLS	13	6.69	0.09
740	7	I305	PLS	53	0.52	0.15

Sample No.	Location	Rock No.	Geological Index	Zn Content (ppm)	Mg Content (%)	S Content (%)
741	7	I309	PLS	30	1.34	0.22
743	6	I311	PDO	231	9.89	0.12
748	11	I331	PLS	48	0.67	0.21
749	11	I333	PDO	15	9.67	0.16
750	11	I335	PDO	13	9.17	0.16
751	9	I353	PLS	27	5.10	0.16
753	21	L301	PLS	766	0.25	0.09
756	21	L306	PDO	1,868	8.00	0.15
757	21	L311	PLS	855	0.63	0.10
758	21	L314	PLS	393	0.51	0.25
759	21	L315	PLS	1,508	4.47	0.22
761	21	L318	PDO	89	8.90	0.28
762	21	L319	PLS	152	0.69	0.29
764	21	L321	PLS	129	0.34	0.09
767	21	L328	PLS	1,048	2.67	0.07
769	21	L331	PLS	563	0.35	0.22
770	6	L337	PLS	269	0.71	0.19
771	6	L338	PLS	279	0.28	0.15
773	6	L353	PDO	1,787	8.50	0.24
778	22	L379	PLS	35	4.07	0.20
779	22	L382	PDO	13	9.51	0.23
780	22	L384	PDO	14	10.16	0.21
781	22	L386	PLS	88	0.36	0.22
784	22	L397	PLS	23	0.32	0.26
785	11	L410	PDO	12	10.57	0.32
789	22	L434	PDO	11	9.93	0.24
795	10	L467	PLS	58	0.31	0.20
797	10	L492	PLS	296	0.27	0.17
805	23	L626	PDO	72	9.98	0.17
806	23	L629	PDO	17	9.62	0.12
807	23	L635	PDO	17	9.00	0.09
808	8	M307	PDO	50	9.55	0.14
809	8	M312	PDO	30	8.69	0.08
810	8	M314	PLS	130	0.31	0.19

Sample No.	Location	Rock No.	Geological Index	Zn Content (ppm)	Mg Content (%)	S Content (%)
811	8	M315	PLS	80	0.40	0.05
812	8	M329	PLS	20	0.43	0.15
813	10	M341	PLS	1,940	6.58	0.25
814	10	M343	PLS	740	5.44	0.08
815	6	M372	PLS	2,650	0.63	0.10
816	22	M380	PSS	40	0.47	0.09
817	22	M399	PSS	90	0.50	0.54
818	22	M401	PDO	20	10.54	0.09
819	22	M403	PDO	30	9.92	0.11
820	22	M411	PDO	20	10.00	0.05
821	22	M413	PDO	20	9.27	0.07
822	22	M416	PDO	10	10.17	0.07
823	22	M418	PLS	20	6.58	0.05
824	11	M427	PDO	40	9.61	0.05
825	11	M435	PDO	140	9.59	0.13
826	11	M436	PLS	50	1.80	0.12
827	13	M456	PDO	20	9.80	0.05
828	10	M459	PDO	690	9.23	0.03
829	10	M463	PLS	690	0.26	0.48
830	22	M465	PLS	20	5.68	0.12
831	22	M466	PDO	10	10.13	0.02
832	22	M469	PDO	10	9.68	0.06
833	9	M492	PLS	20	0.91	0.10
837	4	M496	PDO	60	9.38	0.04
838	9	M505	PLS	10	4.41	0.15
839	9	M506	PLS	1,710	2.78	0.08
840	8	P319	PDO	210	9.52	0.13
843	7	P327	PDO	20	9.25	0.11
844	22	P369	PLS	80	0.38	0.11
845	22	P385	PDO	10	9.65	0.09
846	22	P411	PDO	20	8.90	0.11
848	4	P472	PLS	30	3.59	0.10
849	4	P490	PLS	130	0.57	0.17
851	13	P511	PDO	30	9.79	0.12

Sample No.	Location	Rock No.	Geological Index	Zn Content (ppm)	Mg Content (%)	S Content (%)
853	7	P523	PDO	220	9.39	0.20
854	7	P528	PLS	80	0.47	0.16
865	21	S302	PLS	910	8.63	0.12
866	21	S306	PLS	130	0.29	0.13
868	21	S309	PLS	490	0.31	0.10
869	21	S310	PLS	10,000	5.63	0.09
870	21	S311	PLS	5,230	0.33	0.23
871	21	S312	PLS	2,650	0.42	0.11
872	21	S319	PLS	320	0.31	0.12
873	21	S320	PLS	50	0.27	0.19
874	21	S321	PLS	400	0.33	0.14
876	21	S323	PLS	30	0.41	0.14
877	21	S324	PLS	530	0.39	0.16
878	21	S326	PLS	100	6.58	0.15
880	6	S341	PLS	220	0.25	0.10
882	22	S345	PDO	-	10.37	0.15
884	22	S347	PDO	-	9.38	0.21
886	22	S349	PDO	-	9.32	0.31
887	22	S350	ore	-	9.67	0.65
889	22	S352	PDO	-	9.72	0.15
890	6	S376	PSS	40	7.83	0.08
891	6	S377	PLS	110	0.25	0.07

Chapter 3 Ore Deposits

Indications of metal ore mineralization are known in many places in the survey area such as that at Tambo Maria and at San Roque, in addition to actual worked mine of San Vicente. According to the genesis and the species of the metal ores, they are grouped into the followings;

1. Strata-bound lead-zinc deposits in the Pucara Group.
2. Disseminated lead-zinc deposits in the Pucara Group.
3. Contact metasomatic ore deposits formed at the contact surface between intrusion of igneous rocks and carbonate rock of the Pucara Group.
4. Vein type copper-lead-zinc ore deposits in the Pucara Group and in the Mesozoic diorite.
5. Porphyry copper deposits in Tertiary monzonite.

The description of the individual type of mineralization is given in the Volume 1, 4 and 5. Among the above-mentioned, the types of 3, 4 and 5 are observed to form merely small scale minerallization and are regarded not to be very significant based on each environment of the emplacement of the mineralization. On the other hand, types of 1 and 2 are thought to be important and further examination is necessary. These two types of the mineralization are described hereunder.

3-1. Strata-bound Lead and Zinc Deposits

The mineralization of this type has so far been found limitedly in the southern part of the surveyed area. The ore deposit of San Vicente located at the south of San Ramon is the only deposit worked at present in the surveyed area. The deposit of Pichita Caluga at the west of San Ramon, which is out of operation at the moment, is thought to be an extension of the deposit at San Vicente. The indication of mineralization at Tambo

Maria, which was discovered through the survey in 1976, is located 17 km south of Oxapampa. It has been evident by the stratigraphical correlation completed in this survey that the above ore deposits and indications are emplaced in the dolomite beds belonging to the III member. Mineralization of this type has not been found in any other formation in the Pucara Group.

3-1-1. Indications of Mineralization at Tambo Maria

To obtain full information for the elucidation of the mineralization, specially detailed geological survey on the scale of 1 to 2,500 has been carried out in the area including this indication as is the case of the area around the indication at San Roque. (Refer to PL. I-2, I-6) And the following results are obtained.

(1) Dolomite around the indication is the most extensive in Oxapampa area, about 400 meters in thickness. Zebra-structure develops up to 150 meters in thickness with the extention over 2.5 km. The trend is mostly NNW-SSE direction with the dip of 40^{0} of 50^{0} to the west. The zebra-structure is constituted by bands of recrystallized white dolomite and fine dark dolomite (0.1 to 0.2 mm), and they form distinct bandings of the thickness of 2 to 5 mm. The zebra-structure is distributed in various scales, long and narrow or massive about 10 cm in diameter. In another words, as for the above-mentioned zebra-dolomite of the thickness of 150 meters extending over 2.5 km, not the whole of it has zebra-structure, but it partly has dark-colored dolomite without banding. The area of the distribution of this zebra-dolomite is in good harmony with the regional geo-structure, but the directions of the individual bands of the zebra-structure are not always harmonized and are fairly irregular locally. They are mostly oblique to the regional geo-structure and characteristically have no particular directions.

(2) The mineralization mainly of sphalerite is found in the parts where

zebra-structure develops particularly well, in the zebra-dolomite. In such parts, the size of crystals of dolomite in the white band so far observed reaches to about 5 mm, and the thickness of each component band is seen to have developed up to 2 cm. The well-developed zebra-structure, however, is only about several meters wide now. In the trench dug to trace the extension about 50 meters southeast of it, zebra-structure is not found and the northwest extension is not pursued. Such well-developed zebra-structure has been found only in San Vicente ore deposit and in the mineral indication at Tambo Maria, through the past and present surveys, and none has been recognized in other palces. The widened zebra-structure here shows E-W direction with gentle dip of 20° to 30° whoreas the regional trend is NNW-SSE, Small fissures of N-S direction is remarkable in zebra-structure compared to that of the other areas. Slighly brecciated structure is observed along the fissures in the structure. Consequently, it can be said that mineralization is localized to the parts where structural irregularities are seen in zebra-dolomite. In the narrow zebra-structure, the disseminated sphalerite is not completely recognized.

(3) Ore minerals are mainly shalerite, and galena is not recognized with naked eye. Sphalerite is rather coarse grained and maltose-colored. In the zebra-structure, ore minerals are recognized along the boundary of white dolomite and dark-colored dolomite, or in a part of the white dolomite close to the boundary plane. Oxidation of ore minerals is remarkable near the surface, and most sphalerite has been replaced by smithsonite in many parts.

Average grade of the mineralized part (thickness is 35 cm in average) is Cu 0.02%, Pb 0.015% and Zn 9.34%, and the ratio of oxidized zinc to total zinc is 79.55%.

(4) The sphalerite grains contained in the indication of Tambo Maria (Sample No. S343) are, under microscope (Refer to A. I-3, I-4), euhedral

and are replaced by smithsonite along margin of grains or along cleavages. Pyrites (partly replaced by goethite) are recognized to be euhedral among gangue minerals, but are never found as inclusion in sphalerite grains. A dolomite bed with slight zebra-structure has been found about 7 Km north of the indication at Tambo Maria. In this dolomite (Sample No. L416), euhedral sphalerite (slightly less than 0.1 mm in diameter) and stringer of sphalerite with the width of 20 to 90 microns are recognized. Sphalerite grains of several microns in diameter are also recognized in the secondary dolomite veins at the south of the indication. It is interesting to see occurrence of sphalerite in recrystallized dolomite.

3-1-2. San Vicente Ore Deposit

Details of this ore deposit has been given in Volume 1, 4 and 5, but it is described here again for the examination and comparison with the deposit at Tambo Maria.

The San Vicente ore deposit is quite extensive as the exposures of the mineralization are traced over 15 km in north and south of the proper San Vicente deposit, which is located at the middle-stream of Uncush valley branched from Tulumayo River, running near San Ramon. The deposit is emplaced, as is the case of the indication at Tambo Maria, in dolomite bed of limestone-dolomite beds belonging to the III member. At present, 9 layers of mineralization are confirmed to exist. (Levin et al., 1973) The III member here is composed mainly of dolomite with alternation of sandy limestone, dark (bituminous) limestone and limestone, trending N-S direction or NNW-SSE direction with the dip of 50° to 55° to the west.

The thickness of dolomite reaches to about 400 meters and zebra-structure is contained everywhere in it. The zebra-structure is, as that found at Tambo Maria, composed of bands of dark dolomite and white dolomite, thick or thin banded. In this area of the mineralization, thick bandings are predominant; that is, in the zebra-dolomite where the proper San Vicente ore deposit is emplaced, thin zebra-structure is seen filling up the space left amongst the masses of the thick zebra-structure, or is observed along the margin of the zebra-dolomite.

The ores, composed mainly of sphalerite, comprise banded ore associated with thick zebra-dolomite and show brecciated form.

Toward the dark dolomite band from the white dolomite, grain size of the sphalerite contained in the banded ore becomes smaller and the concentration of the sphelerite grains is also decreasing. Therefore, the repetition of the following succession is usually observed.

White dolomite---Sphalerite---Dark dolomite bearing sphalerite
---Dark dolomite---Dark dolomite bearing sphalerite
---Sphalerite---White dolomite.

The intensely mineralized part in which disseminated sphalerite develops well and bands of white and dark dolomite are recognized only traceably, is called massive ore by the miners.

The brecciated ore is the ore of the dissemination type in the brecciated dark dolomite cemented with white dolomite, in the same sort of relation as seen in the case of the banded ore.

The mineralized part lies usually in a scale of 3 to 5 meters in thickness with maximum thickness so far observed of about 20 meters. The ore grade is several per cents to over 25% of zinc content. The individual orebodies* are, viewing in detail structurally, well harmonized with the general trend of the surrounding beds, NNW-SSE or N-S direction, but where the trend of dolomite changes from N-S to NNE-SSW direction or the

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* The ores containg over 10% of Zn are worked at the San Vicente mine. Accordingly, the mineralized parts of the ore grade of more than 10% are called orebodies.

dip is gentle less than 40^{0}, the ore bodies are swelled or the grade becomes higher remarkably. The mineralization is associated with thick zebra-structure. In case the mineralization is with thin zebra-structure. It is often observed that mineralization disappears along the strike extension in spite of the continuation of the thin zebra-structure.

Under microscope, it is characteristic that sphalerite grains contain abundant inclusions of pyrite, which is marked contrast to the case of the mineralization at Tambo Maria where sphalerite never contain any inclusion of pyrite. As was considered in the Volume 4, this is thought to be because the ore deposit at San Vicente was formed in rather high temperature, leaving pyrite separated from sphalerite on the way of cooling after mineralization. On the other hand, in the case of the mineralization at Tambo Maria, it is thought that the sphalerite precipitated after isolation of iron content through the mineralization in rather low temperature.

3-2. Disseminated Lead and Zinc Deposits

Mineral indication of disseminated type has been found about 5 km northwest of Oxapampa. It is weak dissemination mainly of galena in limestone-dolomite beds belonging to the Pucara Group. Based on this finding, the detailed geological survey has been carried out around the mineralization in the present year, and the dissemination of galena has been recognized at several localities in the vicinity of the igneous rock distributed in the west. (Refer to PL. I-14, I-1 and PL. I-2)

3-2-1. Mineral Indication at San Roque

Detailed geological survey of the scale of 1 to 2,500 has been carried out around San Roque in the present year. (PL. I-6(1)) The followings are confirmed by the results of the survey.

(1) Around the mineral indication at San Roque, limestone belonging to the

V member is distributed and it has become evident that dolomite is distributed in lenticular form merely in the east side and in the west side of the area. In the northern part of the mineral indication, dolomite over 100 m in thickness distributed. Limestone is locally crystallized and along the igneous rock distributed of the west side it is partly silicified. It characteristically contains abundant fossils being megascopical or microscopical.

(2) The mineralization is found over 3 km north and south direction, along the center of San Roque Valley, at the old working gallery about 500 meters to the south of it as well as at the old drill-site 500 meters north of the valley, and around the drill-hole No.52-1 performed in this year's survey.

(1) Along the San Roque Valley, calcite veinlets of the N-S or NNW-SSE direction develop well in limestone. Dissemination of galena is observed in calcite veinlets or surrounding limestone as crystal grains of about 0.5 mm.

Analysis result of the disseminated block shows the following contents.

Pb : 5120 ppm   Zn : 152 ppm (Sample No. L319)

Pb : 0.27%   Zn : 0.14% (Sample No. OF007, Refer to Volume 5)

(2) The old working gallery and the surrounding area are collapsed with land-slide, and information on the condition of the tunnel and on the geology of the underground is not available, but dissemination of galena is found in limestone, left as wastes at the mouth of the old tunnel, where grains of galena reach up to 2 cm in diameter, in a form like leaves of bamboo grass. The analysis result of the disseminated ore left as waste shows Pb:15.8% and Zn 0.63% (Sample No. OF017, Refer to Volume 5)

(3) At the north of San Roque valley, there is an exploration tunnel excavated in the alternation of limestone and dolomite. Surface

geology is unavailable but, in the tunnel, dissemination of galena 5 to 7 mm in diameter is recognized along faults in the fault zone zccompanied by clay, running almost parallel to the trend of the alternation, NNW-SSE. The ore grade of the most remarkably disseminated block so far observed is Pb 2.48% and Zn 0.42%. (Sample No. C416)

(4) At the south of the drill hole No. 52-1, performed in the present year's survey, galena-dissemination is recognized in dark dolomite. The dolomite is silicified a little. Two types of occurrence are recognized of galena; the one is that associated with minute calcite-veinlet (0.5 cm width) and the other is as thin film in small cracks around calcite veinlets. The ore grade of the dissemination of the type of thin film is Pb 0.22% and Zn 0.28% (Sample No. M494).

As above, it is characteristic as for the mineralization near San Roque that the dissemination of galena occurs along faults, along calcite veinlets or along cracks in limestone or dolomite. Although sphalerite grains are rarely visible with naked eye, small amount of sphalerite is usually contained in the dolomite as shown each chemical analysis of the samples. The analysis of the dolomite located 100 m east of the lead mineral indication at the mouth of San Roque valley, shows particularly high values of Zn 10,000 ppm (Sample No. S310) and Zn 5,250 ppm (Sample No. S311) though sphalerite is invisible with naked eye.

(3) The microscopical particulars of the ore minerals in San Roque area is that botryoidal pyrite are remarkably recognized. Botryoid is an aggregate of many small spherules about 10 microns in diameter and looks to have orientation slightly. Galena and sphalerite of granular (max. 30 micron) or veinlet (10 micron) forms are recognized in the neighbours of these botryoidal pyrite. These galena and sphalerite are anhedral with pyrite distinctively. They sometimes contain many pieces of fossils as bivalves

or gastropoda. (Sample No. C416, L305, L319, L320, L324 S322B, L329)

There is a large crystal of galena up to 7 mm in diameter. Under microscope, galena is replaced partly by cerussite, which has also been confirmed by X-ray diffraction.

(4) In this year, diamond drilling of four holes was carried out in this San Roque area in addition to the geological survey. The results of the drilling is given in detail in the PART III. It is notable that sphalerite is recognized in the drill-hole No. 52-1 and that galena is recognized in the hole No. 52-3.

3-2-2. Other Mineral Indications

Another mineralization basides San Roque, indications of lead-mineralization, are found at the north of Chontabamba and at the south of Chontabamba River, etc. As shown on the PL. I-14, both mineralization are slight galena dissemination in weakly silicified limestone around the igneous rock distributed in the west side. An old working gadlery is found at the south bank of Chontabamba River, which is thought to be excavated for the mining of lead minerals. There is a record of production of about 10 tons of lead-zinc ore (Pb 22%, Zn 3%). At present, state of the underground in the tunnel is unavailable.

About 1 km south of this indication, there is an old working tunnel of 220 m in length excavated in limestone and dolomite to reach the igneous rock in the west side. No mineral indication has been found on the surface. The tunnelling is thought to have been carried out for the geochemical prospecting, but no mineral indication has been caught in the tunnel with naked eye in the present survey. The highest values of the chemical analysis of the samples collected from this gallery are Pb 11,400 ppm and Zn 5,900 ppm. (Sample No. P588)

Chapter 4 Geochemical Survey

4-1. Purpose and Methods

This geochemical survey has been carried out to extract high potential area for the emplacement of the metal ore deposits in the survey area, obtaining information on the mineralization, accompanied by geological survey.

In the detailed survey area of last year's survey, geochemical prospecting by samples of rocks as well as soils were conducted. Rock-geochemistry has been thought to be effective. According to that, the present geochemical survey has been carried out, by collecting samples of rocks in the selected areas for specially detailed survey in this year. Also, in the new areas extracted for detailed survey in the present year, samples of rocks in addition to soils have been collected duplicatedly.

In the whole area for the reconnaissance, of total area of about 20,000 km^2 samples of soils and river sediments were collected in the surveys performed in 1975 and in 1976. By the elucidation of the results of such surveys, the detailed surveys were conducted in several selected areas. However, at the period when the reconnaissance finished, some areas were thought to require more geochemical information. Geochemical survey by soil samples, in addition to geological survey, has been carried out in such areas, to obtain necessary information. Also, geochemical survey has been conducted by soil samples in the following areas; that is, in the areas requiring more informations among the areas where semi-detailed survey was conducted in 1976 (about 2,000 km^2), and in the areas necessary to collect more informations, selected newly for the semi-detailed survey.

About 1 kg of soil samples were collected from B-1 bed directly below the humus along the mapping routes. Rock samples were collected at the outcrops which came across the mapping routes, and in the trench excavated in the present year's survey as well as in the exploration tunnels located in the survey area. The collected soil samples were dried naturally and the collected rock samples were crushed in the small iron mortar. By quartering them after sizing under 80 mesh, 10 grams of material were prepared for chemical analysis. The prepared materials were brought to Japan and analysed about the index three elements by the atomic absorption method. (The index elements are Cu, Zn and Ni in the reconnaissance and Cu, Pb and Zn in the detailed and the semi-detailed surveys.) Additional two elements of Mg and S were also analysed on part of the rock samples collected in the detailed survey. Flow sheet of chemical analysis is given on A. I-12 and the results of the analysis are shown on A. I-13.

4-2. Elucidation and Examination of the Results

The analysis results in the present year are treated as below. Electronic computer of IBM 370-145 was utilized for the statistical treatment.

4-2-1. Geochemical Prospecting by Rock Samples

(1) Analytical Research

We treated statistically the analytical results of the 931 rock samples collected in the detailed survey area in the present year. The elucidated results are shown in the Table I-3 and Fig. I-8(1). The average contents of elements are Cu 9 ppm, Pb 50 ppm and Zn 60 ppm. Overwhelmingly abundant samples show the values of Pb around 35 ppm and of Zn around 20 ppm. That is, it has become evident that they show such pattern of dispersion as the peak of the histogram, is situated at the lower value than the average value. And it is particularly distinct in case of Zn.

The samples of the lower value than the average are distributed mostly in the eastern part of the surveyed area, and the numbers of the samples are not balanced between the eastern part and the western part of the area. As it is thought that these factors might give some influence to the calculation of the average. Then, the statistical treatment of the data on the samples collected in the detailed survey areas in the south of Oxapampa was performed respectively in the eastern part and in the western part after divided into such two parts. The results are shown in Fig. I-8 (2), (3) and in Table I-3.

By the results of the statistical treatment, the values of the samples collected in the western part comprise the population with the excess of higher values on each element of Cu, Pb and Zn. The average values are Cu 8 ppm, Pb 70 ppm and Zn 154 ppm. There remains a tendency that the peak is situated at the lower value than the average in case of Pb and Zn, though not in Cu. Another peak of 300 ppm is seen in Zn histogram.

On the other hand, the values of the samples in the eastern part comprise the population showing normal logarithmic distribution, the average values of which are Cu 6ppm, Pb 31 ppm and Zn 23 ppm. They are remarkably lower than the average values of those in the western part. Especially, it is noteworthy that the average value of Zn is lower than that of Pb.

As mentioned above, the values of Cu, Pb and Zn contained in the rocks do not show, by statistical treatment, simple normal distribution, but they show dispersion of the concentration at certain values. Also, it has become evident that the values are quite different in every area. Therefore, on the 467 rock samples there has been carried out another analytical research in addition to the above, based on which Fig. I-9 shows the histograms of Cu, Pb and Zn values of the smaples in each block of the detailed survey areas. (Blocks are defined according to the map number of the route map.) The numbers of the samples in each block are fairly different. By the comparison of the position of the peaks, not the frequency, in the histograms, the following three types of dispersion have appeared, which can especially be said of the elements of Pb and Zn.

(1) The group where the frequency of the average value is high.

(2) The group where the frequency of the higher value than the average is high.

(3) The group where the frequency of the lower value than the average is high.

The average values in each group are as follows.

(Group)	Cu (ppm)	Pb (ppm)	Zn (ppm)
(1)	7	39	66
(2)	8	88	217
(3)	6	31	23

There is little variation of the values of Cu, but the values of Pb and Zn change in wide ranges in every group. The samples of the east Pusagno area (route map No. 11) belong to the group (1). The samples of around San Rouqué, Pusagno, and Huancabamba area, (route map No. 4, 8, 10, 20, and 21) locating near by the igneous rock belong to the group (2). Furthermore, the samples of the area from Oxapampa to Tambo Maria, where dolomite distribute dominantly, belong to the group (3).

Therefore, in regard to geochemical prospecting by rock samples, two types of anomaly are able to be selected from above three groups. One is the anomaly of San Roque type, being equal to group (2), in which there are thought to be the high frequency of higher value samples, and their threshold values are decided as following:

Cu : 22 ppm, Pb : 194 ppm, Zn : 412 ppm.

The other is anomaly of Tambo Maria type being equal to group (3), in which there are thought to be the high frequency of lower value samples and their threshold value of Zn is decided as 27 ppm.

(2) The Examination of the Results

The anomalous zones extracted by the threshold values above-defined are shown on PL. I-II, I-14, and Fig. I-10. From the mineralized part of the mineral indication at Tambo Maria, no sample for the geochemical prospecting has been collected and the area has not been included in such anomalous zone, but it is not necessary to mention that the area comprises super-anomaly zone as for geochemical prospecting.

By the check up with the results of the geological survey, the followings can be said on the anomaly of San Roque type.

(1) Most of those anomaly zones are recognized in close vicinity to the igneous rock.

(2) Cu-anomaly zones are distributed independently by themselves, but the anomalies of Pb and Zn are located rather contiguously, partly duplicated. However, any such tendency has not been recognized as to form zonal distribution in which Zn-anomaly zones are close to the igneous rocks while Pb-anomaly zones are farther to it.

(3) The anomaly zones seem to correspond to the distribution of dolomite mostly, but they are also located in the area occupied by limestone. Therefore, it can be said that the country rocks are not related to the anomaly zones.

Considering the above-mentioned and the locations of the anomaly zones, it can be said that the anomaly of San Roque type is formed by the influence of the igneous rocks intruded in the west side. But Pb-anomaly zones are not necessarily distributed in accordance with the distance from the igneous rock, and even the reverse case is recognized. Therefore, it is thought that the cause of the anomaly zones would have been the rearrangement of the metal elements of Pb and Zn essentially contained in limestone or in dolomite, affected by the intrusion of the igneous rock, rather than the hydrothermal mineralization related to the igneous rock. That the Pb-indication recognized with naked eye at San Roque is located nearer to the igneous rock than the part of high grade zinc is thought to be one of the evidences for the elucidation of the above.

The anomaly zones of Tampo Maria type are recognized over 10 km in extension, including the mineral indication at Tambo Maria. Other than this, anomaly zones of that type are located at the north of Oxapampa and at Pusagno.

(1) The anomaly around Tambo Maria extends over 10 km along the most thick dolomite in the survey area and along the area where the main zebra-dolomite is distributed.

(2) While the content of Pb is mostly 30 to 40 ppm and is common to the whole area including the extension of the anomaly zones, it is characteristic that the Zn content is lower than Pb-content in the anomaly zones of Tambo Maria type.

(3) The mineral indication at Tambo Maria is included in this zone, in which the sample L416 of the dolomite, containing small veinlets of sphalerite, is located.

(4) The only igneous rock adjacent to the anomaly zones is a small stock of Tertiary monzonite observed about 1 km northeast of the mineral indication at Tambo Maria.

As mentioned above, it is evident that the anomaly zone around Tambo Maria is characteristic in the point that Zn content is lower than Pb content, which is not observed in any other area than this anomaly zone and that a Zn super-anomaly, a mineral indication, is located in this zone. Furthermore, considering from the fact that the anomaly zones of this type are distributed in association with zebra-structure which is thought to have been formed by recrystallization upon structural movement, it might be said that the strata-bound ore deposits as seen at Tambo Maria would have been the results of remobilization of the elements, that is, the zinc would have concentrated tothe parts as seen mineralized at present after remobilized from the original place where zinc content might have been higher than that of lead. Details are given in the chapter 5.

4-2-2. Geochemical Survey by Soil Samples

(1) Detailed geochemical survey

As for the soil samples in the detailed survey areas, total 2,094 soil samples including 1,840 samples collected in the works in 1976 have been treated statistically, the results of which are shown in Table I-3 and in Fig. I-7. With the content of each element of Cu, Pb and Zn in soil samples, roughly normal logarithmic distribution has been obtained. Viewing that further in detail, it shows slight excess of higher values and the curve-line is such as the cumuletive frequency curve of the Zn and has characteristically zig-zag including positive to negative or reverse turns. However, in case of each element, no sharp border line can be drawn to distinguish abnormal group from others in the population. Accordingly, three elements are regared to show approximate normal logarithmic distribution. Considering the results of the statistical treatment of the whole population and the group of samples from the localities corresponding to the area occupied by limestone and dolomite of the Pucara Group, the threshold values are established as follows.

	Cu (ppm)	Pb (ppm)	Zn (ppm)
Threshold values of weak anomaly (t')	30	120	400
Threshold values of strong anomaly (t)	70	150	2,000
Threshold values of extra-strong anomaly (2t)	140	900	4,000

The above values are same as employed for the geochemical survey in 1976, which means that the threshold values have not been affected by the additional 254 samples collected in the present year, which occupy too small part to give influence to the threshold values as they are only 12% of the whole 2,094 samples treated statistically.

The anomalous values in the area where soil samples were collected in the present year are shown in Pl. I-13, and the anomalous values in all the detailed survey areas are shown in Fig. I-10. The anomalous zones extracted in the present survey are Zn and Pb anomalies in the area occupied by the Pucara Group in the west of Pusagno, and no Cu-anomaly has been recognized.

The results of the geochemical survey by soil samples in the detailed survey area, including the results of the above mentioned survey in the present year, are summarized as follows.
(Refer to Table I-4)

The samples showing anomalous values of Cu are located mostly in the area occupied by the Pucara Group, and also some high values of Cu are observed in the area occupied by the Mitu Group and by the diorite or granite of late Mesozoic Era. There is no Cu-anomaly corresponding to Pb and Zn anomalies, as described later, in the Pucara Group, but most of the Cu-anomalies correspond to the area along the faults of NNW-SSE direction (in the northern part) or of N-S direction (in the southern part) across the detailed survey area. As late Mesozoic igneous rocks are recognized along the fault, it is thought that the Cu-anomalies are due to the activities of the igneous rocks. However, as the highest value of Cu content is merely 188 pp, the possibility of the existence of remarkable mineralization is thought to be quite small. The behaviors of Pb and Zn are almost same and the samples of high values of respective element of Pb and Zn are located mostly in the area occupied by the Pucara Group. Some samples of the high values of Pb and Zn are also distributed in the area represented by the late Mesozoic to Tertiary igneous rocks intruded the western part of the Pucara Group, such as granite-porphyry, quartz-porphyry, rhyolite and dacite. Regionally, more samples of high values are also seen located in the area where the Mitu Group and diorite of late Mesozoic Era are distributed.

Porthermore, in the area occupied by the Pucara Group, the overwhelming majority of the high values are concentrated along the western belt abutted the igneous rocks. Less amount of high values are found in the central belt and almost none in the eastern belt. In the western belt, the anomalous zone seems to extend along the strike of the beds and situates within 2 km of the igneous rocks. Therefore, it is thought that the anomaly is due to the influence of the intrusion of the igneous rocks. However, as stated in the paragraph of the geochemical survey by rock samples, the anomaly is not of the character of the mineralization directly related to the igneous rocks.

Around the mineral indication found at Tambo Maria, no high value sample of any of Cu, Pb or Zn has been found, the reason of which is thought to be that the metal elements have been washed out previously in the very steep topographical features as is considered in the Vol. 5 (Part II, chapter 4.).

(2) Geochemical survey in the semi-detailed survey.

The number of the samples collected through the semi-detailed survey carried out in the present year are only 11% of the total number of the samples including those collected in the same survey in 1976. Therefore, the extraction of the anomalous values has been done by the threshold values defined last year by the results of the statistical treatment. The threshold values are as follows.

	Cu (ppm)	Pb (ppm)	Zn (ppm)
Threshold values of background (M)	13	36	105
Threshold values of weak anomaly (t)	28	104	369
Threshoed values of strong anomaly (2t)	63	304	1,297

The anomalies showing these results are given in PL. I-15.

The localities of all the samples of high values of Zn in Tingo Maria area are concentrated in the area occupied by the Pucara Group.

But, the average value is only 105 ppm and is far lower than that in Oxapampa area. The high values of Cu and Pb are distributed in the almost same area as those of Zn.

In the Huancabamba area, high values of Cu, Pb and Zn are concentrated along the boundary zone between the Pucara Group and the igneous rocks intruding in the west side. Some samples of high value of Cu are found in the area where the igneous rocks are distributed, but the values are less than 500 to 600 ppm and it is not likely that they indicate the possibility of unexposed mineralization.

Some samples of high value of Pb are recognized in the area where the Oriente Group is distributed in the central part of the surveyed area. No sample of high value is found in the areas of Rio Snata Cruz and Raymondi.

(3) Reconnaissance area.

The number of the soil samples collected through the reconnaissance carried out in the present year is 265, which is only 8% of the number of the total samples including those collected in same work in 1976. As is the case of the samples of the detailed survey, described in the paragraph (1), it is thought that the threshold values for the anomalous values are little different from those defined by 2,892 samples collected in the works of the last year. Therefore, no statistical treatment has been performed, but the results of the statistical treatment on the samples of 1976 are again employed for the consideration. The threshold values defined for the elucidation are as follows.

	Cu (ppm)	Zn (ppm)	Ni (ppm)
Threshold values of the background (M)	20	100	30
Threshold values of weak anomaly (t)	70	200	100
Threshold values of strong anomaly (2t)	140	400	200
Threshold values of extra-strong anomaly (3t)	-	600	-

The anomalous values extracted by the above results are shown in PL. I-16.

Several anomaly zones have been extracted by the results of the works in the present year, as are the Cu-Zn anomaly in Rio Huallaga area and the Zn anomaly in Rio Oxabamba area. Zn-anomalies are limited in the area occupied by the Pucara Group, as is the results obtained from the works carried out last year.

The results of the examination on the general anomaly map are summarized as follows.

(1) High values of Cu are recognized in the area around the mineral indication of vein type developed in the granite or in the metamorphic rocks, and also are found in the area corresponding to the Jurassic diorite. However, as the highest value is 1,400 ppm (around the ore vein near Churmazu) and the area is limited in extention, the possibility of the emplacement of remarkable mineralization is thought to be very small.

(2) Most of the localities of the samples showing high values of Zn are concentrated in the area where the Pucara Group is distributed. Some of the high values are recognized in the area occupied by the Mitu Group. The anomaly zones of the high values in the Pucara Group are found in the following areas;

San Vicente, Pichita Caluga, Paucartambo, west of Oxapampa, Huancabamba, Monopampa, Tingo Maria.

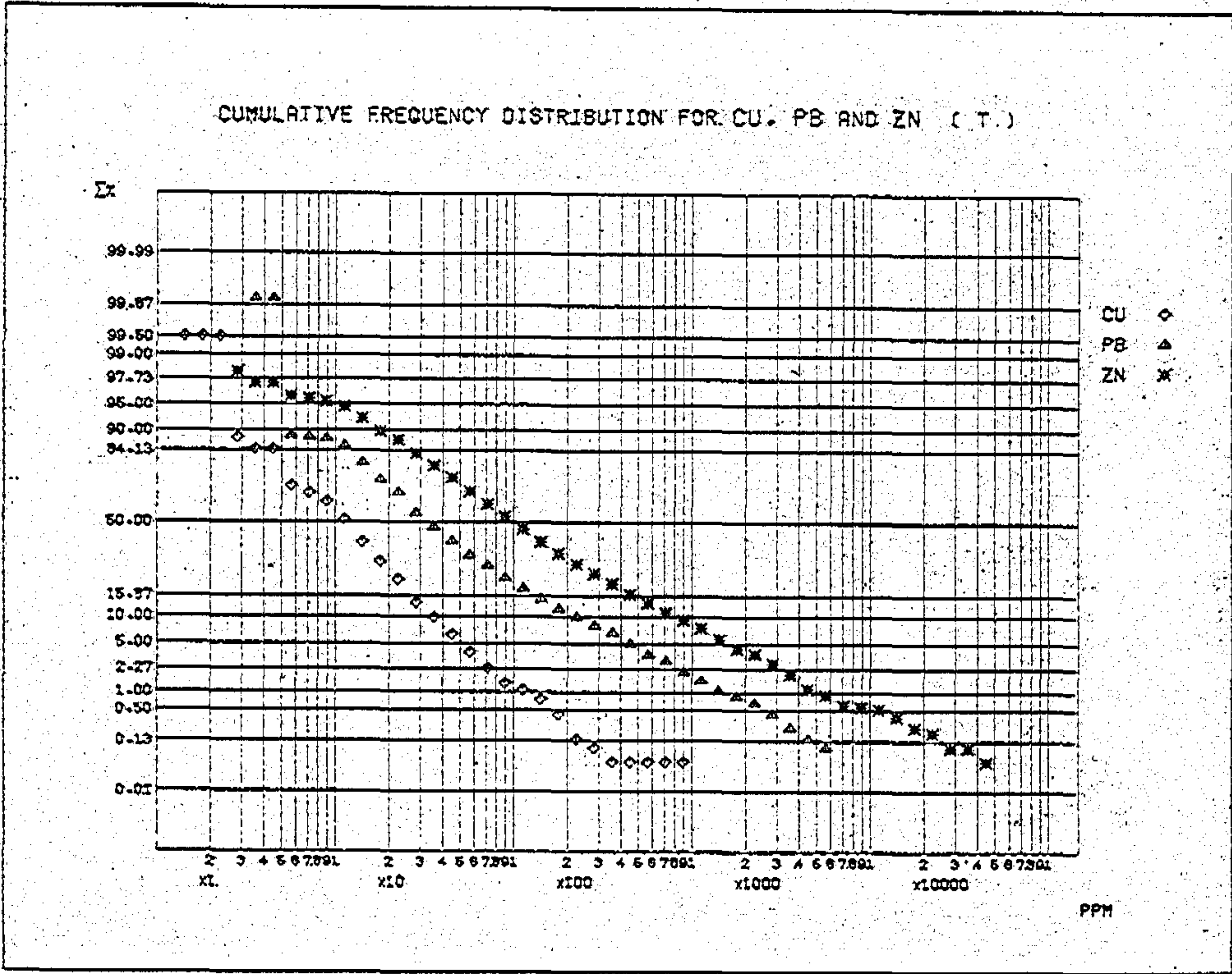
In these anomaly zones, the highest value is 5,000 ppm and the anomaly zones are constituted by the values about 1,000 ppm. The form of the anomalies are composed of scattered high values in several areas or of comparatively concentrated high values. The form of the anomalies might depend upon the rough density of the survey routes or sampling points. In the anomaly zones scatteringly distributed in the west of

Oxapampa, the detailed survey has brought about more absolute values and made the form of distribution clearer, and finally it has led to the discovery of the Pb-Zn mineralization. Therefore, in the area where high values are gathered even if scatteringly, it is desirable to continue such survey as is able to clarify the form of anomalies.

(3) High anomalies of Ni are recognized in the area occupied by the gneisses and by the Mitu Group as well as in the area where Jurassic diorite is exposed.

4-3. Comparison of the Geochemical Survey by Soil Samples to That by Rock Samples

Anomalous areas of the geochemical prospecting both by soil samples and by rock samples are shown in Fig. I-10. The threshold values of each anomaly have been obtained through the statistical treatment of the analysis results of the samples. Anomalies of each element by each method are roughly duplicated in San Roque area and in Pusagno area, where especially strong anomalies are distributed. In another areas, anomalyies of each element are almost adjacent. Accordingly, in regional investigation, both methods are efficient. As the remobilization of the elements are considered by the results of the geochemical survey by rock samples, and the mineral indication at Tambo Maria which it was impossible to catch by the geochemical exploration by soil samples, has been extracted in the anomaly of Tambo Maria type of the geochemical survey by rock samples, it can be said that the geochemical survey by rock samples is effective for the exploration of this type of mineralization.



CUMULATIVE FREQUENCY DISTRIBUTION FOR CU, PB AND ZN (T)
Σx
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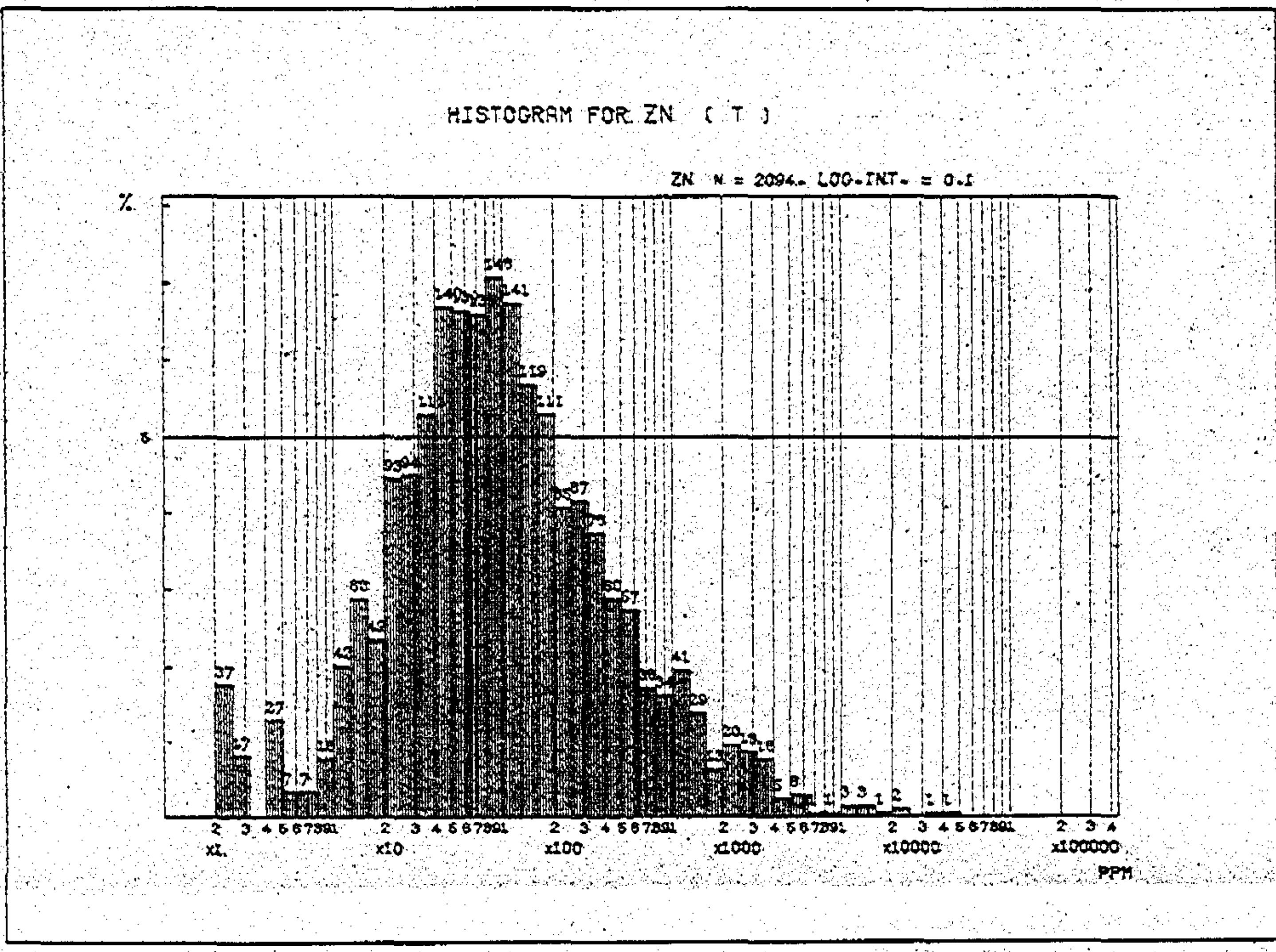
99.87
99.50
99.00
97.73
95.00
90.00
84.13
50.00
15.87
10.00
5.00
2.27
1.00
0.50
0.13
0.01
CU
PB
ZN
x1
x10
x100
x1000
x10000
PPM



HISTOGRAM FOR ZN (T)
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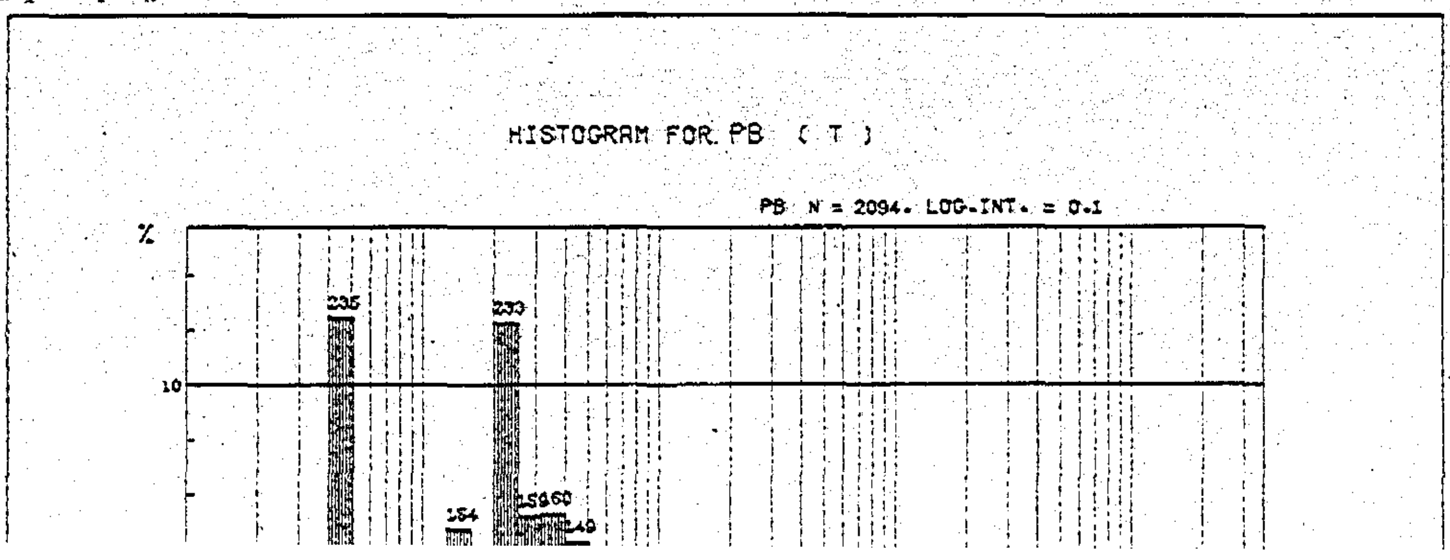
%
5
x1
x10
x100
x1000
x10000
x100000
PPM



HISTOGRAM FOR PB (T)
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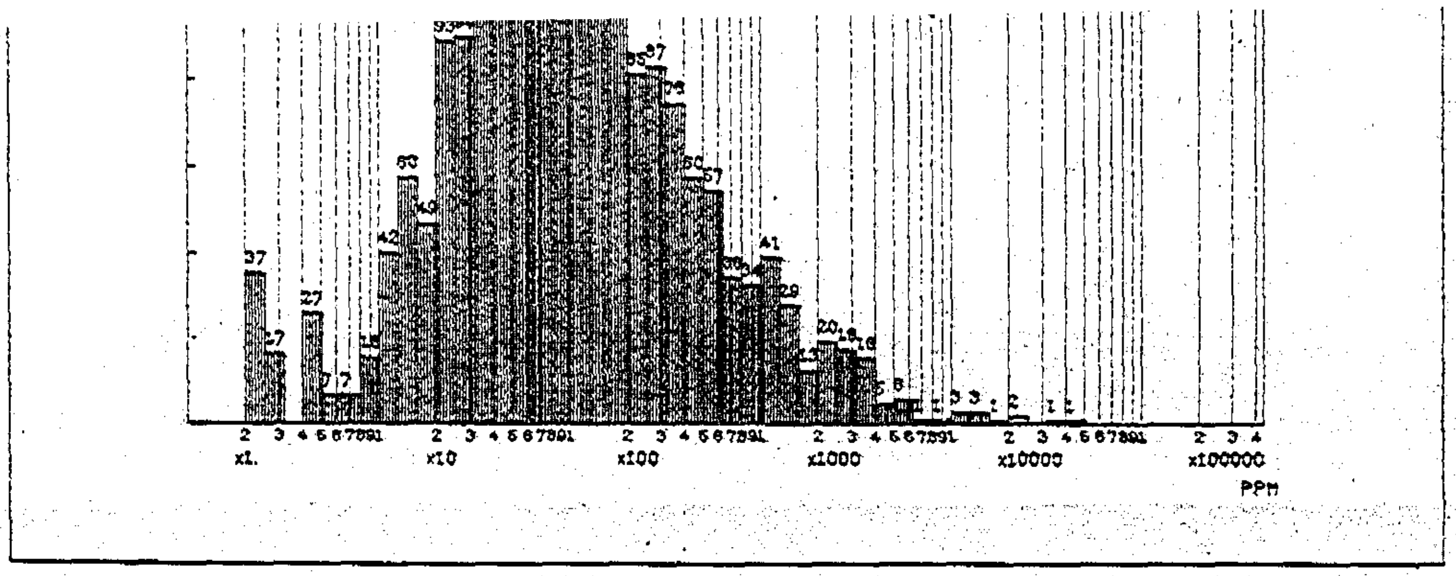
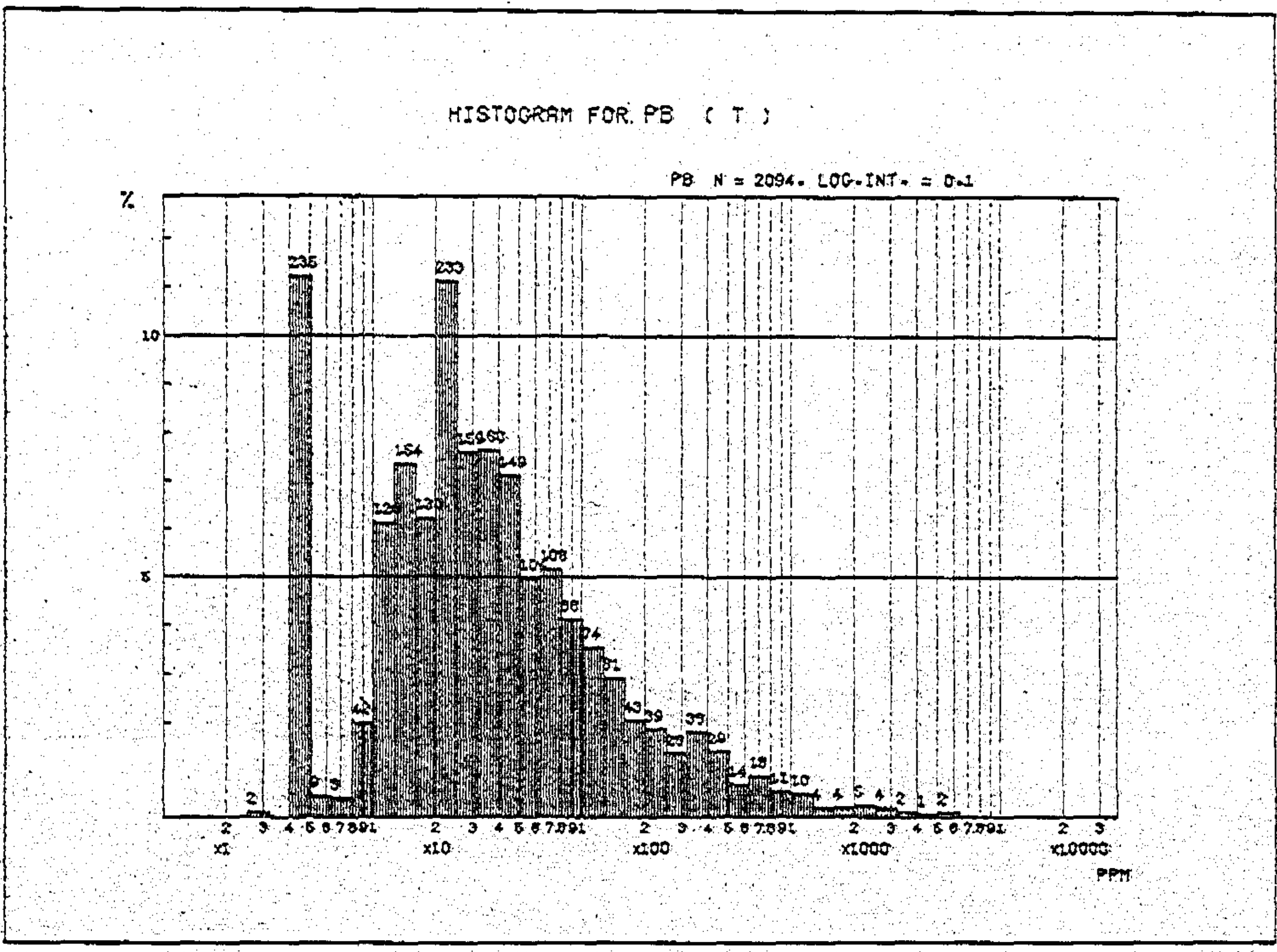
235
233
154





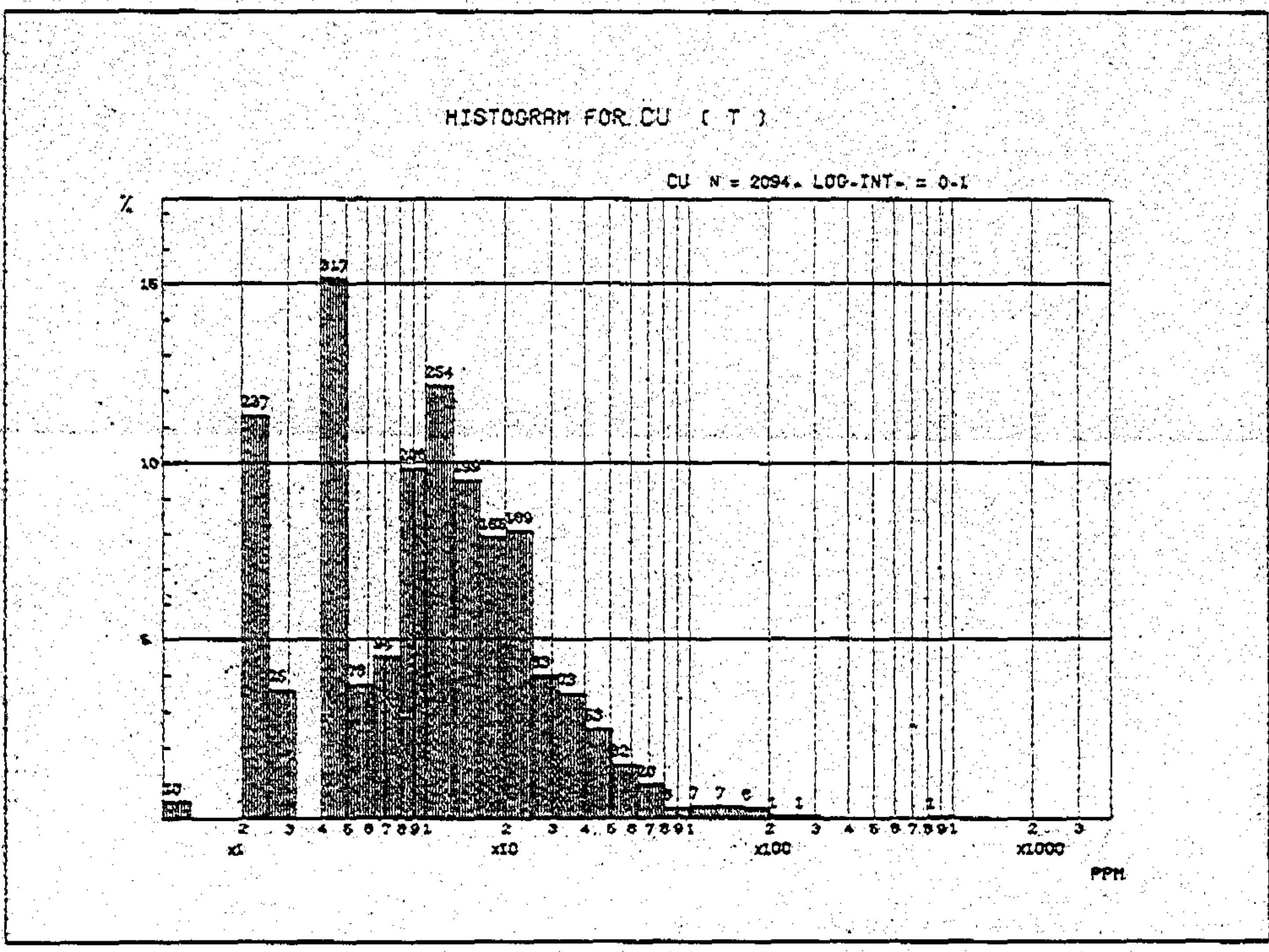
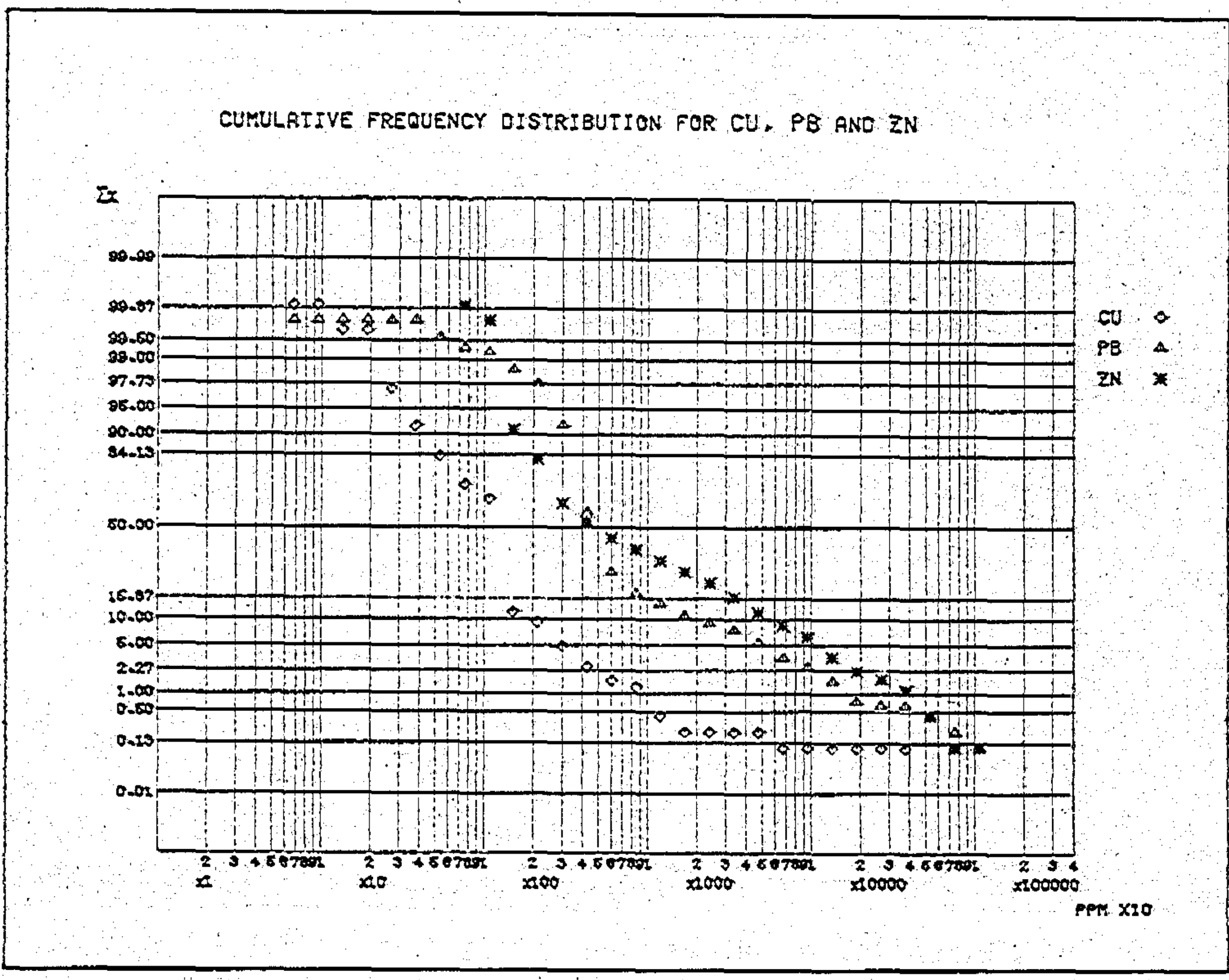
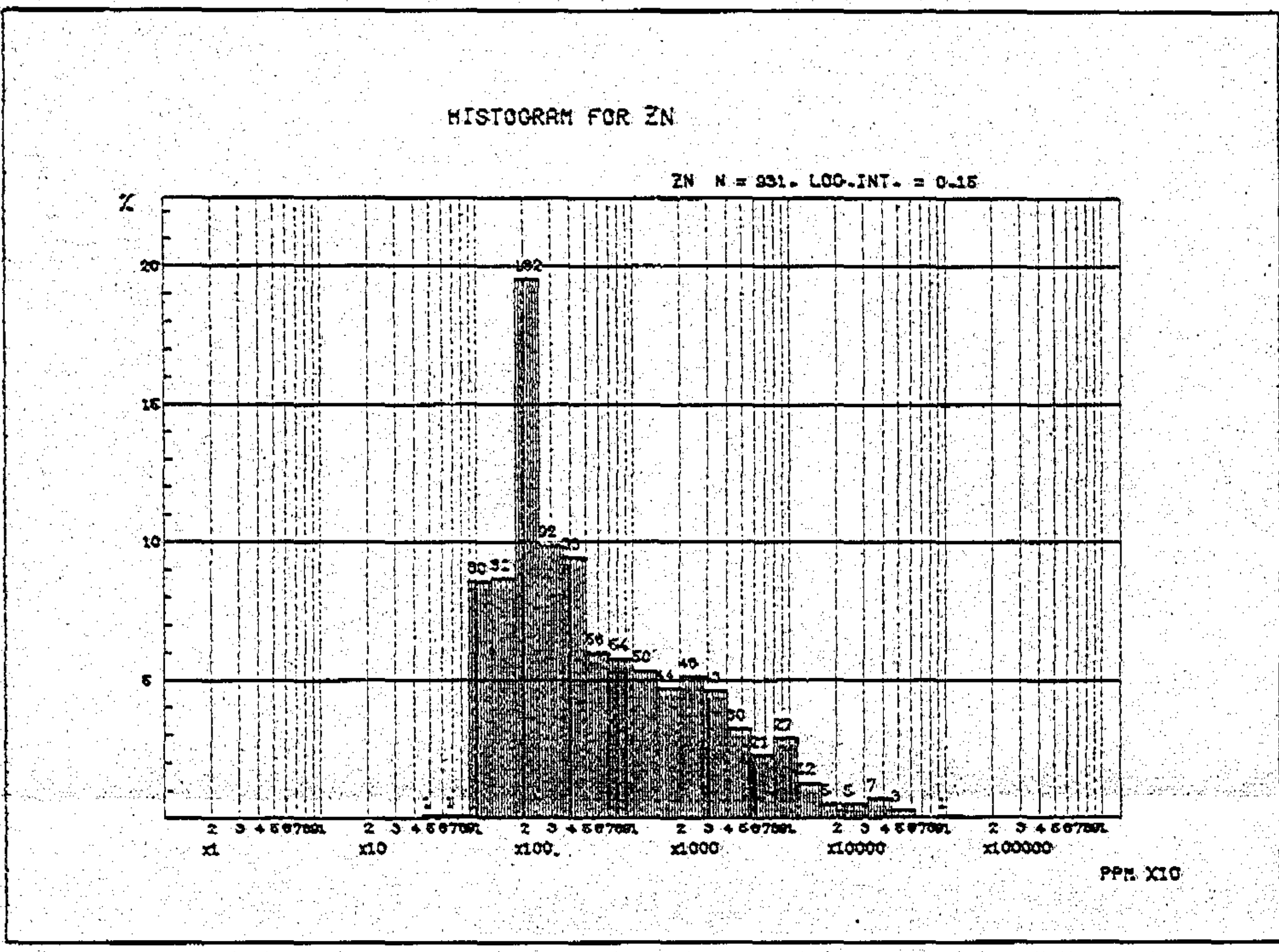
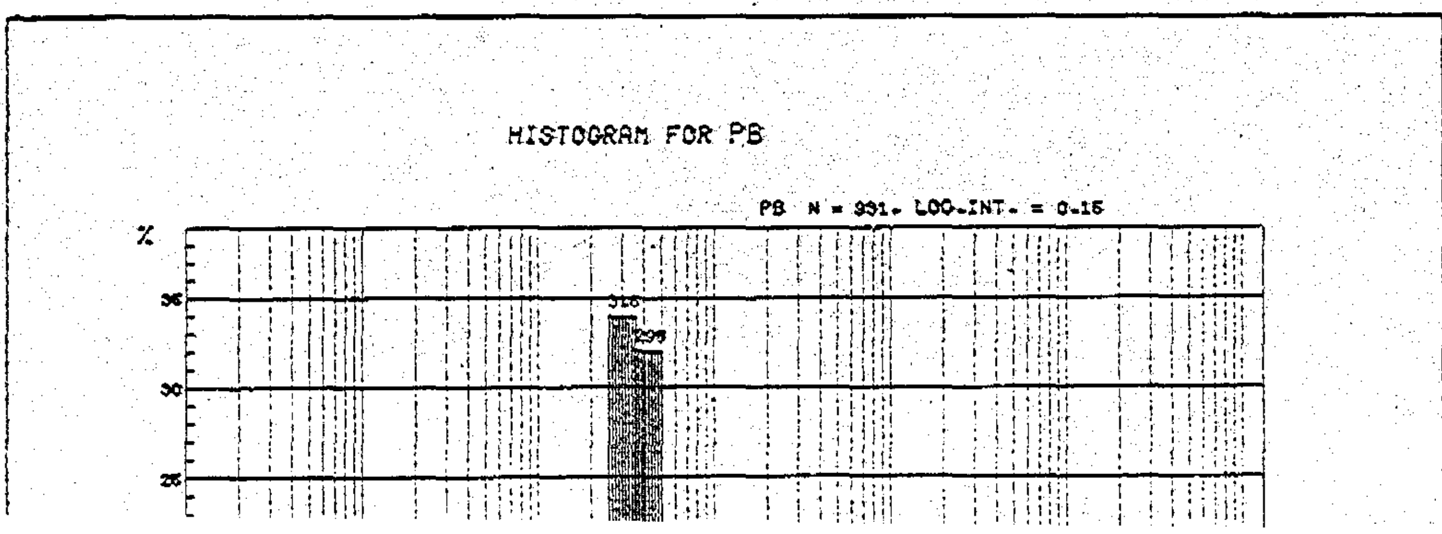


Fig. I-7. Cumulative frequency diagrams and histograms for Cu, Pb and Zn on soil collected in the detailed survey area.


CUMULATIVE FREQUENCY DISTRIBUTION FOR CU, PB AND ZN
CU
PB
ZN
PPM X10


HISTOGRAM FOR ZN
ZN N = 331. LOG.INT. = 0.15
PPM X10


HISTOGRAM FOR PB
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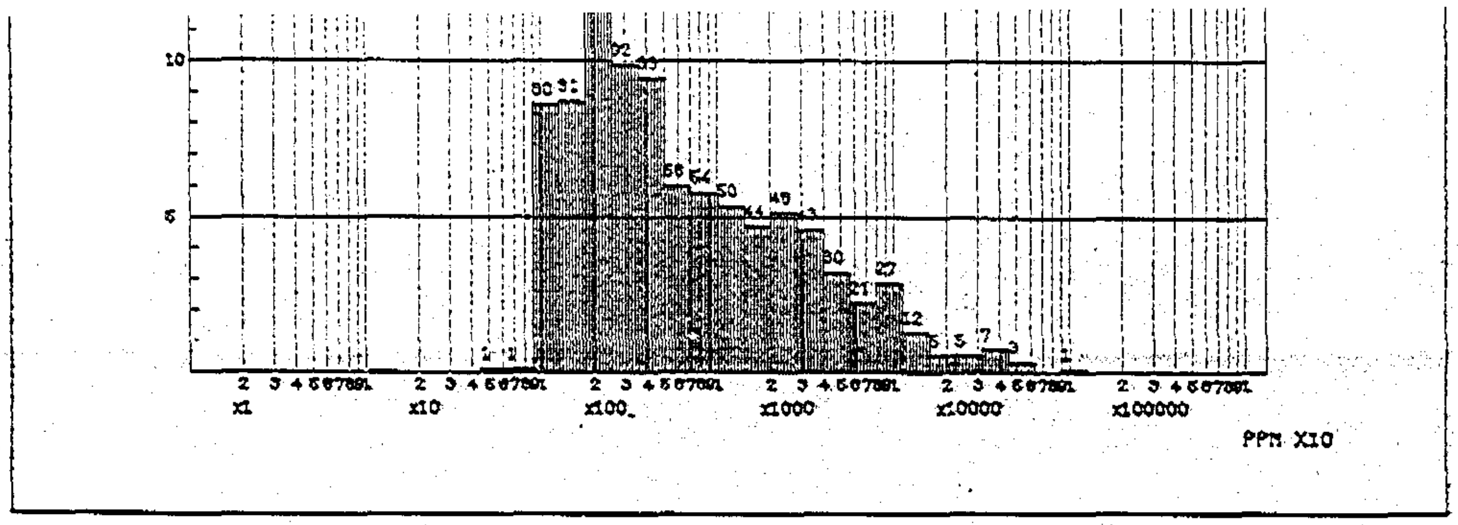
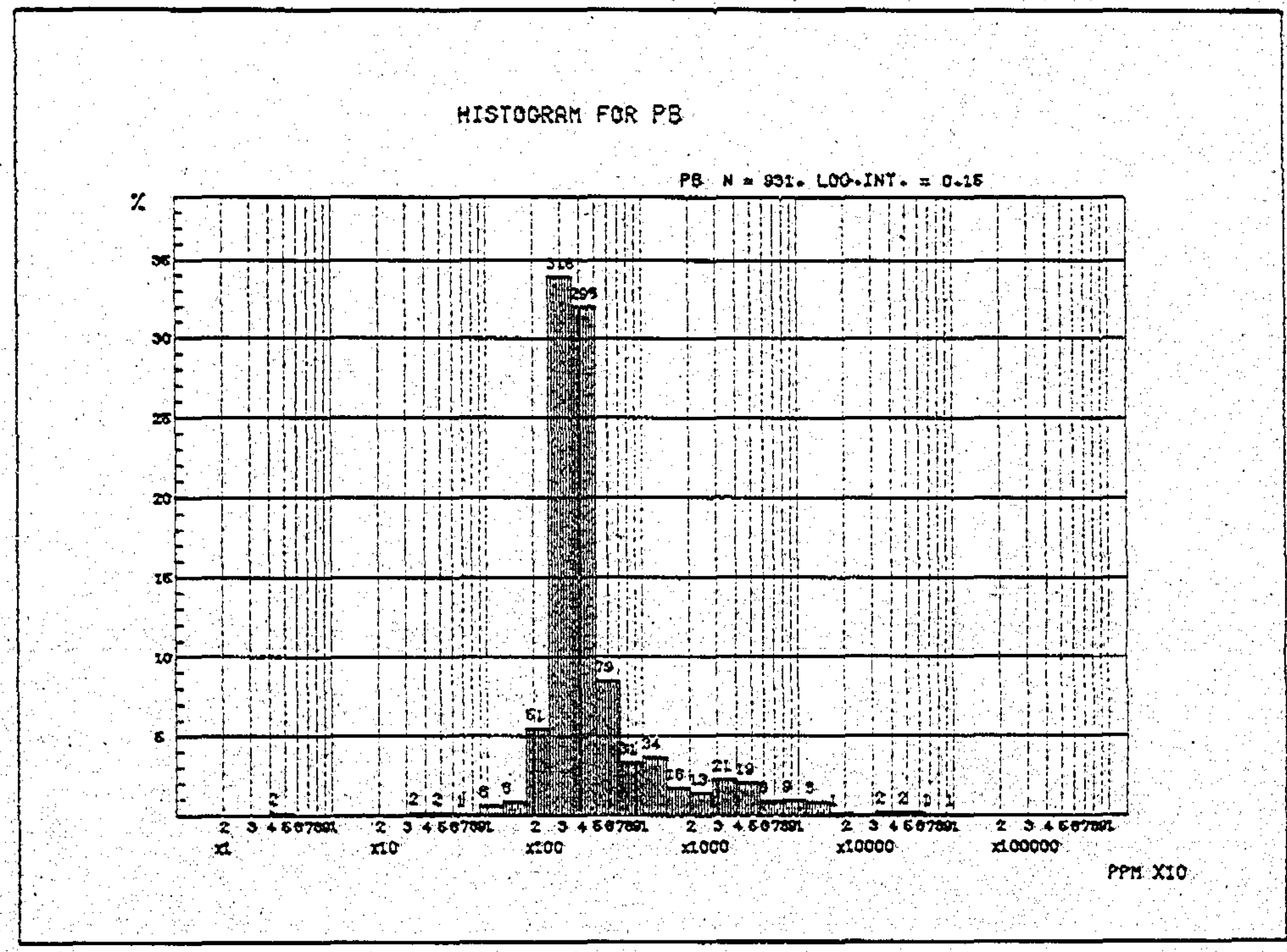




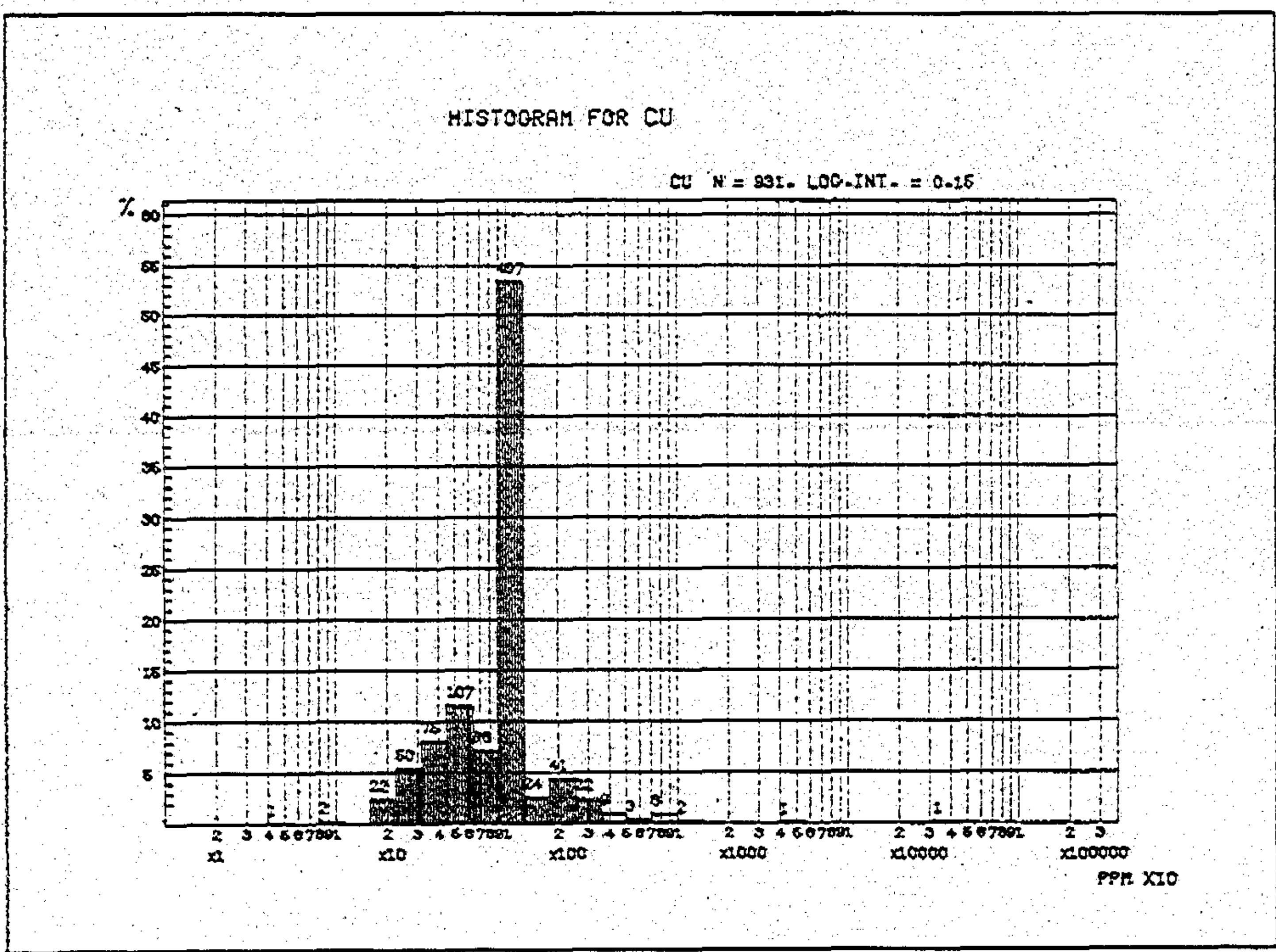
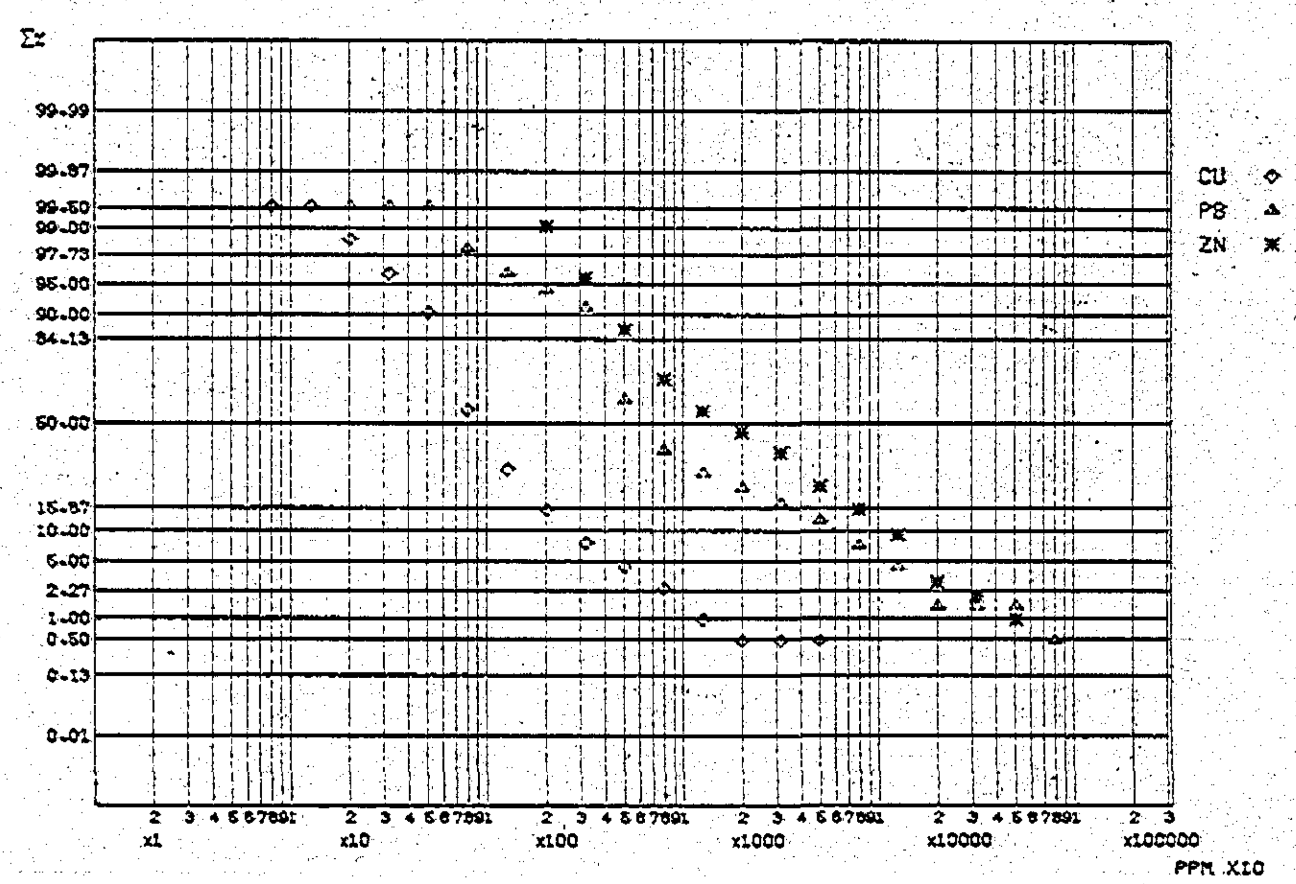


Fig.I-8. Cumulative frequency diagrams and histograms for Cu,Pb and Zn on rock.
(1) Entire surveyed area

CUMULATIVE FREQUENCY DISTRIBUTION FOR CU, PB AND ZN



HISTOGRAM FOR ZN

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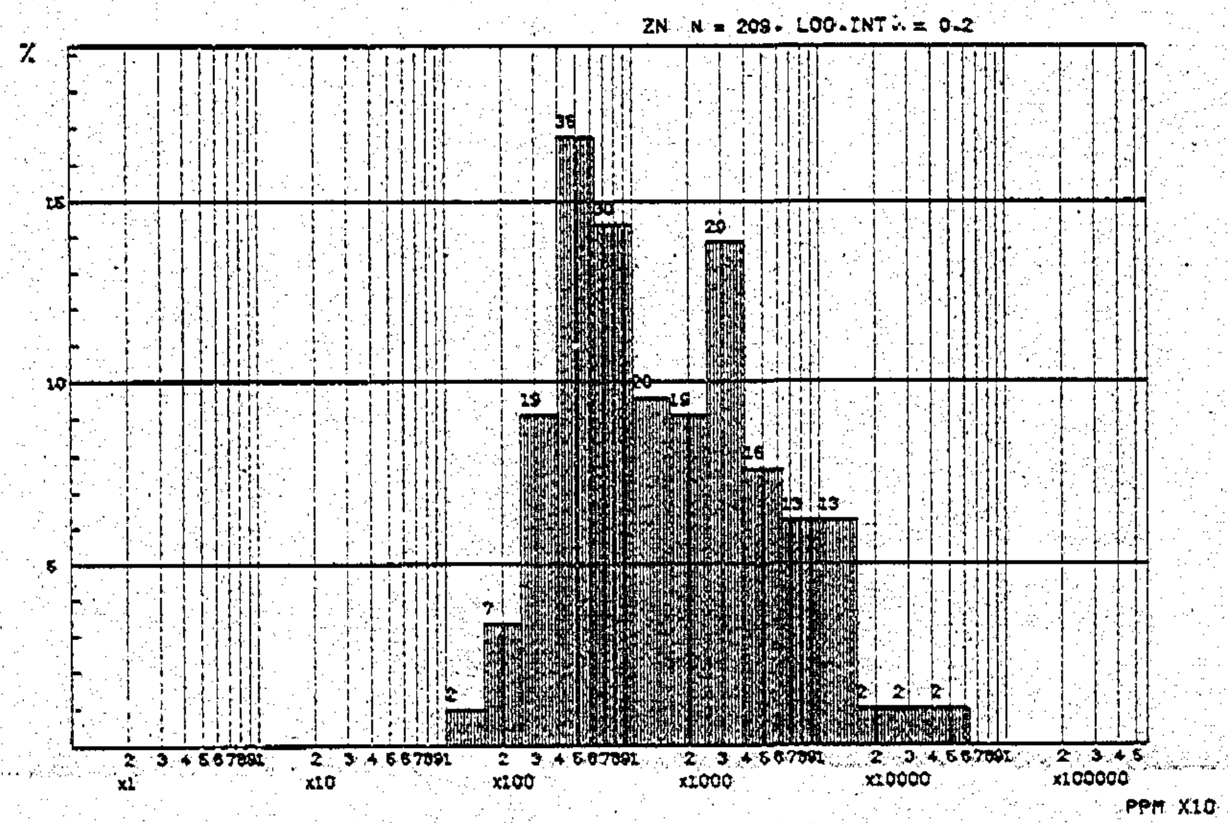

HISTOGRAM FOR PB

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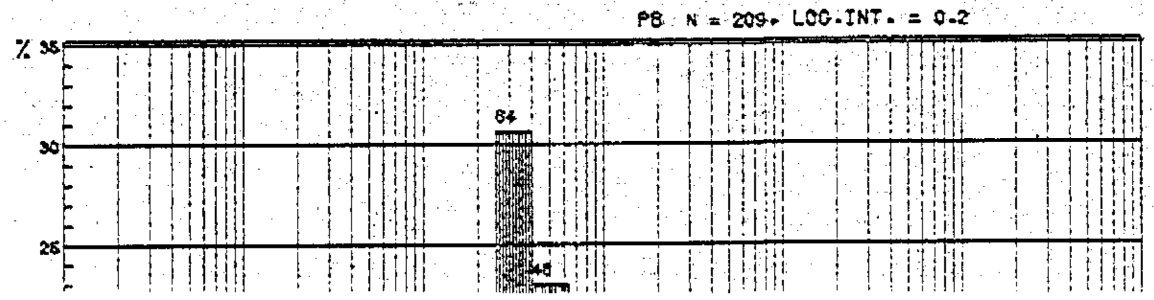
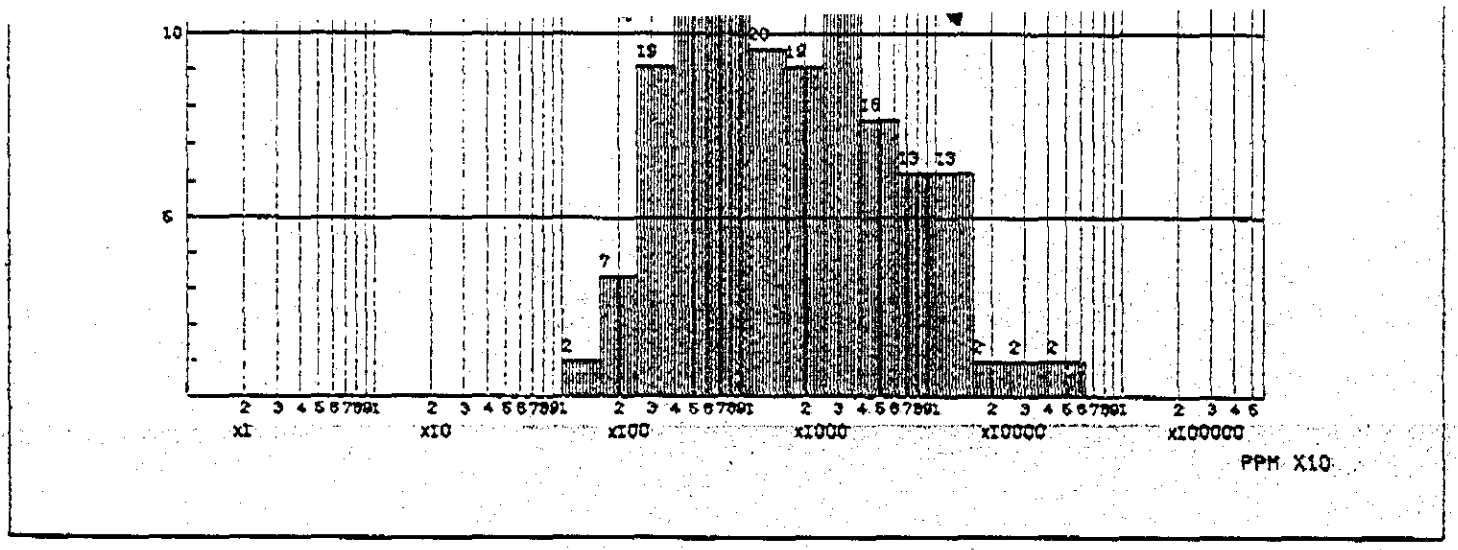
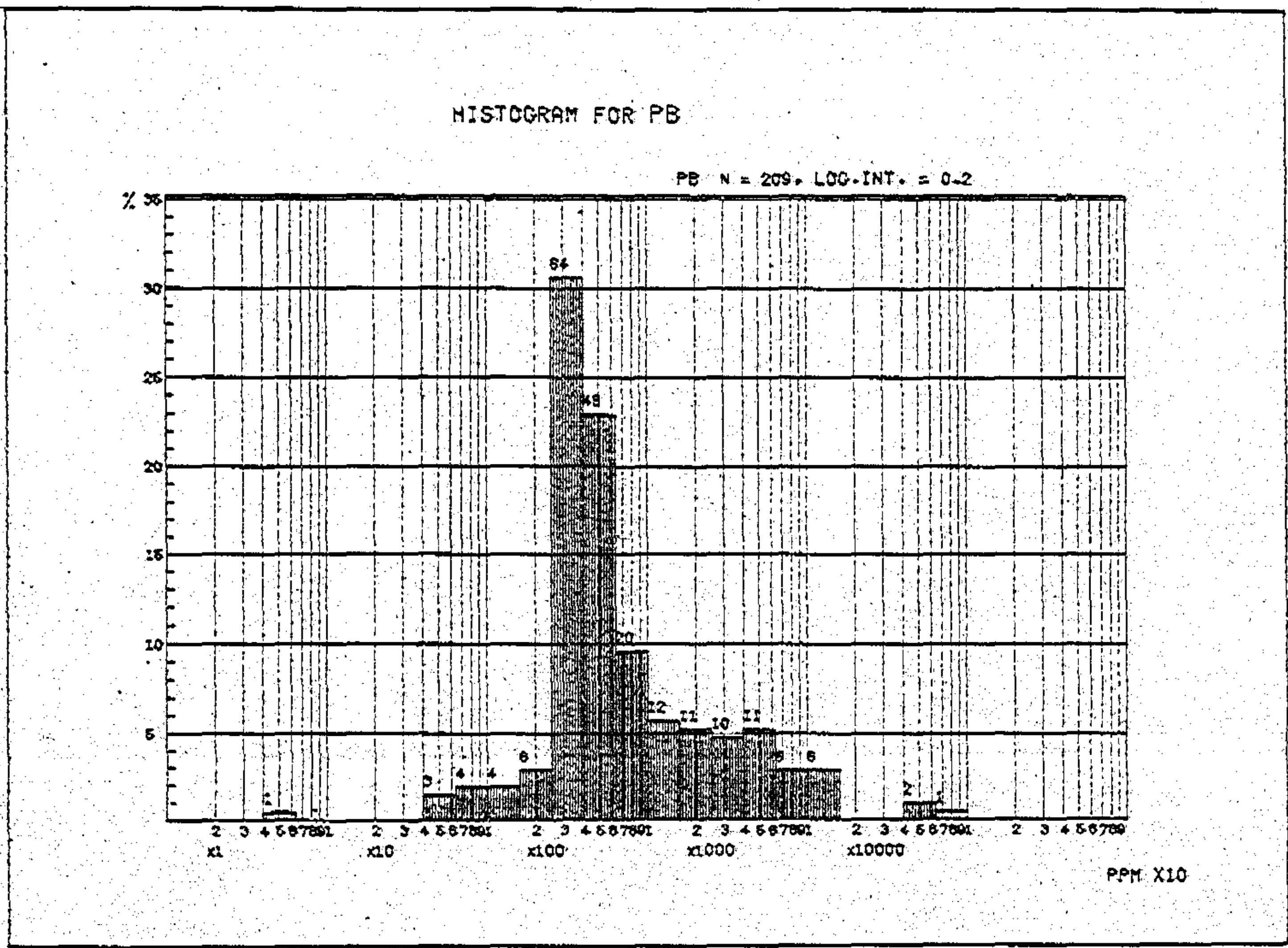






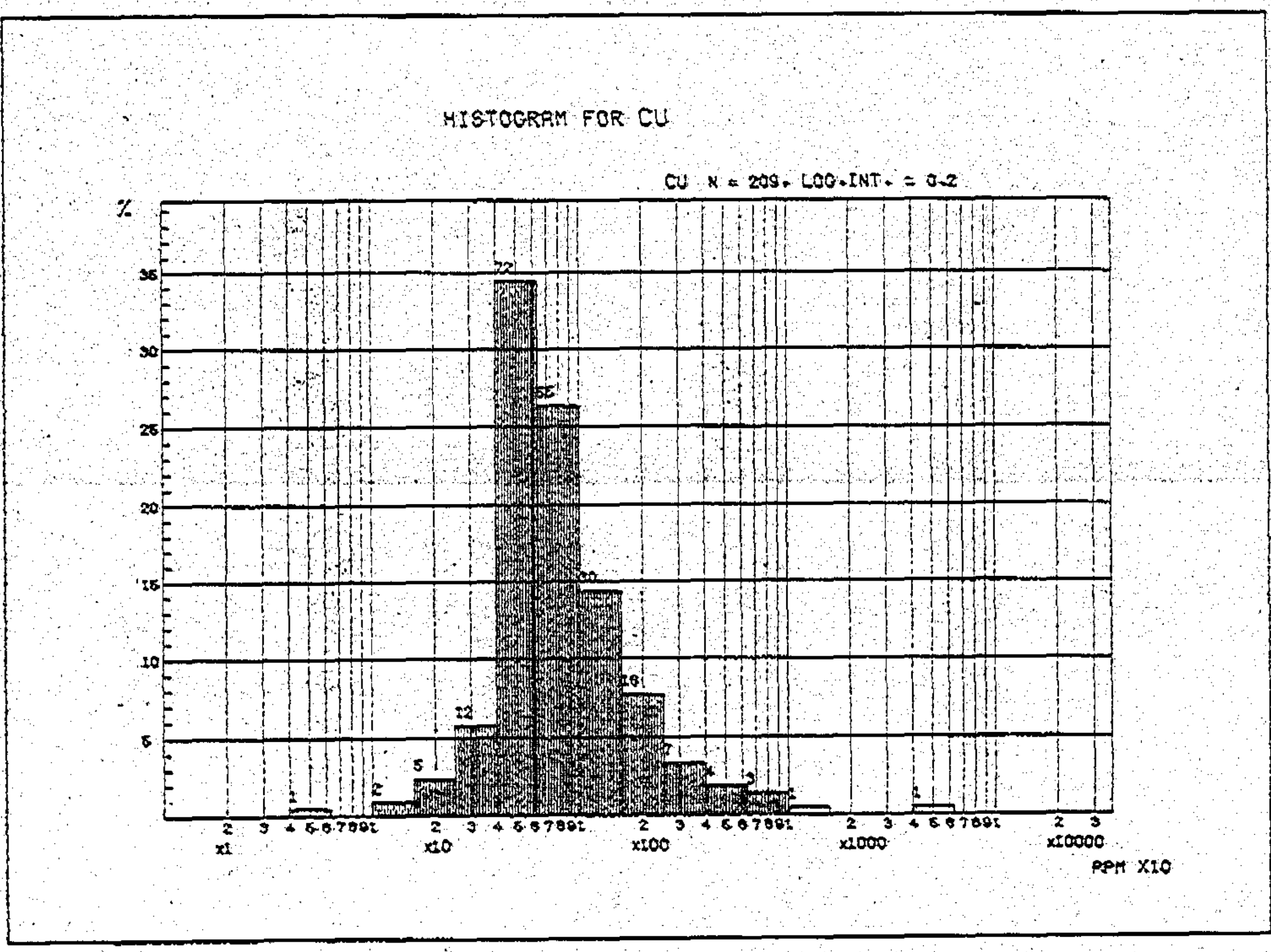
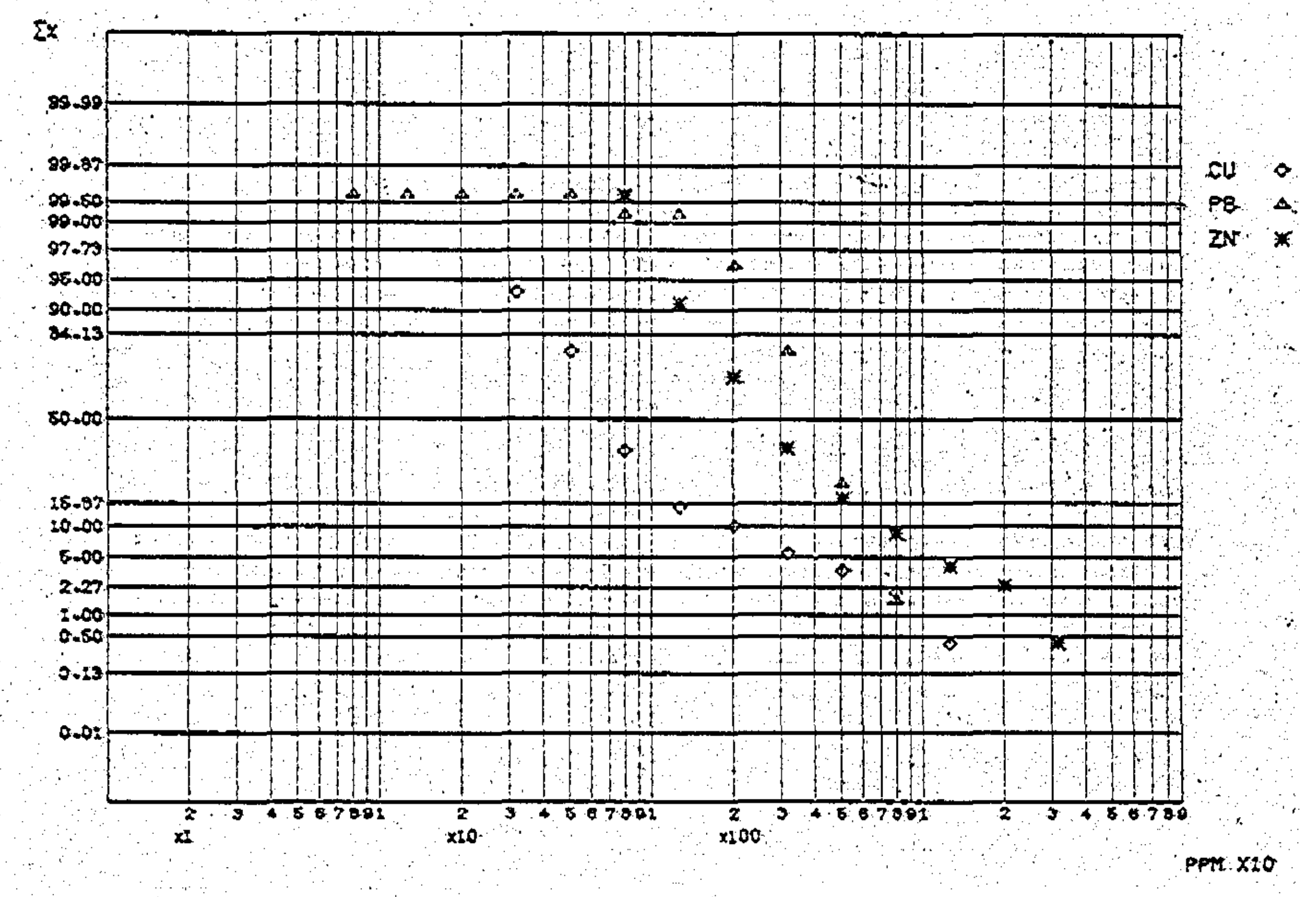
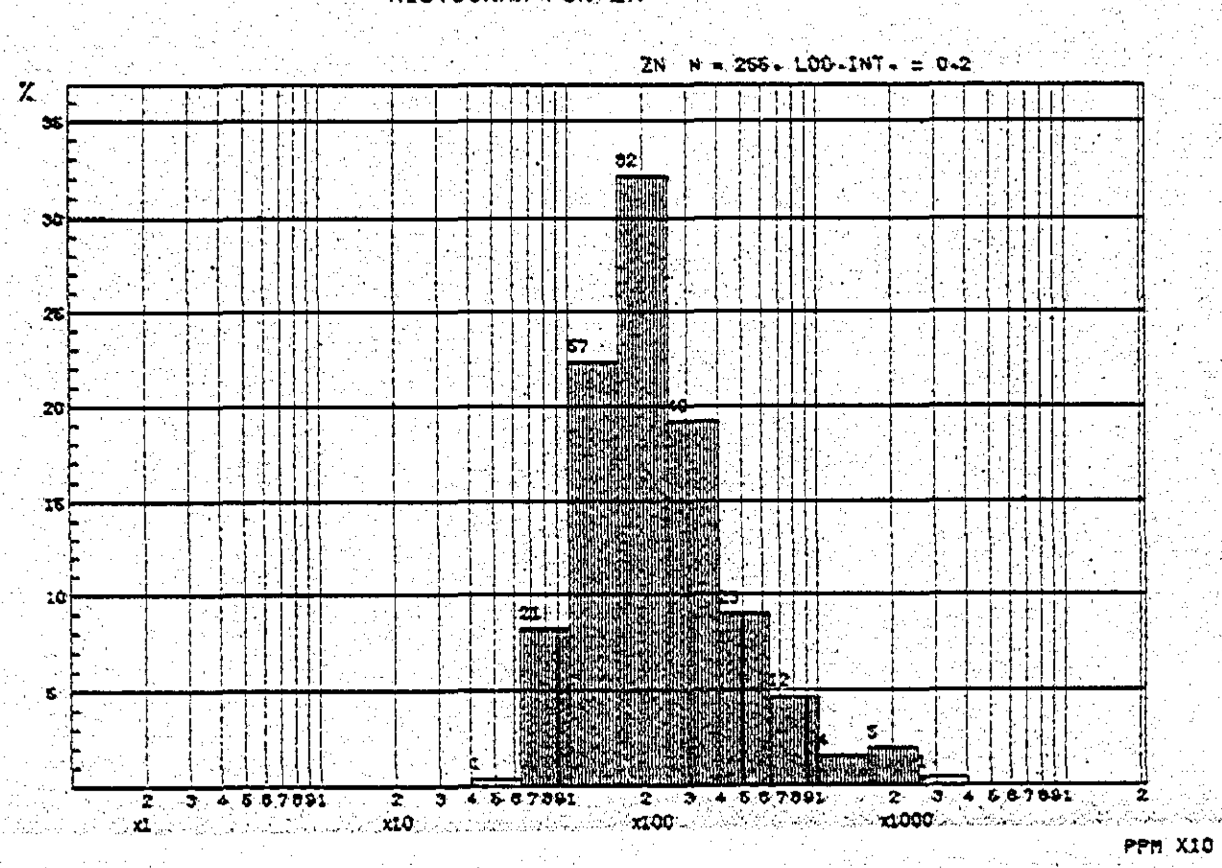


Fig.I-8 Cumulative frequency diagrams and histograms for Cu,Pb and Zn on rock.
(2) Western side of the surveyed area

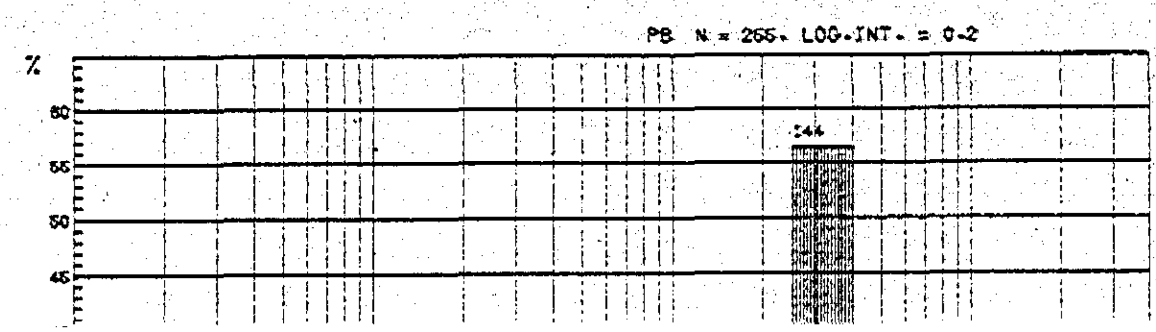
CUMULATIVE FREQUENCY DISTRIBUTION FOR CU. PB AND ZN

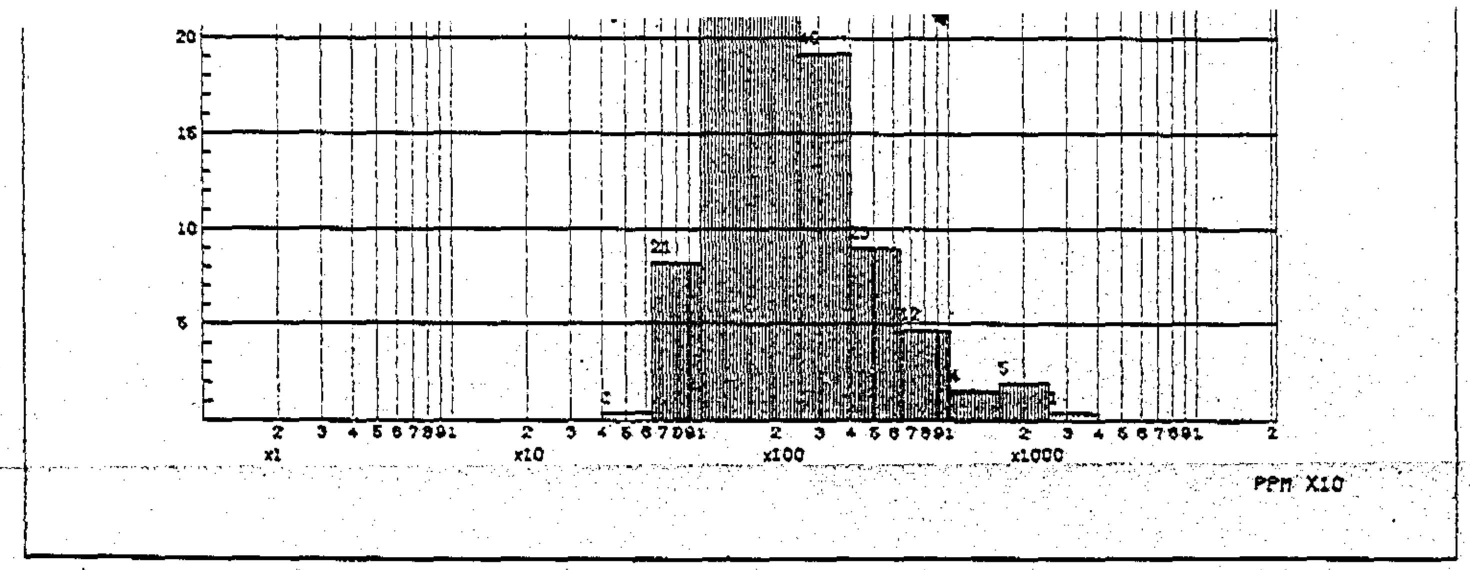


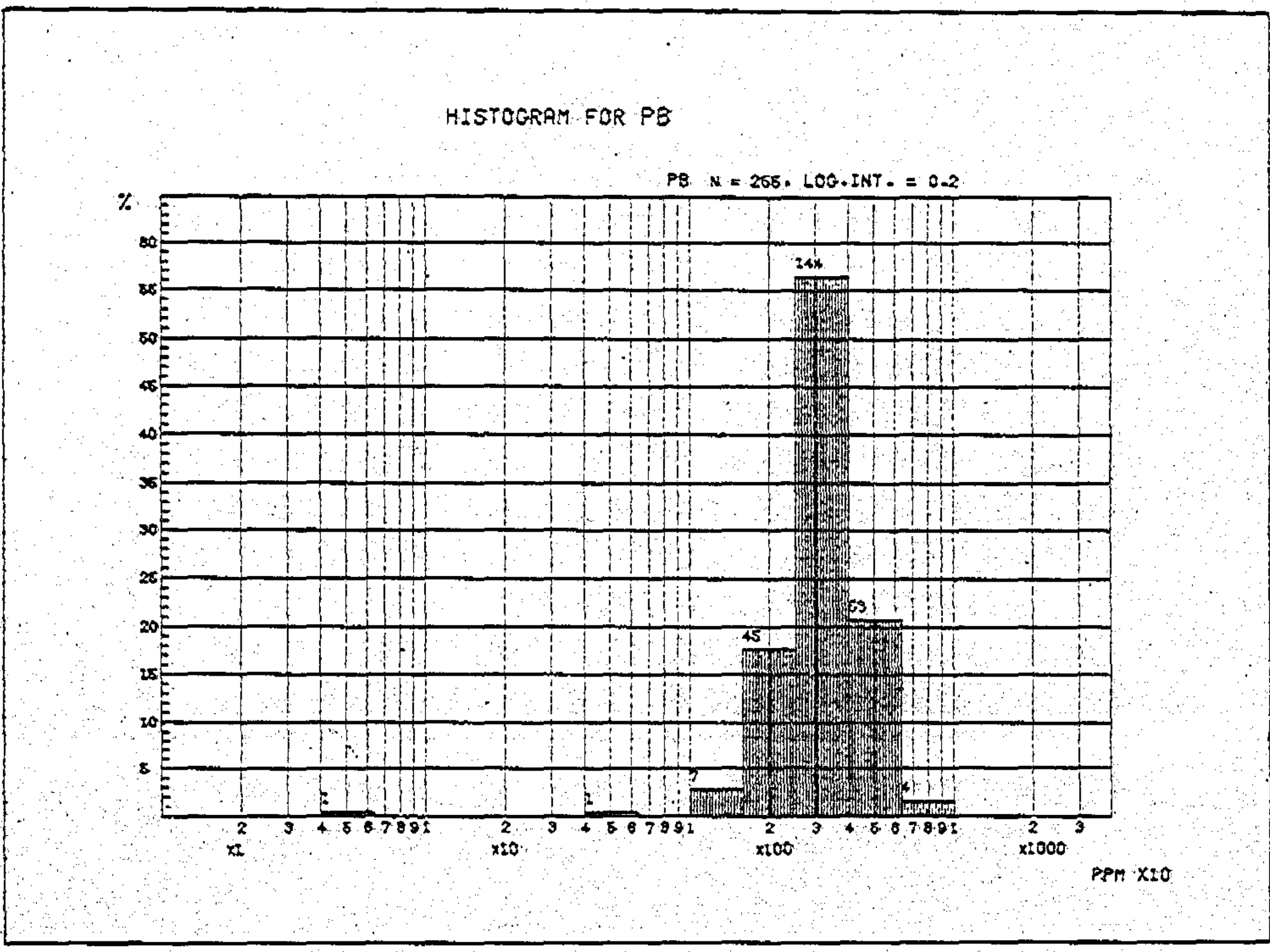
HISTOGRAM FOR ZN



HISTOGRAM FOR PB







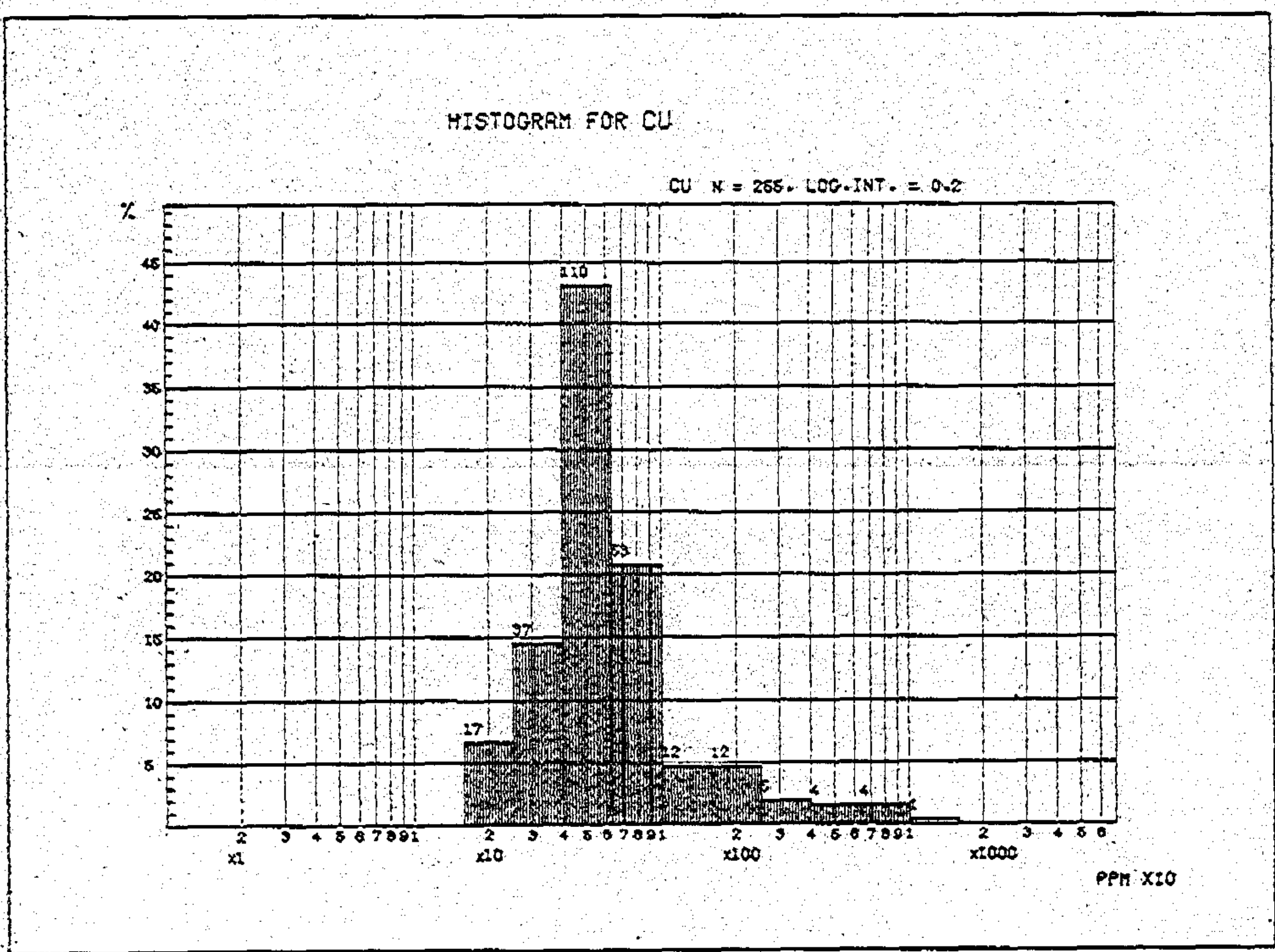
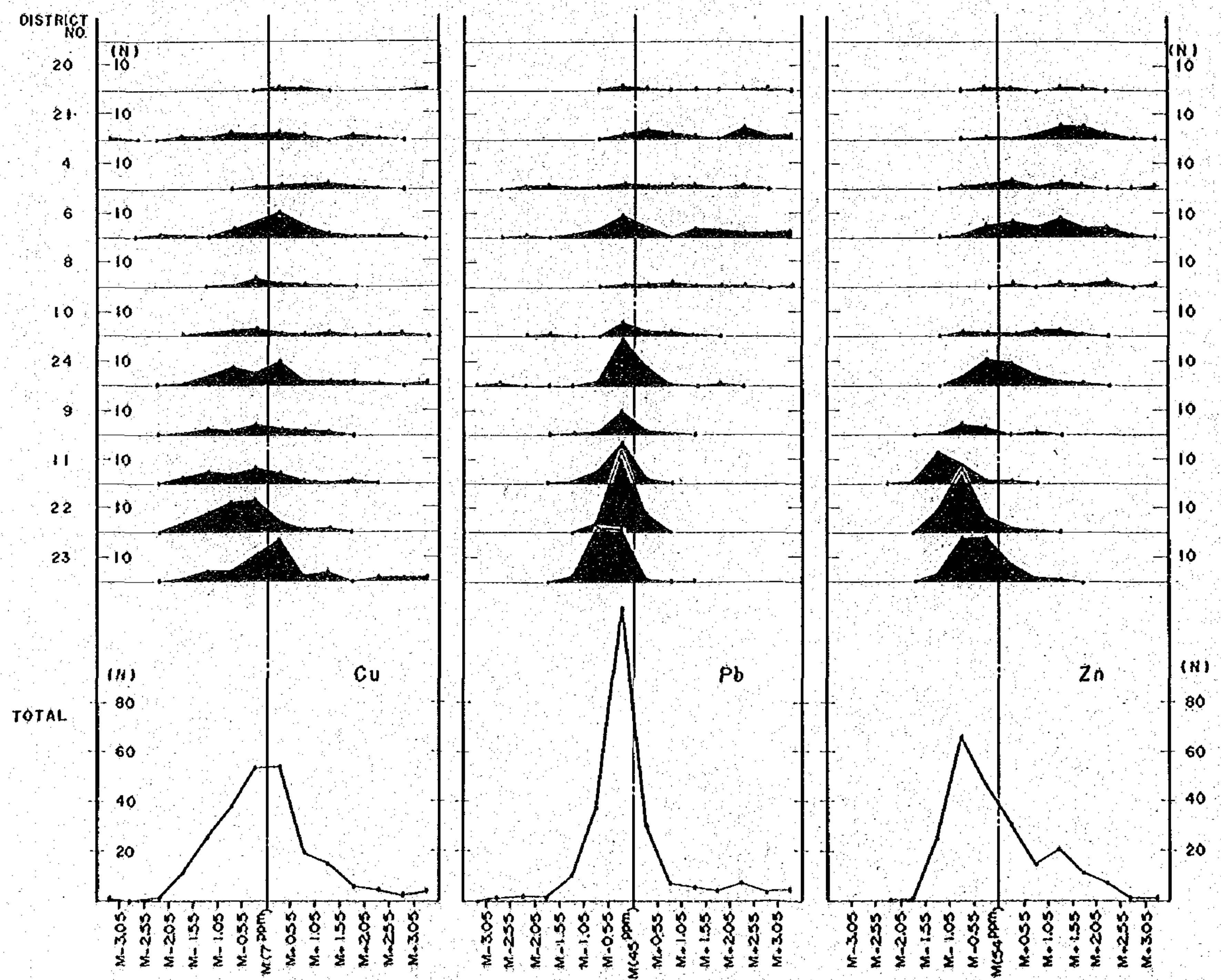


Fig.I-8 Cumulative frequency diagrams and histograms for Cu,Pb and Zn on rock.
(3) Eastern side of the surveyed area



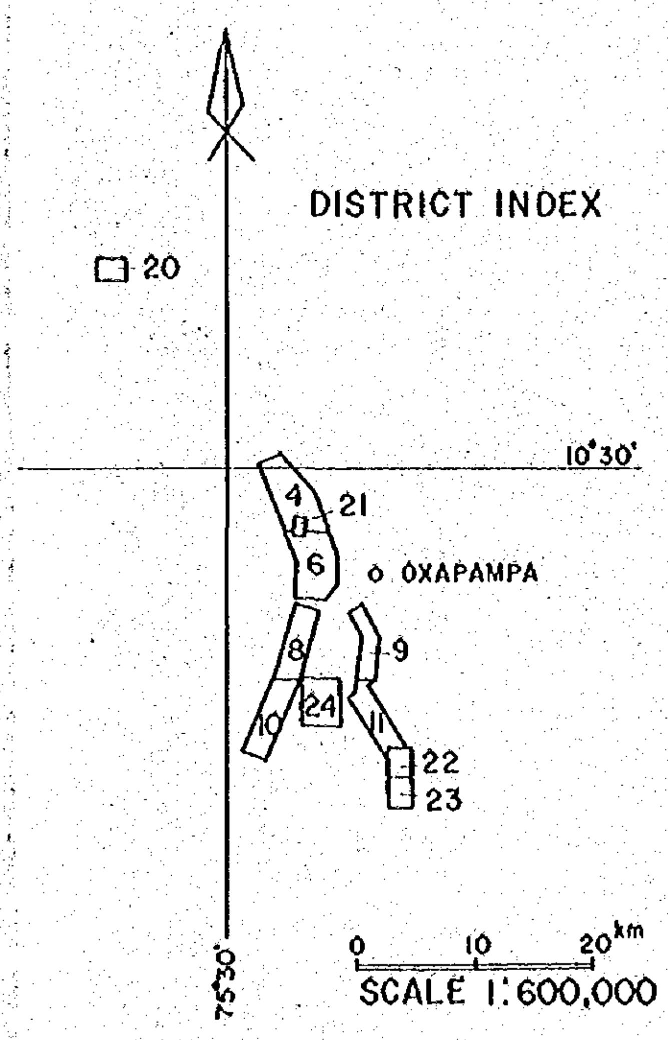


Fig. I-9. Histograms for Cu, Pb and Zn on Rock in Each Districts of the Detailed Survey Area

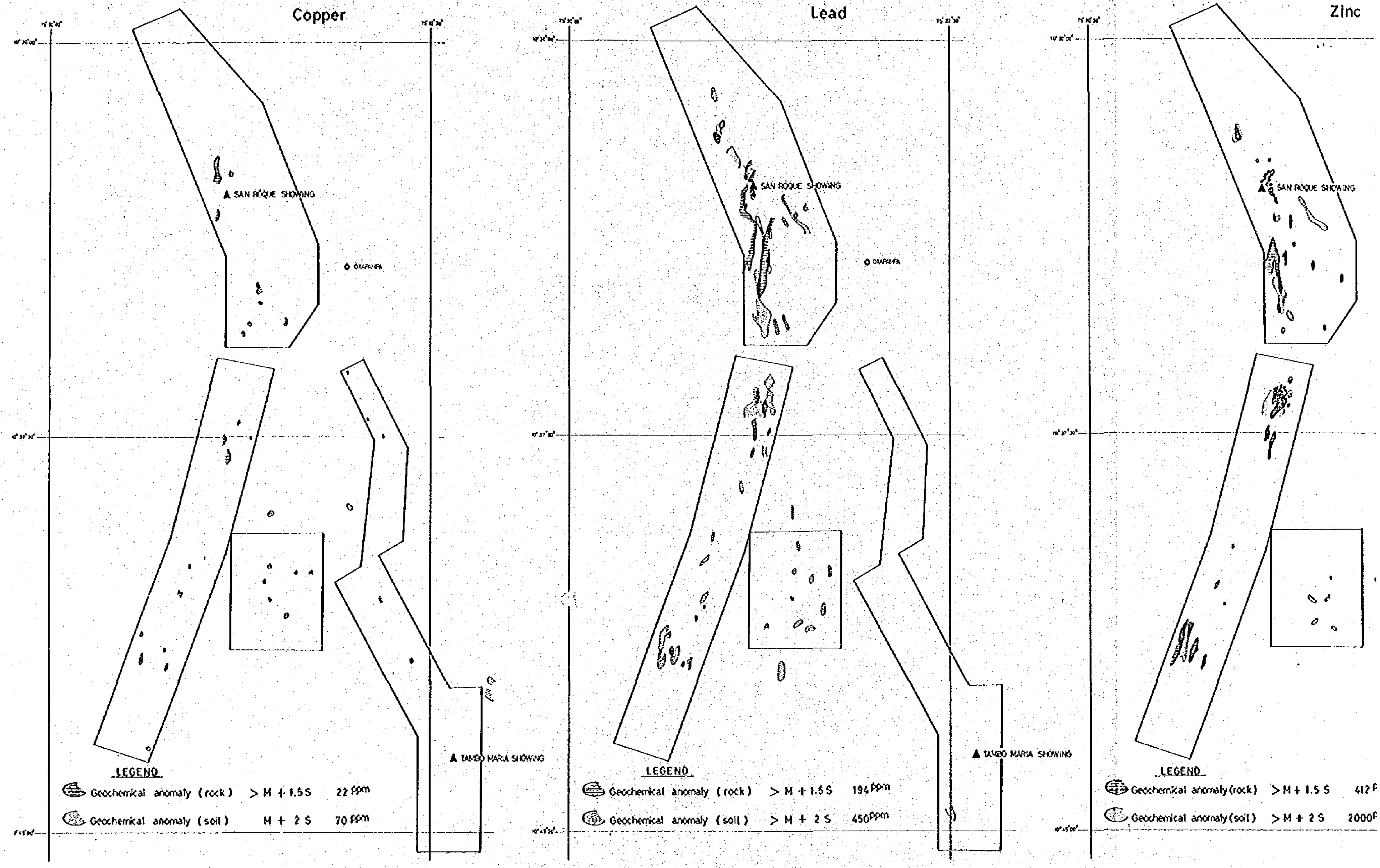
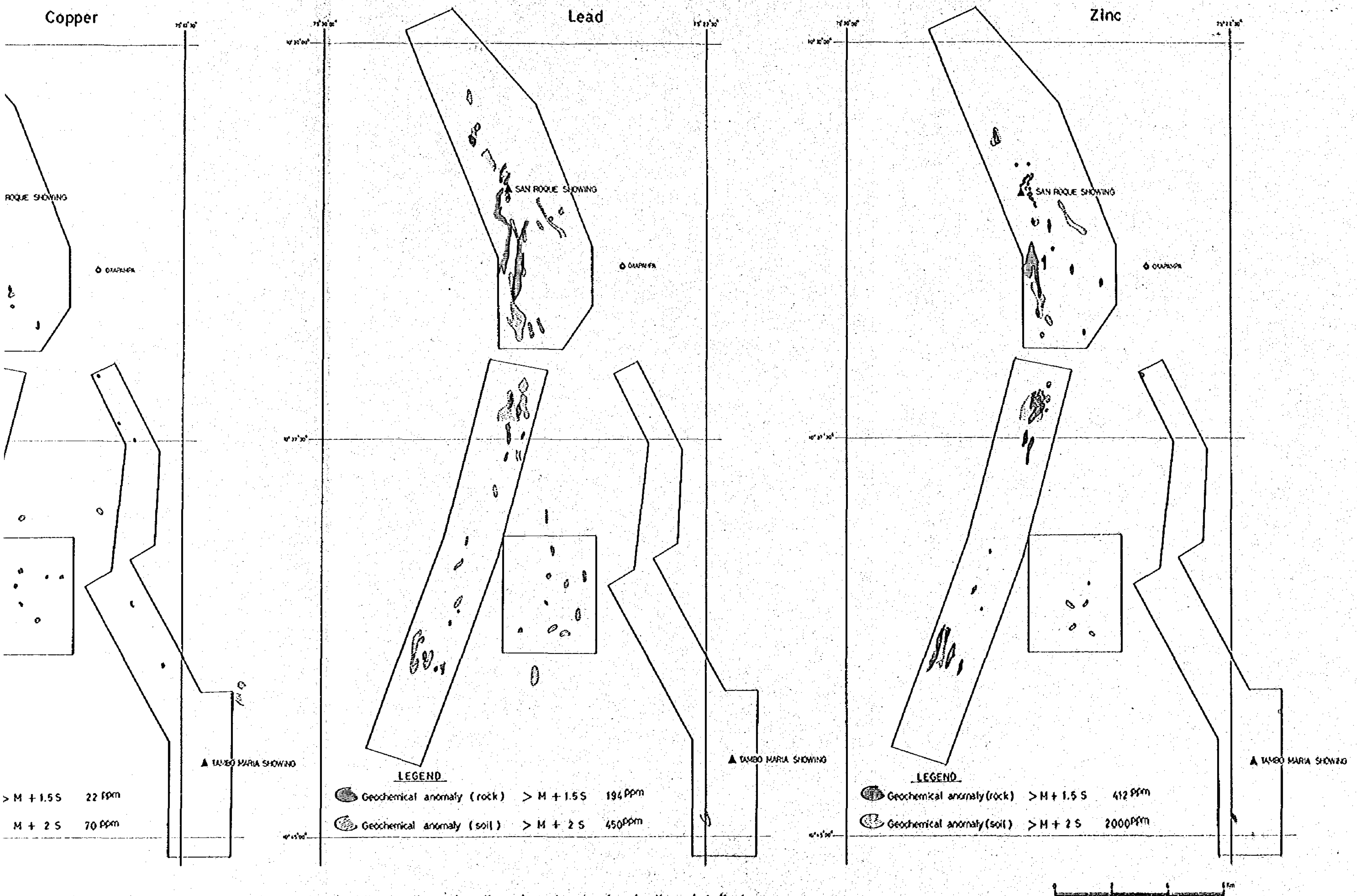


Fig. I — 10. Correlation maps between geochemical anomalies of soil and rock samples in the detailed survey area



Correlation maps between geochemical anomalies of soil and rock samples in the detailed survey area

Table I・3. Statistical analysis of geochemical samples

(1) Rock of the detailed survey area (931 samples)

	Cu	Pb	Zn
	ppm (Cu-log)	ppm (Pb-log)	ppm (Zn-log)
Maximum	3,520	11,400	10,000
Minimum	1	3	6
Average (M)	9 (0.933)	50 (1.698)	60 (1.777)
Standard Deviation (σ)	- (0.2886)	- (0.4097)	(0.6206)

(2) Rock of the Pusagno area (209 samples)

	Cu	Pb	Zn
	ppm (Cu-log)	ppm (Pb-log)	ppm (Zn-log)
Maximum	516	7,300	4,220
Minimum	1	3	14
Average	8 (0.894)	70 (1.843)	154 (2.187)
Standard Deviation (σ)	- (0.3584)	- (0.5517)	- (0.5458)

(3) Rock of the Tambo Maria area (259 samples)

	Cu	Pb	Zn
	ppm (Cu-log)	ppm (Pb-log)	ppm (Zn-log)
Maximum	103	83	258
Minimum	2	3	6
Average (M)	6 (0.777)	31 (1.496)	23 (1.362)
Standard Deviation (σ)	- (0.3215)	- (0.1579)	- (0.2879)

(4) Soil (2,094 samples)

	Cu	Pb	Zn
	ppm (Cu-log)	ppm (Pb-log)	ppm (Zn-log)
Maximum	950	6,000	44,370
Minimum	1	3	2
Average (M)	10 (0.978)	34 (1.536)	96 (1.984)
Standard Deviation (σ)	- (0.4132)	- (0.5636)	- (0.6726)

Table I-4. Numbers of anomalous samples on soils classified by each formation and lithology in the detailed survey area

Cu(ppm)	PDO	PLS	PSS	QU	ME	CH	OR	MI	TY	TH	TR	HP	CO	HD	TOTAL
< 1	1	6	3	0	0	0	0	0	0	0	0	0	0	0	10
1 ~ 2	11	78	30	20	1	7	41	1	3	0	0	27	18	0	237
3 ~ 4	8	34	8	5	0	2	4	1	1	0	0	3	8	1	75
5 ~ 6	18	139	34	19	3	12	15	5	3	0	32	15	21	1	317
7 ~ 10	45	169	29	29	4	40	9	5	1	0	12	16	17	2	378
11 ~ 15	52	211	23	28	12	66	18	8	2	0	4	9	18	2	453
16 ~ 25	31	150	28	17	7	31	11	10	1	1	4	4	12	2	309
26 ~ 40	19	87	21	17	2	5	3	9	0	3	0	2	6	7	181
41 ~ 64	9	37	4	11	0	3	1	6	0	0	0	3	6	5	85
65 ~ 103	3	9	2	0	1	0	1	3	0	0	0	0	1	6	26
104 ~ 165	2	9	1	0	0	0	0	3	0	1	0	0	1	1	18
165 <	0	4	0	0	0	1	0	0	0	0	0	0	0	0	5
TOTAL	199	933	183	146	30	167	103	51	11	5	52	79	108	27	2,094

Pb(ppm)	PDO	PLS	PSS	QU	ME	CH	OR	MI	TY	TH	TR	HP	CO	HD	TOTAL
<5	0	2	1	0	0	0	1	0	0	0	0	0	0	0	4
5 ~ 9	10	83	27	36	12	41	45	2	0	0	6	10	18	2	292
10 ~ 18	10	125	33	35	7	31	23	10	2	2	7	9	37	5	336
19 ~ 34	31	223	50	32	11	58	24	19	4	1	28	14	29	9	533
35 ~ 66	40	182	28	26	0	24	6	9	2	2	7	22	13	4	365
67 ~ 126	41	137	23	11	0	7	3	5	1	0	2	8	7	6	251
127 ~ 241	22	76	9	5	0	4	1	5	0	0	0	5	3	1	131
242 ~ 460	20	53	8	1	0	2	0	1	2	0	1	9	1	0	98
461 ~ 881	13	27	3	0	0	0	0	0	0	0	1	2	0	0	46
882~1,685	8	11	1	0	0	0	0	0	0	0	0	0	0	0	20
1,685 <	4	14	0	0	0	0	0	0	0	0	0	0	0	0	18
TOTAL	199	933	183	146	30	167	103	51	11	5	52	79	108	27	2,094

Zn(ppm)	PDO	PLS	PSS	QU	ME	CH	OR	MI	TY	TH	TR	HP	CO	HD	TOTAL
< 3	2	13	5	7	0	0	10	0	0	0	0	0	0	0	37
3 ~ 4	0	2	3	2	0	3	10	0	0	0	0	1	0	0	21
5 ~ 9	1	18	11	3	0	0	7	0	0	0	3	1	9	0	53
10 ~ 21	12	54	29	12	4	10	24	2	4	0	9	7	13	1	181
22 ~ 44	15	101	29	26	3	57	18	14	2	1	22	14	36	1	339
45 ~ 96	43	177	24	58	15	55	22	17	2	1	14	20	24	8	480
97 ~ 209	29	214	40	20	7	26	9	12	1	3	3	15	13	15	407
210 ~ 453	25	160	27	9	1	7	2	5	0	0	0	13	10	0	259
454 ~ 983	31	97	3	7	0	7	1	1	1	0	0	3	3	1	155
984 ~ 2,133	16	58	8	2	0	2	0	0	0	0	1	5	0	1	93
2,134 ~ 4,627	21	23	4	0	0	0	0	0	1	0	0	0	0	0	49
4,628 ~ 10,037	2	7	0	0	0	0	0	0	0	0	0	0	0	0	9
10,037 <	2	9	0	0	0	0	0	0	0	0	0	0	0	0	11
TOTAL	199	933	183	146	30	167	103	51	11	5	52	79	108	27	2,094

Geological Index

Sedimentary rocks

PDO : Pucara Group — Dolomite
PLS : Pucara Group — Limestone
PSS : Pucara Group — Sandstone
QU : Quaternary (gravel & sand)

ME : La Merced Formation
CH : Chonta Group
OR : Oriente Group
MI : Mitu Group

Igneous rocks

TY : Tertiary — Volcanic Breccia
TH : Tertiary — Monzonite porphyry
TR : Tertiary — Rhyorite & Dacite
HP : Tertiary-Cretaceous Quartz porphyry & Granite porphyry
CO : Cretaceous Granite
HD : Jurassic Diorite complex

Chapter 5 Consideration on the Genesis of Ore Deposits

The mechanism of the formation of the strata-bound and the disseminated ore deposits stated in this surveyed area has not been elucidated sufficiently even in the developed mine of San Vicente. In Oxapampa area, the situation at present is not very impressive as for the exploration as the surface survey is just on schedule and diamond drilling has been carried out only in an area of San Roque. Therefore, it is quite difficult to take out any conclusive elucidation on the genesis of the mineralization in this area.

However, by the survey results obtained up to the present, this area is thought to be the most important area for high possiblity of the potentiality of these deposits, where further survey will be required to obtain more informations on mineralization. This is why some consideration on the genesis is given below, in the sense that it might be rather suggestive for the determination of orientation of the exploration program.

5-1. Mineralization of the Strata-bound Type

There is a big difference on the scale of mineralized zones between Tambo Maria mineral indicationand San Vicente ore deposit. But they have common nature that the most enriched mineralization is associated closely with the dolomite accompanying structural disturbance or zebra-structure, and also it can be said that they have similar nature and paragenesis of ore minerals. Accordingly, it would not make difference if the consideration is given to the genetical problem with the view that both mineralizations are of the same nature in the points of the historical development of the mineralized zone.

The outline of the ore deposits are described in the chapter 3 and 4, the summary of which is given here as below.

1) The mineralized part is characteristically associated with zebra-structure, especially with thick zebra-structure.

2) The mineralized part is remarkable associated with the geological localization, i.e. the disturbance of the structure as folds or faults.

3) The ore minerals mainly of sphalerite are dense in the white bands of the zebra-structure and less concentrated in the dark bands of it. Furthermore the grains of the crystals of ore minerals are bigger in the white bands.

4) Around Tambo María showing, where the zebra-structure in dolomite is developed, although carbonate rocks contain more Zn than Pb in most chemical analysis, the mineralized part carries more Pb than Zn on the contrary.

From the above, for the consideration of the history of the mineralization, the mechanism of the genesis of zebra-structure and the relation between zebra-structure and ore minerals should be examined in the first place.

(i) The Mechanism of the Genesis of Zebra-Structure

The development of zebra-structure is thought to be due to the "filling up" of the space or recrystallization caused by structural factors by such reasons as stated below. (Refer to Volume 4)

- Difference of grain size of the crystals is recognized between dark dolomite and white dolomite.
- White dolomite is fairly pure as no accidental foreign material has been recognized under microscope.
- Brecciated dolomite is composed of breccias of fine grained dark dolomite cemented with white dolomite.

The distribution of zebra-structure in the present detailed survey areas is shown in PL.I-14. Based on this illustration, almost all the zebra-structures except for those in Tambo Maria area are not so notably extensive. However, the zebra-structures in every places develop in the same direction as that of the Pucara Group, namely NNW-SSE, direction and are thought to have been formed by the recrystallization of white dolomite in the space caused by the tectonic movement concerning the folding-structures of the Pucara Group or the fault-structures like Tingo Maria-La Merced tectonic line. The fissures of NNW-SSE, N-S, NNE-SSW etc. develop well in the San Vicente area, including the overthrust separating the igneous bodies in the west. Accordingly, the space caused by such tectonic movement would have played significant role for the formation of the zebra-structure. The zebra-structures are thought to have been formed through the rhythmical sedimentation of white dolomite and dark dolomite.

(2) Relation of Zebra-Structure to Ore Minerals

In zebra-structure, there is a difference of grain size of the crystals of dolomite, and also the density and the grain size of sphalerite are variable in dark bands of dolomite. That is, sphalerite is concentrated along the contact with the white dolomite, where the grains have rather bigger sizes. It is considered from this fact that the concetration of sphalerite to the present position would have been, at the same time or rather prior tothe formation of zebra-structure, due to the replacement of the dark dolomite by sphalerite, penetrating through the boundary plane between the white dolomite and the dark dolomite. The sphalerite has been concentrated more in amount and well-developed in grain size along the boundary plane zone where the ingredients of sphalerite gathered actively. The enriched ore bodies are associated with well-recrystallized zebra-structure of thick bands,where the geological structural controll is repeatedly considered. Accordingly, the concentrations of the ore minerals in the strata bound lead and zinc deposits were promoted in every stage of recrystallization of dolomite.

In Tambo Maria area, Zn-indications are found in the anomaly of the geochemical survey by rock samples. In this anomaly of Tambo

Maria type the content of Zn in rocks is lower than that of Pb inside, on the contrary that the Zn is higher than the Pb outside in the anomaly. The difference of the content of Zn to Pb is about 30 to 40 ppm in the anomaly. Those facts are suggesting, not that the content of zinc in the rocks was originally very low in this anomaly zone, but that the remobilization of zinc with the formation of the zebra-structure in dolomite, would have resulted in present distribution.

5-2. Relation between Mineralization of Strata-bound Type and Dissemination Type.

The most noteworthy matter on the lead-zinc mineralization of the dissemination type around San Roque is, as stated in chapter 4, that it would be the result of rearrangement of lead and zinc contained originally in the carbonate rocks under the influence of the intrusion of igneous rocks. Although the mineralization is associated with igneous rocks, it would be unlikely that the elements to compose the ore minerals would have been supplied directly from the intrusive igneous rocks. The features of the rearrangement by the remobilization of essential lead and zinc are as same as the both mineralization, at Tambo Maria and at San Vicente. The aspects of the mineralization and the mechamism of the formation of the ore deposits in San Roque area, confirmed by the diamond drillings performed in the present year are described in detail in the Part III of this volume. The summary is given below.

(1) Precipitation of lead and zinc ions contained in the sea-water under reducing environment, at the same time of the sedimentation of the limestone.

(2) The remobilization and the concentration of primary galena and sphalerite to the dolomite, and their recrystallization, associated

with the diagenesis of the carbonate rock after precipitation.

(3) The rearrangement forming zonal distribution of ore minerals, under the influence of the intrusion of the igneous rocks. (The zonal distribution is represented by the mineralization of the dissemination type on the surface.)

From the above, the sedimentary environment of these ore deposits bedded in or closely upwards the muddy rocks, is thought to be the same kind as that of the Mississippi Valley type, Strata Bound Lead - Zinc Ore Deposits.

The following two common points are discussed on the mineral indications of Tambo Maria, the ore deposit at San Vicente, and the mineralization caught by the diamond drillings at San Roque.

(1) They are emplaced in the dolomite

(2) They are distributed in the muddy beds or in the beds closely overlying the muddy beds.

The differences are as follows.

(1) Recrystallized dolomite (zebra-dolomite) and cryptocrystalline dolomite.

(2) High grade and low grade of the metal content

As for the ore deposit at San Vicente and the mineral indication at Tambo Maria, the zebra-dolomite would have developed around the space which was formed with the lateral pressure of the regional geo-structure in this area. It has been considered that, for the purification of the dolomite crystals, the impurities such as sphalerite and galena were recrystallized and concentrated on the opposite side to the recrystallization of the dolomite. The development of zebra-structure has little been recognized in the dolomite distributed in San Roque area. The reason is thought to be that the development of space by the structural factors was poor in this area. To venture to say, such an concentrated high grade ore deposit as seen at San Vicente at present might have been formed in San Roque area, if the area had been situated in the environment to form zebra-structure. In another words, it is considered that the ore deposit at San Vicente or the mineral indication at Tambo Maria might be a result of the development of the indication as caught by the drillings at San Roque, viewing from the above-mentioned common properties or different points.

The ore deposit at San Vicente and the mineral indication at Tambo Maria contain high grade ores. It is not evident on that occasion of the rearrangement, whether the above two mineralizations are the results, on that occation of rearrangement, of the remobilization and the concentration (secondary) of the metals which were originally contained in limestone and concentrated in the process of dolomitization (primary) or there are some additions of metal ingredients supplied by the igneous activity.